

School of Population Health

**The Impact of Regularity of Primary Care on Emergency
Department Presentations and Hospital Admissions**

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Doctor of Philosophy
in the discipline of
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Author's Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Human ethics The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council Statement on Ethical Conduct on Human Research (2007) – updated March 2014. The research study received human research ethics approval from the Curtin University Human Research Ethics Committee (HREC) (EC00262), Approval Number HRE2017-0579.

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Statement of Contributors

This thesis began under a project led by Curtin University Professor of Health Economics and Data Analytics and University of Western Australia Adjunct Associate Professor of Health Services Research Rachael Moorin funded by the National Health and Medical Research Council (NHMRC). Throughout this thesis I was supported by an Australian Government Research Training Program scholarship. Neither the NHMRC nor the Research Training Program had any input into the design, analysis, interpretation, or dissemination of any of the manuscripts making up this thesis.

My supervisors were Rachael Moorin, Curtin University Health Economics and Data Analytics Discipline lead and Curtin Health Research and Data Analytics Hub co-director Suzanne Robinson and John Curtin Distinguished Professor of Economics and Finance Mark Harris. Mark Harris provided predominantly econometric advice throughout the thesis. Suzanne Robinson provided ongoing advice on the policy and practice implications of each study, clarity on aspects of the Australian health-care system in which this work is set, and the structure of individual papers and the overall thesis. Rachael Moorin, in addition to leading the project from which this thesis developed, provided extensive advice on the make-up of the data collections used through the thesis, development of analysis files, the analysis techniques used, interpretation of findings, and cohesiveness of the thesis.

Editing services were provided by Amanda Ellis. Advice provided by Amanda Ellis were limited to Standard D of the *Australian Standards for Editing Practice*, that is, Language and Illustrations, and Standard E, Completeness and Consistency.

I was responsible for the overall conception of the thesis and the individual studies making up the thesis, critiquing the literature, maintaining ethics approvals, preparation of data files for analysis, conducting analysis under advice from supervisors, presenting and interpreting findings and writing manuscripts and the overall thesis.

Other co-authors are listed within individual manuscripts throughout the thesis and attribution statements signed by all co-authors are included in Appendix G.

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Abstract

As in other developed countries, the Australian health care system is under increasing pressure due to an ageing population and an increasing prevalence of chronic conditions, the availability of increasingly expensive medical technologies, and increasing consumer demands for health care. In response to these challenges there have been attempts to improve the care delivered in the primary care setting, to improve patient health and reduce demand on hospitals. Continuity of care is considered a cornerstone of well-performing primary care systems and there has been much research into the role of continuity of care in improving patient outcomes. This thesis contributes to the literature by examining the role of regularity of contacts with the general practitioner (GP) as a measure of continuity of care. Regularity of GP contacts is assessed using measures based on the variance in the number of days between visits, with regular contacts taken to indicate planned, proactive care. Continuity is also assessed via more commonly used indices which capture patients' tendency to consistently visit the same GP, rather than switching between GPs.

The thesis consists of one commentary paper (published) and five empirical studies (four published, and one not submitted). The commentary paper provides an overview of the availability of the data captured in general practice clinical information systems (CISs) to support research in Australia. The empirical studies are a set of observational studies using a number of data collections including administrative data collections in Western Australia (WA), linked survey and administrative data in New South Wales (NSW), and CIS data from general practices in WA and NSW.

The commentary paper provides an overview of Australia's history as a leader in research using administrative data collections and describes the current availability of CIS data in supporting research. CIS data is a potentially useful resource on account of the clinical information captured, which is not typically available in administrative collections. The manuscript shows that although the availability of CIS data for research is improving, Australia does lag behind some other developed countries in this space.

The first empirical study compared two previously published measures of regularity of GP contacts to a newly developed measure, in terms of their suitability to measure associations with hospitalisation outcomes. This study was performed among patients with and at risk of diabetes in WA from 1990 to 2004. The newly developed measure was designed to be less correlated with the frequency (number) of GP contacts than the previously developed measures. Analysis found that it was in fact less correlated with frequency, which is beneficial in estimating associations with hospitalisation outcomes. The newly developed measure, called the modified regularity index, was used in subsequent studies.

The second study assessed associations between regularity of GP contacts and diabetes-related hospitalisation and hospitalisation costs in WA from 1990-2004. This study coincides with the introduction of a new policy in 1999 designed to improve the continuity and quality of care in general practice for patients with diabetes and other chronic / complex needs. This study found that through this period more regular GP contacts were associated with reductions in the rate and costs of diabetes-related hospitalisation. However, the introduction of the new policy had minimal impact on care patterns. Leading up to the new policy, a slight reduction in regularity of GP contacts was recorded, which appeared to stop following the program's introduction, and there was little evidence for change in the associations between regularity and hospitalisation outcomes.

The third study assessed the impact of regularity and continuity of GP contacts on hospital and emergency department (ED) use in WA from 2005–2015, among cohorts with prior hospitalisation for seven different conditions. In this analysis different study designs and analysis techniques were employed to provide some evidence as to the robustness of effect estimates. In the first instance the design and analysis adopted reflected many of the empirical studies on the topic of continuity of care. In two subsequent analyses the design and analysis methods were modified to remove likely sources of bias. The first analysis showed negative associations between regularity / continuity and hospital / ED-use outcomes, however these associations reduced in magnitude or disappeared when study designs and analysis methods with reduced risks of important biases were used. This pattern was apparent across all clinical cohorts assessed.

Study four explored potential causal pathways underlying relationships between regularity / continuity and downstream outcomes. In this study CIS data covering practices in WA and NSW were used to examine the impacts of regularity and continuity on processes of care and evaluated health outcomes among patients with type 2 diabetes. Process of care indicators were the completion of pathology testing within recommended timeframes, and evaluated health outcomes were the recording of glycosylated haemoglobin (HbA1c) within target range. This study found that regularity and continuity were associated with increased pathology testing (reflected in a reduced likelihood of monitoring tests being missed, and an increased likelihood of test overuse). However, changes to processes of care were not reflected in significant improvements in the likelihood of recording healthy HbA1c levels.

Finally, study five further examined potential causal pathways by examining the impact of regularity and continuity on the use of statin medications among people at risk of cardiovascular disease events. This analysis found that both regularity and continuity were associated with improved adherence to statin medication (among existing statin users) and an increased likelihood of initiating statins (among non-users). This study then included a mediation analysis in which statin use was the mediating variable with cardiovascular hospitalisation / ED use being the outcome. The mediation analysis found that although regularity and continuity were associated with reductions in hospital / ED use, only a very small effect was mediated through improved statin use, that is, the most likely causal pathway by which hospitalisation outcomes may be influenced.

Various analyses also tested for interactions between regularity and continuity in their associations with outcomes, finding little evidence of interaction effects. Similarly, sensitivity analyses investigated the extent to which the choice of continuity measure impacted on associations, and found little evidence of difference between measures.

These studies present several important findings and contribute substantially to the continuity of care literature. The major contributions of this thesis to the literature are as follows:

1. The modified regularity index is developed and presented as an alternative measure of continuity of care, with advantages over the few previously published measures of regularity. This index is demonstrated to have an additive relationship with more commonly used measures of continuity (rather than a substitutive or multiplicative relationship). This demonstrates value in capturing regularity of GP contacts alongside more commonly used continuity measures along with presenting an updated method to do so, which will contribute to future research by facilitating a fuller assessment of the impact of GP contact patterns on patient outcomes.
2. This thesis demonstrates that where policies promoting primary care management have been introduced in the past, GP contact patterns and patient outcomes did not change substantially. This indicates challenges in the development of financial incentives which lead to desired changes in practice and outcomes at the population level, indicating the need for quality evaluation alongside the implementation of new primary care policies.
3. This thesis demonstrates that relationships between regularity / continuity of GP contact and hospital / ED outcomes are highly sensitive to the study design and statistical analyses used. Depending on the design and analysis used, studies may report substantial protective effects or find no significant association at all. Many of the empirical studies of continuity of care use methods which, according to the findings of this thesis, risk overstating potential beneficial effects. This thesis demonstrates that where studies into regularity / continuity of care are conducted, alternative designs and analyses should be adopted and reported to improve our understanding of the robustness of associations. A clearer understanding of the associations with hospitalisation outcomes and potential effect sizes is essential to the development of primary care policy.

4. Regularity and continuity are demonstrated to be associated with process of care measures (appropriate pathology testing and medication use). This is in line with mechanisms of action commonly described by researchers in theorising how continuity / regularity may influence hospitalisation / ED use outcomes. However, when analyses are extended to incorporate these outcomes the evidence for a protective effect on outcomes is more modest. This presents a major contribution to future research, by demonstrating how causal pathways may be more fully assessed to add evidence on potential benefits of continuity of care, and to policy, in suggesting that policies to enhance regularity / continuity are likely to result in more modest changes to outcomes than suggested in much of the existing literature.

5. Overall, this thesis suggests that on account of the outcomes assessed, study designs chosen, and analyses used, the existing literature on continuity / regularity of care may inflate the potential benefits of these patterns of care. The thesis presents multiple approaches for researchers to improve the evidence produced in this area. The thesis presents important analytical choices that can be assessed within the familiar framework of observational studies using purely administrative collections, presents approaches that can be adopted using the more detailed clinical data available in CISs, and presents how mediation methods can provide a fuller assessment of possible causal pathways. Although the research in this area to date may be hampered by a reliance on a relatively narrow set of continuity of care measures and general reliance on a narrow set of study designs and analysis methods, this thesis demonstrates that alternative approaches can be applied in this area to strengthen the evidence base and support the development of primary care policies which will maximise patient health and reduce reliance on hospitals.

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List of Abbreviations

ACSC	Ambulatory Care Sensitive Condition
ACT	Australian Capital Territory
AMA	Australian Medical Association
AIHW	Australian Institute of Health and Welfare
APDC	Admitted Patients Data Collection
ARIA	Accessibility/Remoteness Index of Australia
BMI	Body Mass Index
CDE	Controlled Direct Effect
CDL	Centre for Data Linkage
CDM	Chronic Disease Management (used in reference to a specific government program)
CHeReL	Centre for Health Record Linkage
CIS	Clinical Information System
COC	Continuity of Care (used in reference to a specific measure)
COPD	Chronic Obstructive Pulmonary Disease
CPCSSN	Canadian Primary Care Sentinel Surveillance Network
CPRD	Clinical Practice Research Datalink
CVD	Cardiovascular Disease
DALY	Disability Adjusted Light Year
DLB	Data Linkage Branch
DOCLE	Doctor Command Language
DRG	Diagnosis Related Group
ED	Emergency Department
eGFR	Estimated Glomerular Filtration Rate
EHR	Electronic Health Record
EMRALD	Electronic Medical Record Administrative Linked Database
EPC	Enhanced Primary Care
GDP	Gross Domestic Product
GP	General Practitioner
GRHANITE	GeneRic HeAlth Network Information Technology for the Enterprise
HbA1c	Glycosylated Haemoglobin
HIV	Human Immunodeficiency Virus

HMDC	Hospital Morbidity Data Collection
HREC	Human Research Ethics Committee
ICD	International Classification of Diseases
ICD-10-AM	International Classification of Diseases – 10 th edition – Australian Modification
ICPC	International Classification of Primary Care
IHD	Ischaemic Heart Disease
IQR	Interquartile Range
IRR	Incidence Rate Ratio
IV	Instrumental Variable
LOINC	Logical Observation Identifiers Names and Codes
MACSS	Multipurpose Australian Comorbidity Scoring System
MAGNET	Melbourne East Monash General Practice Database
MBS	Medicare Benefits Schedule
MMCI	Modified Modified Continuity Index
MPR	Medication Possession Ratio
NDE	Natural Direct Effect
NHS	National Health Service
NIE	Natural Indirect Effect
NPS	National Prescribing Service
NSW	New South Wales
NWIS	NHS Wales Informatics Service
OR	Odds Ratio
PBS	Pharmaceutical Benefits Scheme
POLAR	Population Level Analysis & Reporting
PPH	Potentially Preventable Hospitalisation
PPRL	Privacy Preserving Record Linkage
PHN	Primary Health Network
PHRN	Population Health Research Network
PM	Proportion Mediated
RACGP	Royal Australian College of General Practitioners
RCT	Randomised Controlled Trial
RR	Relative Risk
SAIL	Secure Anonymised Information Linkage
SECON	SEquential CONTinuity Index

SEIFA-IRSD	SocioEconomic Index for Areas – Index of Relative Social Disadvantage
SLK	Secure Linkage Key
SNOMED	Systematized Nomenclature of Medicine
SQL	Structured Query Language
SURE	Secure Unified Research Environment
T2DM	Type 2 Diabetes Mellitus
TCE	Total Controlled Effect
UPC	Usual Provider of Care (also referred to as Usual Provider Continuity)
WA	Western Australia
WADLS	WA Data Linkage System
WHO	World Health Organisation

Chapter 1 Overview, aim and objectives

This thesis falls under the broad topic of continuity of care. The overall aim of this thesis is to examine the impact of regularity of contacts with the general practitioner on hospital and emergency department use. Regular contacts are viewed as a measure of continuity of care, indicating planned, proactive care.

The specific objectives are:

1. Describe the availability of general practice data in Australia for observational research
2. Assess indexes used to measure regularity, with sub-objectives:
 - a. assess two previously published measures of regularity in comparison to a newly developed measure
 - b. compare regularity to commonly used measures of continuity by investigating interactions between exposures in influencing outcomes
3. Assess associations between regularity and hospital / ED outcomes, with sub-objectives
 - a. determine impacts of historical changes to primary care policy on regularity and the associations between regularity and outcomes in patients with diabetes
 - b. investigate contemporary associations between regularity and hospitalisation / ED outcomes across conditions
 - c. determine the sensitivity of estimates of these associations to study design and statistical analysis
4. Provide an improved understanding of the possible causal pathways underlying associations between regularity and hospital / ED outcomes, with sub-objectives
 - a. investigate associations between regularity and appropriate use of pathology testing and patient health as indicated by results on pathology tests
 - b. investigate associations between regularity and the appropriate use of preventive medications
 - c. assess appropriate medication use as a mediator of relationships between regularity and hospital / ED outcomes

Where possible, analyses relating to regularity of general practitioner contacts are extended to also assess common measures of continuity to provide a greater contribution to the continuity of care literature.

This is a hybrid thesis, which includes five manuscripts and additional analysis. The structure of the thesis is outlined below.

Chapter 2 provides an overview of the key features of the Australian health-care system then discusses the role of continuity as a key feature of primary care. It introduces the framework of health service utilisation used through the thesis, and describes how continuity of care is theorised to influence patient health outcomes. The chapter then provides a critique of the literature concerning continuity of care and introduces the concept of regularity of GP contacts. Finally, this chapter discusses the observational methods and administrative data that are generally used in the empirical literature in this area.

Chapter 3 outlines the methods for the thesis, namely the data collections used, ethical and data access approvals, and the measures of continuity and regularity in the existing literature used within this thesis.

Chapter 4 provides an overview of the data collections available in Australia which are suited to observational work in this area, addressing objective 1. Manuscript 1, “Using general practice clinical information system data for research: the case in Australia”, is a commentary providing an overview of the availability of information from general practice clinical information systems. CISs provide more detailed clinical information than is available in typical administrative collections.

Chapter 5 compares two published measures of regularity of GP contact with one newly developed measure (an extension of one of these existing measures) in terms of their associations with frequency of GP contacts and measures of association with hospitalisation outcomes. This chapter includes manuscript 2, “Regularity of contact with GPs: Measurement approaches to improve valid associations with hospitalization”, and additional analyses. This chapter addresses objective 2a.

Chapter 6 investigates associations between regularity of GP contact and hospitalisation outcomes among people with and at risk of diabetes in response to objective 3a. These associations are assessed from the years 1990 to 2004, in order to assess how these associations may have changed after the introduction of new primary care policies. This analysis, in manuscript 3, “Regularity of contact with general practitioners and diabetes-related hospitalisation through a period of policy change: a retrospective cohort study”, finds that there was a slight reduction in regularity of GP contact in the years leading up to the introduction of new policy, though this trend ceased following introduction of the policy. The negative association between regularity of GP contact and hospitalisation remained did not change significantly following introduction of the policy.

Chapter 7 performs some similar analyses using more up-to-date data to perform some similar analyses and understand these associations in more modern times. In this chapter, associations between continuity and regularity with hospital and ED outcomes were assessed among cohorts with different clinical conditions. Different study designs and analyses were used. Firstly a design / analysis was used to reflect much of the empirical literature on continuity of care. Associations were then estimated using designs and analyses intending to remove potential sources of bias. This study finds that although negative associations between regularity / continuity of GP contact were observed when using methods similar to much of the continuity of care literature, these were substantially reduced when study design and analysis removed likely biases. This chapter addresses objectives 3b and 3c.

Chapter 8 utilises general practice data to investigate the impacts of regularity and continuity on quality of care, based on the completion of pathology tests in line with clinical guidelines, and objective measures of patient health, based on results on these pathology tests within target ranges. This analysis is included in paper 4, “Associations between regular GP contact, diabetes monitoring and glucose control: a study using general practice data”, and finds that regular GP contacts reduce the likelihood of monitoring tests being missed, but change in monitoring do not translate into improvements in patient health. This chapter addresses objective 4a.

Chapter 9 provides an examination of a second potential causal pathway via which regularity and continuity of care may impact on hospital and ED-use outcomes, in response to objective 4b. Firstly manuscript 5, “Regularity and continuity of GP contacts and use of statins amongst people at risk of cardiovascular events”, demonstrates that among people at risk of cardiovascular disease (CVD), higher regularity and continuity of care are associated with improved statin use. This chapter additionally investigates possible interaction effects between regularity and continuity, finding little evidence for interactions to address objective 1b. Finally, mediation analysis is performed in which regularity and continuity of care are found to influence hospitalisation outcomes, with improved statin use a partial mediator of this relationship, addressing objective 4c.

Chapter 10 provides a discussion of the implications of the thesis for policy and research, and discusses future research priorities.

This thesis has relevance both in terms of policy and future research.

For researchers in the area of continuity of care, this thesis firstly demonstrates the value of capturing information on regularity of GP contact alongside more commonly used measures of continuity of care. Regularity of GP contacts can be measured using the same administrative data typically used in studies of continuity, so this represents an extension to existing literature which would be straightforward for other researchers to incorporate. Secondly, the thesis demonstrates how the understanding of potential causal pathways can be improved by measuring effects of continuity on intermediate care process outcomes, rather than solely assessing hospitalisation outcomes. Thirdly, the thesis demonstrates the use of some analytic techniques beyond multivariate regressions to improve understanding of associations with outcomes.

From a policy perspective, this thesis makes a significant contribution by improving understanding of the influence of patterns of GP contacts on patient health outcomes, in the context of a fee-for-service primary care system. The thesis demonstrates the potential value of maintenance of regular GP contacts by patients with chronic conditions, alongside further evidence on the role of continuity of provider. Like in other countries, current health policies in Australia intend to support patients and reduce costs by strengthening primary care systems in the hope that this will reduce hospitalisation. An improved understanding of the role of GP contact patterns provides important evidence to guide the implementation of new primary care policy. This work may highlight areas where new policies or programs may seek to facilitate continuity or regularity of care to improve patient outcomes. Similarly, policies intending to modify other aspects of primary care (for example, rapid access policies) may be able to be viewed in terms of their potential to additionally affect regularity and continuity, and improve understanding of potential adverse outcomes.

Chapter 2 Introduction

This chapter will use the literature to provide an overview of the context and framework of the thesis. Firstly the chapter will describe the pressures facing the Australian health system and health systems elsewhere. Following this, key features of the organisation and funding of the Australian health system relevant to the current work are summarised. This chapter then goes on to introduce key concepts, definitions and the study framework.

2.1 Australian health system and context

2.1.1 Population ageing and chronic conditions

Australia has some of the best health outcomes in the world, with a life expectancy above that of most Organisation for Economic Co-operation and Development countries (1, 2), good survival for many cancers, low smoking rates (2) and a low rate of infant mortality (3). As with most developed countries, an ageing population and increases in chronic disease are contributing to substantial strains on health systems in Australia. The proportion of the population aged 65 and older was eight per cent in 1964 (4), compared to 15.9% in 2019 (5) and this growth is projected to continue (6). Increases in life expectancy represent a combination of years in good health and years with chronic illness and disability (7). This puts pressure on health expenditure; Australians aged 65 and older have more than triple the rate of health expenditure compared to the population as a whole (8); almost half of those older than 65 have five or more long-term conditions and this number increases further with increased age (1). Alongside these demographic changes there is an increasing prevalence of chronic disease risk factors including obesity (1, 9), risky alcohol consumption (10) and insufficient exercise (10). Additionally, new medical technologies and pharmaceuticals are increasingly expensive (11-14), wage growth in the health sector exceeds inflation (11) and community expectations for health care are increasing (13-15). There are substantial inequities in health care with people living in regional and remote areas having comparatively poor access to services and poorer outcomes among Aboriginal Australians than non-Aboriginal Australians (1). Meanwhile fragmentation in service delivery resulting from a split in responsibilities between levels of government creates challenges in delivering quality care to patients (1, 16). These factors have led to dramatic increases in health expenditure. From 1989-90 financial year to the 2013-14 fiscal year health expenditure increased from 6.5% to 9.7% of gross domestic product (GDP) (17), though growth in per-person expenditure has slowed since (18).

Similar problems are seen elsewhere. Health expenditure growth is expected to outpace GDP growth in almost all OECD countries to 2030, with chronic disease risk factors a major concern across these countries (19). The National Health Service (NHS) in the United Kingdom has experienced a 50% increase in annual expenditure from 2008-09 fiscal year to 2016-17, driven by a combination of increased utilisation, and increases in the use of high-cost pharmaceuticals and chemotherapy (20). In the United States high-cost technology is a major driver of health spending growth, as in Australia, with increasing unit prices also important to growth in health expenditure (21). Similarly, in Canada, per capita health expenditure in recent years has increased by 1.2% a year, after adjusting for inflation (22).

2.1.1.1 Chronic illness

The term “chronic illness” can have variable meanings across settings; some definitions state that a disease must be present for some minimum period (23) to be considered chronic while others do not (and this minimum period varies across definitions provided by different agencies) (24). Cancers are often defined as chronic diseases (25) though some sources suggest that only certain cancer types are (24), similarly “non-communicable disease” is often used interchangeably with chronic disease despite there being clear examples of infectious disease leading to chronic illness (e.g. human immunodeficiency virus (HIV)) (24, 25). Accordingly, there is no definitive list of which conditions are defined as chronic diseases.

There is, however, general agreement that these are diseases which are long-lasting and with persistent effects. The Australian Institute of Health and Welfare (AIHW) suggests that chronic diseases are typified by having a complex causality with multiple factors contributing to their onset, have a long and possibly asymptomatic development period, involve a long course of illness with potential for subsequent health complications, and are often associated with functional impairment or disability (26). These diseases can typically be controlled but not cured (23).

The Global Burden of Disease study reports the disability-adjusted life years (DALYs) attributable for various conditions internationally. A DALY represents the loss of the equivalent of one year of full health, and includes years of life lost to a condition and years lived with disability as a result of the condition (27). This study has found that over the last 30 years, several of the most important conditions in terms of DALYs are chronic conditions (ischaemic heart disease (IHD), diabetes, stroke, chronic kidney disease, lung cancer, and musculoskeletal disorders) (28). Deaths from non-communicable diseases have increased across low and middle income countries while deaths from infectious disease have declined; meanwhile in high-income countries health improvements have stagnated due in large part to lack of progress on chronic disease risk factors (28). Even in low–middle and middle income countries there has been a rapid shift towards non-communicable diseases as the major disease burden, with these conditions accounting for about 38% of total DALYs in 1990 compared to 66% in 2019 (29).

As with most countries, chronic diseases account for a large and increasing burden of disease in Australia (15). Many of the conditions causing the greatest burden of disease in Australia and Western Australia (WA) are chronic illnesses. When conditions are ranked according to the DALYs they are responsible for in WA, chronic heart disease, chronic obstructive pulmonary disease (COPD), osteoarthritis, stroke, type 2 diabetes, asthma and rheumatoid arthritis are all in the top 15 (30). Similarly, many of the problems most frequently managed by general practitioners are chronic conditions. Hypertension is the most common condition managed at GP attendances, with diabetes, arthritis, lipid disorders, and asthma also common reasons for attendances (31).

2.1.1.2 Policy responses in Australia to the management of chronic disease in primary care

Governments in Australia have made some efforts made to respond to the challenge of increasing chronic disease prevalence. In 2005 a National Chronic Disease Strategy was produced by the National Health Priority Action Council (32). This strategy had objectives around preventing the onset and slowing the progression of chronic disease, improving the wellbeing of patients, reducing hospitalisation and enhancing capacity of the health workforce to manage chronic disease. The strategy outlined four action areas considered vital to address chronic disease: (1) Prevention across the continuum, (2) Early detection and treatment, (3) Integration and continuity of prevention and care, and (4) Self-management. Primary care has multiple roles across these action areas. Primary care has a crucial role in early detection and intervention on account of the sector's role in screening, identification of risk factors, and the role of the GP as a gatekeeper of referrals to specialist and diagnostic services. Similarly, actions to improve continuity of prevention and care necessarily involve primary care as these health care practitioners are best placed to link with the network of acute, specialist and allied health services that patients may require. General practice and other primary care providers are also well suited to enable patients in self-management of their conditions (32).

In recent years, the Coalition of Australian Governments Health Council has produced a National Strategic Framework for Chronic Conditions, superseding the 2005 strategy (33). The framework's vision is "All Australians live healthier lives through effective prevention and management of chronic conditions". In comparison to the 2005 strategy, the 2017 strategic framework takes a broader view of the social and individual determinants of health, though the role of primary care remains constant. Early detection of chronic conditions, coordinated and continuous care, support with self-management are all focuses of the framework and primary care remains central to these goals, although the framework does not generally go as far as to assign specific responsibilities to sectors or professions (33).

2.1.2 The Australian health–care system

2.1.2.1 Structure of the Australian health–care system

The Australian health–care system is complex, with funding and responsibilities split between federal and state / territory governments, and public and private providers and insurers (12, 16, 34). This complexity results from Australia’s history as a federation of states and ongoing political debates concerning funding and organisation (16, 35), rather than reflecting a deliberate design. This section provides an overview of key features relevant to the current work.

2.1.2.1.1 Federal responsibilities

Australia’s Federal Government administers Medicare, the nation’s universal public insurance system (36). The scheme ensures that all Australian citizens and permanent residents, except prisoners (37), have access to medical and hospital services. Treatment in public hospitals is fully subsidised via Medicare and free to in-patients and out-patients (36). Out-of-hospital services can involve patient co-payments though safety nets come into effect when individuals or families have health spending in excess of specified thresholds within a year (36).

Medicare subsidises out-of-hospital services including general practice, some allied health services, diagnostic testing and more services. These services are provided by private practitioners who set their own fees for patients, a portion of which is covered by Medicare. The government sets a Medicare Schedule Fee which determines the rebate provided to patients for each service; any rebates paid are a percentage of this schedule fee. A 100% rebate is paid for GP consultations, with lower rebates for other services. Safety nets exist for patients whose out-of-pocket costs hit defined thresholds within a calendar year (38). Funding is explained in more detail in 2.1.2.2.

Australia's Federal Government also administers the Pharmaceutical Benefits Scheme (PBS). The PBS supports patient health by providing access to important medications at heavily subsidised costs (12, 36). PBS-administered medications are dispensed by community-based pharmacies (and hospital pharmacies for certain patient groups) (39). On dispensation of a PBS-listed medication the patient pays a co-payment (\$41 for general and \$6 for concessional patients at the time of writing (40)) with the remainder of the pharmacist payment coming from the government. The government's role as the major purchaser of PBS-listed medications gives considerable negotiating power in purchasing, helping to limit expenditure (12).

The Federal Government has a number of other responsibilities in the health and related sectors. These include responsibility for administering aged care facilities (36), registration and regulation of most health practitioners along with training via the tertiary education system (41), and oversight of most disability services (42). In 2015 the government established 31 Primary Health Networks (PHNs) across Australia (43). PHNs are commissioning organisations which aim to improve the efficiency and effectiveness of medical services for patients at risk of poor outcomes, and to improve the coordination of care by ensuring patients receive the right care, in the right place, at the right time (43). The PHNs have several priority areas, which include population health, mental health Aboriginal and Torres Strait Islander health, chronic disease care and other areas (44).

2.1.2.1.2 State responsibilities

One of the major responsibilities of state and territory governments is the operation of public hospitals (which make up the majority of Australia's hospitals), and these are funded by both state/territory and federal governments (12, 16) using an activity based funding framework (45, 46). Legislation concerning private hospitals, along with licensing and reporting are state/territory government responsibilities (36).

States also have a role in the funding and operation of some primary health-care services (34), mental health, maternal and childhood services (12), and ambulance and patient transport (47).

2.1.2.1.3 Private hospitals

In Australia some hospitals are operated privately, along with most medical, dental, allied health, pharmacies and aged care services (34, 36). Private hospitals account for about one-third of all hospital beds (36). Private hospitals are owned and managed on a for-profit basis, or by not-for-profit and religious or charitable groups. These facilities are generally smaller than public hospitals and do not generally operate emergency departments (12).

Despite universal, free public hospital access being guaranteed via Medicare, private health insurance is common, with about half of all Australians purchasing this. Take-up of private health insurance is incentivised by tax penalties for non-coverage which increase with age and income (36). Private health insurance is regulated at the federal level in terms of registration of insurers, the fees charged and benefits paid (12). Private health insurance generally provides faster access to elective surgery (whether in a private hospital or as a private patient in a public hospital) (41), and allows patients to choose their doctor as an in-patient (48). More comprehensive policies may provide reimbursement for some expenditure on allied health (48), dental and other services (12), though do not provide any coverage for GP services.

2.1.2.2 Primary care in Australia

2.1.2.2.1 Relevance of ambulatory care in chronic illness

In Australia and elsewhere, there have been attempts to control healthcare expenditure by shifting the focus away from hospitals towards the primary care sector, both because primary care treatments are less costly (42) and in recognition of the unsuitability of hospitals to manage the chronic conditions that are now a major concern (15, 33).

This approach is in line with a body of literature developed in the last three decades regarding the concept of ambulatory care sensitive conditions (ACSCs). ACSCs are conditions for which it is theorised that hospitalisation may be avoidable if preventive care and quality disease management can be applied, generally in the ambulatory setting (49). This concept was described using different terminology through research that used clinical consensus approaches as early as the year 1990 (50, 51). By the turn of the century, lists of ACSCs had been developed by researchers working with clinical panels in Australia (49), Canada (52), Europe (53), the United States (54) and the United Kingdom (55). Some of the early impetus for the identification of ACSCs was to support indirect assessment of the performance of primary care systems by capturing trends in ED presentations and hospital admissions for these conditions (51, 56). Recent evidence has highlighted that hospitalisation for these conditions may reflect socioeconomic factors (57, 58) or other health system issues such as bed availability (59, 60) as much as primary care quality and access. This has led some to suggest that rates of ACSCs alone should not be used as a measure of primary health care quality, rather that they can be used to investigate specific patient characteristics and determinants (56).

ACSCs have been adopted by Australian governments as performance measures, with hospitalisations resulting from these (potentially preventable hospitalisations (PPHs)) tracked to assess performance (61). ACSCs are grouped into three categories: vaccine-preventable (influenza and pneumonia; and other vaccine preventable conditions); acute (dehydration and gastroenteritis; convulsions and epilepsy; ear, nose and throat infections; dental conditions; ulcer perforation; ruptured appendix; urinary tract infections; pelvic inflammatory disease; cellulitis; and gangrene), and chronic (diabetes complications; nutritional deficiencies; iron deficiency anaemia; hypertension; congestive heart failure; angina; COPD; and asthma) (62).

2.1.2.2.2 Primary care system in Australia, functions and funding

Functions of the primary health care system range from disease screening, treatment of acute problems, management of chronic conditions, health promotion and more (63). Providers of these services include GPs, pharmacists, nurses, Aboriginal health practitioners and many others. Primary health care extends beyond professionals simply treating illness to include support for patient self-management, particularly in chronic conditions.

GPs are the major providers of primary health care in Australia, with greater than 80% of Australians visiting a GP each year. In addition to their role in the treatment and management of common conditions (36), GPs serve as gatekeepers to the other areas of the health system. GPs have responsibilities in prescribing medicines, ordering pathology tests, ordering diagnostic imaging, and referral to specialists, allied health professionals and elsewhere (36, 41). Specialists cannot be accessed without GP referral (12). Most GPs work as part of group practices with only a small minority operating as sole practices (41).

GPs are funded by the Federal Government via Medicare on a fee-for-service basis (36, 41). The Medicare Benefits Schedule (MBS) defines the reimbursements paid to GPs for general attendances. The MBS additionally outlines fees for specific patient-management activities the government aims to incentivise, such as the preparation of care plans, medication reviews, the provision of specific preventative activities to high-risk patients, and other activities (64).

In addition to the fee-for-service payment provided to practices via Medicare, GPs are able to charge patients additional co-payments at their discretion (and patients cannot claim these costs via private health insurance) (12, 41). Doctors who forego any co-payment and instead directly bill Medicare for services provided are referred to as bulk-billing doctors. Historically between 60 and 80% of GP attendances are bulk-billed (41), though the average co-payment for non bulk-billed services has increased steadily over time. This fee-for-service model has been criticised for its incentivisation of service volumes rather than ongoing patient management, which conflicts with the principles of primary care (16, 36, 41). Compounding this lack of incentive for ongoing patient management, patients in Australia are able to attend any GP or practice of their choice (12), with no formal registration system, unlike some other countries.

Funding for other aspects of the primary health-care system differs. Community health services are generally funded by individual states and territories. Dental and other allied health services are largely funded through individuals via a combination of out-of-pocket expenditure and private health insurance rebates (63), though there is increasing funding available via Medicare for allied health practitioners who support patients with chronic conditions (65).

The Federal Government also funds the PHNs which are regional primary care organisations. These are operated by not-for-profit companies and make decisions based on which services should be provided in their region, and who should provide them, based on evidence and the characteristics of the region (43). PHNs can commission health services to meet identified needs and fill gaps in primary care, and work within their regions to encourage the integration of services. For example, a PHN may, based on identified gaps in service delivery, commission a new after-hours service or health promotion program (44). Through this role the PHNs direct national funding to areas of greatest importance. The government funds PHNs via a combination of ongoing operational funding, funding for specific programs and incentive funding for PHNs that meet performance targets. Funds are passed on to service providers by PHNs via their purchasing / commissioning role (66).

2.1.2.3 Promotion of chronic disease management in the fee-for-service context

The Australian Government introduced the Enhanced Primary Care (EPC) program in 1999, and subsequently expanded and modified the program, and renamed as the Chronic Disease Management (CDM) program in 2004 (67). The EPC program was introduced with the aim of improving preventive health and co-ordination of care, in particular among the elderly. The program consisted of new MBS items that allowed GPs to claim reimbursement for providing health assessments, preparing care plans and performing case conferencing for high-risk patient groups (68, 69). The CDM program which superseded the EPC program had similar aims but reduced administrative requirements, expanded the services and conditions covered and included allied health items (70). There are areas where the specific financial incentives available to GPs align with the 2005 and 2017 chronic disease strategies discussed in section 2.1.1.2. For example, incentives to participate in multidisciplinary case conferences align with the action area on integration and continuity of care, while cycle of care items for diabetes and asthma patients require GPs to provide patients with self-care education, along with clinical tests to assess progression of disease (32, 71). Some commentators have framed these programs as being small-scale attempts at improving the care delivered to patients within the context of a fee-for-service system that prioritises service volumes at the expense of continuity (16).

One of the recent developments in the delivery of primary care in Australia is the establishment of Health Care Homes, also known as medical homes. These intend to support patients with complex needs or chronic conditions by providing better coordinated care. Under this model of care each patient has a multidisciplinary care team led by their doctor, with the patient developing a shared care plan with the support of their care team, and having better access to all members of the care team (which may include support by telephone or videoconference), and better coordinated care regardless of who is providing it (72, 73). Although the concept of health care homes has been described for several decades and introduced in different countries (74), the first large-scale implementation of this model of care has begun in Australia in the last five years. Health care homes currently include general practices and Aboriginal Community Controlled Health Services which have opted to participate in the Health Care Homes program (72).

2.1.3 Section summary

This section has provided an overview of the key features of the Australian health system and the major issues it faces. Chronic illnesses are a major cause of ill health in Australia and are putting an ever-increasing strain on the health system, as is the case across much of the world. The Australian health system is not particularly well suited to the management of these conditions. The system is fragmented on account of the sharing of responsibilities between the Federal Government, state and territory governments and the private sector. Even within sectors the fee-for-service approach to funding of health care can result in fragmented, episodic care which does not provide the support required for the long-term conditions now of greatest importance. In recent years there have been some efforts to promote the management of these conditions in the primary care setting, through the introduction of financial incentives within the fee-for-service framework, the introduction of new models of care designed specifically for patients with complex needs, and some structural changes via the introduction of the PHNs intending to support primary care and improve patient outcomes.

2.2 Continuity of care: key concepts and critique of literature

The remainder of this chapter introduces key concepts as follows. Primary care and continuity of care are defined and the role of continuity as a component of primary care is outlined. The Andersen framework of health service utilisation is discussed and continuity of primary care placed within this framework with reference to the empirical literature on continuity of care and the mechanisms of action theorised by researchers. General limitations of the empirical literature on the topic of continuity of care are discussed. The concept of regularity of GP contact as a measure of continuity is introduced. The general approaches to empirical work in this area and the types of data collections used are described. Finally, regularity and continuity are discussed in terms of their potential responsiveness to policy changes.

2.2.1 Rationale and framework

The fragmentation of the Australian health care system and the implications of this for continuity of care presents a problem for patients. Continuity of care is considered an important component of medical care (75). It has been recognised as a central tenet of general practice, according to colleges of general practice in Australia, New Zealand (76) and the United Kingdom (UK) (77), and is a primary objective of family medicine in the United States of America (USA) (78). Continuity of care is of particular concern in the care of people with chronic and complex conditions and is considered a global priority given its relevance to care in low, middle and high-income countries (79). According to Starfield et al., defining characteristics of primary care are first-contact access for each new need, long-term person-focused care, comprehensive care for most health needs, and coordinated care when it must be sought elsewhere (80). Continuity of care is vital to delivering care with these characteristics.

2.2.1.1 Definitions of continuity

Many definitions of continuity of care have been published. One of the earliest was by Hennen in 1975, who outlined four dimensions of continuity (81). The first was the chronological dimension, applying to the natural history of illness and the way in which family physicians use repeated observations over time as a diagnostic and management tool. The second was the geographical dimension, meaning that primary care is applied by the family physician regardless of site. The third was the interdisciplinary dimension, meaning that the GP manages multiple illnesses within the patient, helping them deal with problems of living which may or may not relate to the illness, and coordinating management to the optimal function of the patient and their family. Finally, the interpersonal dimension refers to the building of professional and interpersonal relationships with the patient, their family, and other health professionals involved in their care. A broader definition was published by Shortell in 1976 (82). Shortell defined continuity of medical care as being the extent to which services are received as part of a coordinated and uninterrupted succession of events, consistently meeting patients' needs. This definition is more limited than that put forward by Hennen, in that it does not explicitly consider continuity in the context that multiple providers and specialities may be required in the care of an individual, nor does it consider the quality of the relationship between the patient and doctor, or the understanding of the patient's social situation which may influence health and response to treatment.

Although these are some of the earliest definitions of continuity, more recent definitions have been broadly adopted by researchers and practitioners working on the topic. The two most commonly cited definitions are those published by Saultz in 2003 (83) and by Haggerty et al., also in 2003 (84). Haggerty et al. broadly defined continuity in relation to primary care as the relationship between a single practitioner and patient that extends beyond specific episodes of illness (and noted that definitions differ outside of primary care) (84). Saultz (83) offered a similar definition of continuity, as a longitudinal relationship between patients and those who care for them that transcends multiple illness episodes and includes responsibility for preventive care and care coordination (84). Each of these papers provide definitions of continuity incorporating three levels or types of continuity, resembling Hennen's four dimensions (81). These are summarised in Table 2-1 to allow for a comparison. At the lowest level, informational continuity, both definitions highlight that the information available across episodes extends beyond medical informational to also incorporate information on the patient's social situation and personal values. At the next level of longitudinal / management continuity, the familiarity of the medical home as described by Saultz would support the predictability and security referenced by Haggerty, while the sharing of management plans and protocols described by Haggerty would lead to the organisation of the team of providers as described by Saultz. At the interpersonal / relational level, both definitions highlight the ongoing relationship between patient and provider as a key element. Some differences do exist between the definitions, for example the interpersonal dimension as described by Saultz involves a relationship with a single provider, whereas Haggerty et al. describe relationships with teams of providers, rather than a single provider, in defining relational continuity. These definitions have been adopted by researchers evaluating the effects of continuity of care, with specific measures of continuity often described in terms of the level or dimension they apply to.

Table 2-1: Comparison of commonly cited definitions of continuity published by Saultz and Haggerty et al. in 2003.

Dimension / type of continuity	Definition from Saultz	Definition from Haggerty et al.
Informational	An organised collection of medical and social information about each patient is readily available to any health care professional caring for the patient. A systematic process also allows accessing and communicating about this information among those involved in the care.	The use of information on past events and personal circumstances to make current care appropriate for each individual – this is the common thread linking providers and events. The information should incorporate the medical condition, alongside patient preferences and values.
Longitudinal (Saultz) / management (Haggerty et al.)	Each patient has a medical home where the patient receives most health care, which allows the care to occur in an accessible and familiar environment from an organized team of providers. This team assumes responsibility for coordinating the quality of care, including preventive services.	A consistent and coherent approach to the management of a health condition that is responsive to a patient’s changing needs. Shared management plans or protocols facilitate management continuity, providing predictability and security in future care.
Interpersonal (Saultz) / relational (Haggerty et al.)	An ongoing relationship exists between each patient and a personal physician. The patient knows the physician by name and has come to trust the physician on a personal basis. The patient uses the physician for basic health services and depends on the physician to assume personal responsibility for the patient’s overall health care. When the personal physician is not available, a coverage arrangement assures that longitudinal continuity occurs.	An ongoing therapeutic relationship between a patient and one or more providers. This bridges past to current and future care. A consistent core staff provides patients with a sense of predictability and coherence.

These dimensions can be related back to the four central characteristics of primary care as outlined by Starfield et al. (80) in section 2.2.1. The first characteristic of primary care was that it provides first-contact access for each new healthcare need; both definitions describe continuity in terms of the trusted teams of healthcare staff that would become the first point of contact for any new health need, while Saultz (83) goes further to describe the medical home which the patient would attend when new needs arise. Secondly, the characteristic of long-term person-focused care fits with each of these definitions which highlight the importance of providers having information on patients' social and personal circumstances (supporting person-focused care) while both also describe the ongoing nature of relationships with providers (supporting long-term care). The third characteristic of primary care is comprehensive care for most health needs. Saultz describes the medical home that exists when longitudinal continuity is achieved as being the place where most health care needs are met, consistent with this characteristic, while Haggerty et al. similarly describe management continuity as supporting an ability to respond to changing patient needs. Finally, the characteristic of care being coordinated, even when sought elsewhere, is supported by the sharing of patient information and treatment plans which both definitions of continuity highlight. It is clear then that achieving continuity of care is essential to the delivery of high-quality primary care, and that research into the role of continuity in influencing downstream patient health outcomes is vital to understanding the functioning of the primary care system.

2.2.1.2 Framework: the Andersen model of health service use

Continuity of care can be viewed in the context of Andersen's widely used model of health service use (85, 86). His original model, developed in the 1960s (Figure 2-1), was intended as a way to better understand why people use health services, to measure access to healthcare, and to assist in the development of policies to promote equitable access (85). Under this model the use of health services was theorized to be dependent on predisposing characteristics (demographics, social structure and health beliefs), enabling resources (personal / family and community circumstances) and need, both perceived and as evaluated by health professionals. Andersen discussed a person's having a usual source of care as being a personal or community enabling factor under this model, and has also discussed the importance of improving the understanding of the organisation of medical care to better assess the influence of these enabling factors (85). These enabling factors are considered to have high mutability, that is they are more likely to be amenable to intervention which adds to their value as a target of study in comparison to personal characteristics, for example, which may also affect service use but cannot be modified. (85).

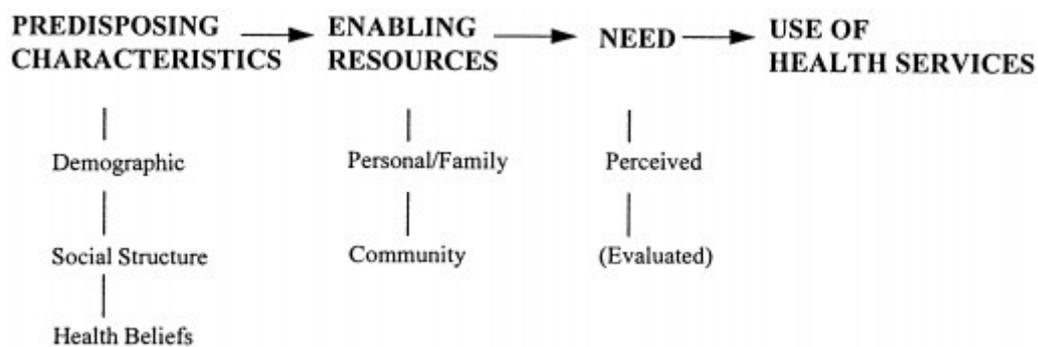


Figure 2-1: Andersen's original (1960's) model of health care utilization

This framework has since gone through several iterations and the most recent version was published in 2014 (86) (Figure 2-2). In this version of the framework use of health services is framed as resulting from contextual and individual determinants, both of which include predisposing, enabling and need factors (86). Although this model is more complex than the original, the role of continuity of care as an enabling characteristic remains. Andersen discusses enabling characteristics on the contextual side as incorporating the structure of services, that is, how care is organised within an individual institution or wider system. Furthermore, one of the personal enabling characteristics discussed is whether an individual has a regular source of care and the nature of that source of care. These enabling characteristics, both contextual and personal, are theorised to affect personal health practices and processes of medical care, such as test ordering, prescribing patterns and the quality of patient–provider communication. These practices and process will ultimately influence health services use and patient health outcomes (both perceived, i.e. subjective reports by patient or provider) and evaluated (i.e. results on blood tests)) (86). One of the major differences the 2014 model has in comparison to earlier versions is the inclusion of feedback loops. Health outcomes (both perceived and evaluated) are recognised as influencing individual characteristics (e.g. perceived need) and health behaviours (85, 86).

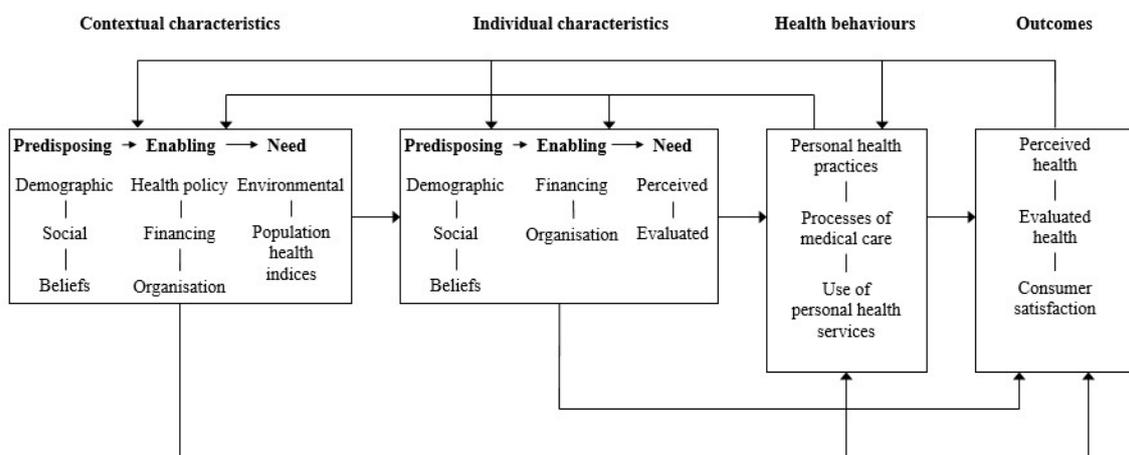


Figure 2-2: The most recent Andersen model of Health Care Utilization

The Andersen model of health service use is well suited to studies of continuity of care: researchers typically describe continuity in terms of it being a modifiable factor which may improve the quality of care received, and seek to understand its associations with outcomes of health service use (hospitalisations and ED presentations), patient satisfaction, mortality or similar outcomes. Despite this, there are only a few examples of studies of continuity of care incorporating the Andersen model in explaining their studies. One empirical investigation by Fortin et al. (87) set in Canada investigated predisposing, enabling and need-related factors as predictors of patient satisfaction with mental health services. This paper found that enabling factors were most influential in predicting satisfaction, and that continuity of care was the most influential factor overall (87). Another study by the same researchers reported similar findings among people who had experienced homelessness: continuity (measured by having a family physician and case manager) was included as an enabling factor, and found to influence satisfaction with services (88). The enabling factors in general were most strongly associated with outcomes. One further study assessed relationships between continuity of care and use of preventive services using the Andersen framework among a general adult population in the United States, finding continuity to be associated with some preventive services (89). In general though, studies on the topic of continuity of care do not generally refer explicitly to the Andersen framework or any other framework, despite authors often describing mechanisms of action that are consistent with the Andersen framework. The lack of consideration of broader frameworks in empirical studies does lead to challenges in interpreting the results of studies, as described in 2.2.2.8, and this will be explored further in this thesis.

2.2.1.3 Mechanisms of action / causal pathways described in studies of continuity of care

Most commonly, authors suggest that continuity of care may influence health service use or mortality outcomes through supporting improved care processes and condition management, hence positively influencing patient health (and reducing need for services). This is hinted at in some of the early literature which states that continuity is associated with improved compliance and cooperation with medical instruction, and improved recognition of health problems by providers (90). Where studies measure associations between continuity and hospitalisation / ED outcomes, most authors suggest that such mechanisms form the causal pathways of the observed associations. According to these studies, improved continuity may mean the GP is more likely to recognise an acute deterioration in condition, with the practitioner's fuller knowledge of the patient's history (91-93). Alternatively, continuity may lead to improved self-management by the patient (94), where strengthening the doctor-patient relationship improves the patient's ability to change his or her own behaviours to improve their health and hence reduce the need for tertiary services (94, 95).

A different mechanism of action is proposed by Gill et al. (96). These authors assessed the effect of continuity of care on ED presentations and suggest that the patient's relationship with the physician may influence the patient's decision to attend either the GP or the ED when a health problem occurs. That is, continuity does not prevent exacerbations of conditions from occurring but instead influences patients' decisions on where to seek care when exacerbations do occur (though the same authors have discussed mechanisms of improved processes of care in other work (97)). Similar mechanisms are discussed by Burge et al., who assessed relationships between continuity of care and ED use among cancer patients at the end of life (98). These authors suggest that poor continuity results in ED presentations as physicians may not have complete understanding of patients' wishes for their care, as opposed to relying on the idea that continuity promotes disease monitoring, self-management or similar factors (98). The notion that continuity impacts on health service use by influencing patients' decision on where to seek care makes sense in the context of ED presentations as patients can self-refer, less so in relation to hospitalisations. The process of care mechanisms are far more commonly discussed in the literature and fit a broader range of outcomes, and are focused on throughout this thesis.

These mechanisms are consistent with the Andersen framework of health service use, under which contextual / personal enabling factors (e.g. continuity of care) affect personal health practices and processes of medical care, which in turn influence health service use and patient health outcomes (86). This is demonstrated in the context of the Andersen framework in Figure 2-3 below. Andersen describes whether the person has a regular source of care and the nature of that source of care as an individual enabling characteristic, while noting contextual enabling characteristics include policies, financing and the organisation of services. These characteristics influence health behaviours, such as monitoring of condition, which ultimately affect patient health. Researchers who publish empirical work tend to describe similar pathways, though generally estimate the associations between continuity and use of tertiary services without explicitly incorporating either the intermediate processes and behaviours, or changes in patient health which influence need for these tertiary services.

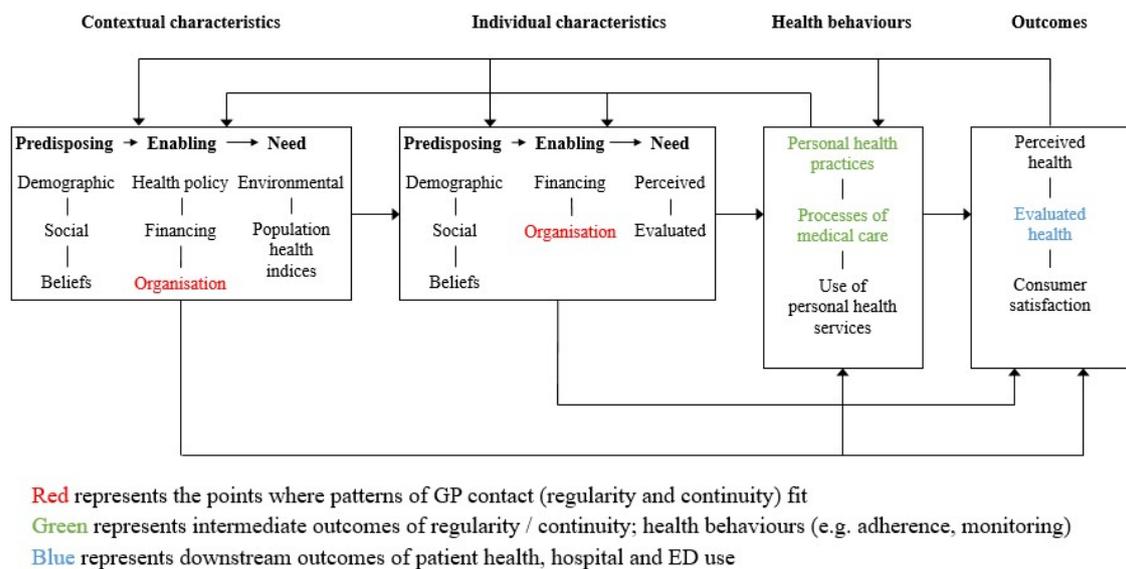


Figure 2-3: The Andersen model of health services use, adapted to demonstrate the role of continuity.

2.2.2 Empirical literature on the topic of continuity of care

2.2.2.1 Observational methods and administrative data in health services research

The challenges of conducting randomised controlled trials (RCTs) in the health services research area is reflected in literature on continuity of care. A 2006 review of the literature found 44 articles assessing continuity of care; only one of these was an RCT with the remainder being observational studies (99). Among the observational research the majority involves the secondary analysis of administrative data. Administrative data are those data generated in the course of healthcare delivery for administrative or financial purposes (100). These data are not collected for research purposes, but can be a useful resource for researchers in many cases. Examples include databases held by hospitals, insurance organisations, government departments and other organisations (100). Such data are increasingly used in epidemiology, surveillance, pharmacoepidemiology, health services research, the social sciences and other areas (100, 101). Note that administrative data differ from clinical data, and some collections will contain both types of data. For example, a general practice data collection may include both administrative data (scheduling and payment information) and clinical data (such as diagnoses, test results, prescriptions etc.)

Hierarchies of evidence have traditionally rated RCTs as providing the highest level of evidence, with observational methods beneath, and case reports or expert opinion as the lowest levels of evidence (102). These ranking systems have been criticised for valuing broad research classification above detailed assessments of the quality individual research projects, as an RCT that is poorly designed or administered will not provide high-quality evidence (103). Moreover, this has led to conflict between researchers who conduct RCTs and those who prefer or conduct observational research, at the expense of a recognition that both types of research have advantages and disadvantages and are suited to different research questions (104).

While RCTs may be well-suited to assessing medication efficacy, where randomisation and blinding are possible, they are much less likely to be suitable for public health interventions, policy changes or features of health system design which are typically studied in the field of health services research. Public health interventions and policies are enacted at the broader system level (103, 104), meaning there is not generally a control population against which to compare those who have been exposed to a policy change. The organisation and delivery of services is not generally possible to allocate on a random basis (104). In addition to these practical issues, there are also types of bias that are generally less likely in observational studies which can make them preferable to RCTs. Where observational studies use administrative data collections there is a reduced likelihood of non-response bias, recall bias and loss to follow-up (100, 105). Observational studies can also involve lower expense than RCTs, generally capture populations which are broader and more representative, can include longer follow-up periods on account of the short-term funding grants that typically facilitate RCTs, can be better suited to rare outcomes as larger cohorts can be studied without the need for active recruitment (100, 106), and avoid some practical and ethical concerns with regards to randomising certain exposures.

Of course, there are disadvantages to observational methods. Some of these relate to the internal validity which RCTs prioritise and deliver when well designed. Confounding bias can occur in observational studies when the groups exposed and unexposed to a risk factor of interest differ in ways which may affect the outcome under study (107), this is particularly problematic when data on these confounders are not available. Reverse causation may occur if researchers using observational methods do not properly consider the order of the exposure and outcome of interest (108) (for example a researcher aims to assess the impact of a given medication on some health event, and fails to account for patients who are prescribed the medication in direct response to the event occurring). Similarly, confounding by indication may occur where patients at higher risk of the health event are more likely to be prescribed the medication for primary prevention, hence the medication may appear to lead to more severe illness as the medicated and non-medicated groups have different baseline risk (109). One of the major limitations is that observational studies relying on administrative data generally do not have detailed clinical information on patients, as the administrative data are collected primarily for financial and administrative reasons, not for research purposes (100, 106).

Many of these challenges can be overcome with appropriate research designs. Appropriate designs can reduce risks of reverse causation, for example case-crossover designs and fixed-effects analyses can reduce risks of confounding by unobserved variables (106), and alternative data sources may provide improved access to clinical data. Previous research has demonstrated that when observational studies are well designed, their results reflect those of RCTs (105, 110).

In the context of continuity of care, the lack of clinical data generally captured in administrative databases may contribute to the focus of the empirical literature on studies of downstream hospitalisation outcomes as discussed in section 2.2.1.3. More detailed clinical data is captured in general practice clinical information systems (CISs) though these data are not always available to researchers. In the context of continuity of care, the clinical data held at general practices can potentially provide for a fuller capture of the care being provided, patient health outcomes and intermediate factors contributing to downstream hospitalisation / health outcomes. An understanding of the information captured in these collections and the suitability of these data for research is addressed in objective 1: Describe the availability of general practice data in Australia for observational research.

Issues touched upon in this section concerning design of observational studies are discussed further in subsequent sections and assessed throughout this thesis.

2.2.2.2 Administrative indices vs self-report in capturing continuity of care

Although studies on the topic of continuity of care are most commonly observational studies using administrative data, some studies instead rely on self-reported data in capturing both continuity of care and the outcomes under study. There is a small body of literature comparing administrative measures of continuity of care to patient self-report measures. These studies are summarised in Table 2-2 below.

Most of these studies take the approach of using linked survey and administrative data collections to construct visit-based measures and compare these to self-reported continuity measures included in surveys. Visit-based measures include examples such as the Usual Provider of Care index (UPC, often referred to as Usual Provider Continuity) which measures the proportion of visits made to the usual provider, these are discussed in detail in section 3.3.1. Comparisons between self-reported and visit-based measures are generally made by calculating correlation coefficients or regressing patient-reported measures on the administrative measures. One study differs in that there is a separate outcome, regressed on both types of continuity measure in order to compare their performance (111).

Most of these analyses reported similar findings, being that there was some degree of correlation between the patient-reported and visit-based measures (Table 2-2). Studies reported that visit-based measures were associated with some patient-reported measures (or domains of measures) and not others (112-114), or correlations between measures existed but these were modest (111, 115). In the one study that used both measures as a predictor of care quality, self-reported and administrative measures both had significant associations with the outcome though the magnitude differed (111). One study (113) reported that on most comparisons the UPC index and visit-based measures were not correlated hence the administrative measures may have limited utility (though another visit-based measure was related to some patient-reported domains). However this study had a smaller sample size than most (n=710, compared to several thousand in Bentler et al., Nyweide et al., and Rodriguez et al.), and most patient-reported continuity domains had very high continuity reported (>90%) hence ceiling effects may have made differences harder to detect.

Despite most papers in this area generally finding modest relationships between the sets of measures, there are contrasting conclusions drawn by authors. Some have suggested that each type of measure had strengths and limitations, that neither was the gold standard and may suit different objectives (114, 115), some have concluded the discordance observed was evidence that administrative measures had limited utility (112, 113), while another suggested the discordance was caused by response bias in the self-report measures, meaning that administrative measures should be preferred (111). The differences in conclusions reached might, in part, reflect the personal views of authors.

A limitation of this literature is that all but one of the studies referenced were conducted in the USA. The AIHW is currently conducting the Coordination of Health Care Study (116) to provide information on patients' experiences of coordination of care. This study includes a large self-report survey which includes questions on patients' continuity and coordination of care, which is being linked to Medicare, PBS and hospitalisation data. This survey will therefore provide the opportunity to understand relationships between patients' experiences of care and administrative continuity measures in the Australian context, although this is not stated as an aim of the study in the documentation published so far (117).

The current thesis relies on measures of continuity derived from administrative data. Although self-reported measures also have value, there is not clear evidence that self-reported measures are superior to administrative measures, particularly in the Australian setting. Nor is there any readily available source of data capturing self-reported continuity measures in Australia, linked with information on outcomes of interest. Finally, as an addition to the existing continuity of care literature, it makes sense to use the same data sources that are most commonly used for research in this area.

Table 2-2: Summary of studies comparing patient-reported and visit-based continuity measures

Reference	Setting and cohort	Administrative measure	Self-report measure	Outcome (if relevant)	Findings	Author conclusions
Nyweide et al. 2014 (114)	USA, 7,898 Medicare beneficiaries	UPC and COC	“Is there a particular medical person or a clinic you usually go to when you are sick or for advice about your health?”, “How long have you been seeing the provider or going to the place?” and similar questions, intending to capture informational, longitudinal and interpersonal continuity.	N/A	Mixed. Continuity of care measured from claims data did not align with patient reports of having a usual care provider. However, high levels of continuity for patients with a usual care provider were associated with a longer patient-provider relationship, greater patient-perceived provider knowledge of the patient’s medical condition and history, and more confidence in the provider.	Neither type of measure should be considered a gold standard, the different measures capture different aspects of patient-doctor relationships.
Rodriguez et al. 2008 (111).	USA, 15,126 patients visiting primary care providers	UPC	Experienced continuity through previous six months: “In the last 6 months, when you were sick and went to the doctor, how often did you see your personal doctor (not an assistant or partner)?”; same question for check-ups	Patient-reported physician-patient interaction quality measures	Modest correlation between administrative and self-reported continuity (r=0.30). Both associated with physician-patient interaction quality, though effect sizes for patient-reported continuity were five times larger than for UPC.	Administrative measures are superior as these are not subject to response bias

Reference	Setting and cohort	Administrative measure	Self-report measure	Outcome (if relevant)	Findings	Author conclusions
Glennard & Annell 2018 (115).	Sweden, 242 practices as unit of analysis	Proportion of patients whose three most recent visits were to same provider	Proportion answering positively to “Do you usually get to see the same doctor / nurse?”	N/A	Visit-based continuity positively associated with patient-reported continuity, though there is substantial variation between measures.	Choice of measure should depend on the objectives of the analysis.
DuGoff 2018 (113).	USA, 710 patients with chronic conditions	UPC and COC	Informational continuity by five items e.g. “Do you think your doctor has a complete understanding of all the things that are wrong with you?” Relational continuity by “How long have you been going to your doctor?” Management continuity by three items e.g. “In the past 6 months, has any doctor given you instructions for one of your conditions that conflicted with what you have been told to do for another condition?”	N/A	The UPC was not associated with any patient experience measure, the COC index was associated with informational and management continuity items.	The administrative measures have limited concordance with patient-reported measures, the administrative measures may have limited utility.

Reference	Setting and cohort	Administrative measure	Self-report measure	Outcome (if relevant)	Findings	Author conclusions
Bentler et al. 2014 (112).	USA, 2,620 Medicare beneficiaries	Sixteen claims-based measures (density, dispersion and sequential indices)	A multidimensional patient-reported continuity of care measure. Asked patients if they had a regular site they visited for their care, and duration of relationship with provider.	N/A	Most claims-based COC measures do not reflect older adults' perceptions of continuous patient-provider relationships and the quality of interactions. The concentration indices were associated with the care site subscale but not the duration subscale, while the dispersion indices were associated with neither. A longitudinality factor (Wolinsky index, longitudinality is a term used in the research) was most closely associated with both.	Administrative claims may be adequate if the objective is only to evaluate visit continuity, it is clear that only patient reports provider adequate assessments of interpersonal continuity.

2.2.2.3 Associations between continuity of care and patient health outcomes

A continually growing body of literature is providing evidence regarding associations between continuity of primary care / GP care and health service use outcomes, with associations demonstrated across different patient populations and health settings.

Studies of continuity of care most commonly assess associations with outcomes relating to patient use of hospitals and EDs, and this literature is summarised in Table 2-3 below. Associations between higher continuity and reduced hospital / ED use have been reported across a range of settings; and these associations have been reported in Australia (118), the US (93, 96-98, 119-123), England (92, 124, 125), Korea (126, 127), Hong Kong (128), Canada (129-131), Sweden (132), and Taiwan (133-136). These studies capture a wide range of patient populations, including patients with diabetes (118, 126, 135, 136), patients with COPD (137), patients with cancer (98), patients with varieties of chronic conditions (92, 121), patients with hypertension (136), and patients with mental illness (125). Other studies have assessed general populations of different age groups (rather than defining populations based on clinical status) with these associations observed among infants (120), children (138), residents of care facilities (130), general adult populations (119, 123, 128, 129, 131, 132, 139), Medicare beneficiaries (122) and veterans in the US (93).

Further evidence has been published regarding associations between continuity of care and mortality outcomes. A review published in 2018 identified 22 studies assessing relationships between continuity of care and mortality outcomes (140). All the studies identified had cohort or cross-sectional designs, from a range of countries and health systems. Most studies recorded a negative association between continuity of care and mortality, with most of these assessing all-cause mortality as the outcome. These studies came from a range of settings, as with the literature on hospital / ED use described above. The majority of these studies (18) reported that higher continuity was associated with reduced mortality though the remainder showed no significant relationship.

Patient satisfaction has also been a commonly investigated outcome. A review on this topic in 2004 identified 20 studies assessing relationships between interpersonal continuity of care and patient satisfaction (141). The authors noted persistent methodological problems. Four RCTs were identified but in none of these was continuity isolated as the sole difference between groups. Four of the cohort studies identified had flaws, including the use of inappropriate continuity measures, assessment of small, potentially unrepresentative sub-cohorts of a larger study, and between-group comparisons where factors other than continuity differed between groups. The majority of studies used cross-sectional designs, and among these studies common flaws included failure to explicitly measure continuity (with proxies used instead), and the use of non-validated measures of either continuity or satisfaction. The majority of studies reported associations between higher continuity and improved satisfaction (and this was more likely among the cross-sectional designs) though the general methodological issues resulted in a weak body of evidence (141). The authors also noted the potential for reverse causation in many studies.

Another review conducted in 2010 found 12 studies assessing relationships between continuity of care and patient satisfaction, and the authors concluded that the effect was variable (142). This review included fewer studies than the 2004 review referenced above, due to a more stringent inclusion criteria requiring continuity and satisfaction to actually be measured. These came from a range of settings and were split between studies using qualitative and quantitative continuity measures. In the only RCT included, those patients randomised to the “continuity” group reported higher satisfaction with the continuity of their care, though did not report higher overall satisfaction with care. Of the nine cross-sectional studies included, only four reported that higher continuity was associated with higher satisfaction, with the remainder reporting no significant association. The studies that used subjective measures of continuity did consistently report associations with higher satisfaction, in contrast with the measures based on visit patterns (142).

Further research published in the time since the 2010 review has been similarly mixed. Among the more recent research continuity has been shown to be associated with patient satisfaction among patients in Finland (143), among patients with schizophrenia in England (144), patients receiving community mental health services in England (145) and patients receiving mental health treatment in the USA (146). Contrasting results were found in a study of patients in the USA which found that part-time primary care physicians had higher patient satisfaction, despite lower continuity compared to full-time physicians (147).

In summary, there have been a number of studies published assessing associations between continuity of care and patient outcomes. Review articles focusing on patient satisfaction outcomes have not found strong evidence for a positive effect on satisfaction. In contrast, associations reported with hospitalisation / ED use and mortality outcomes are generally negative (that is, higher continuity is generally associated with reductions in these outcomes), however there are some limitations to this body of literature, discussed in section 2.2.2.4.

2.2.2.4 Common study designs in the empirical continuity of care literature

There are many papers published assessing relationships between continuity of care and outcomes of hospitalisation and ED use. Most of these are observational studies using administrative data. These studies have similarities in design, generally relating visit-based measures of continuity (such as UPC) to measures of hospitalisation / ED use rates or cost. One important research design issue is whether outcomes are unlagged (measuring continuity and hospital / ED outcomes through the same period) or lagged (measuring continuity through one period and hospital / ED use outcomes through a separate follow-up period). Some key characteristics of this literature are described in Table 2-3 (literature reflecting those studies described in section 2.2.2.3 discussion of associations with hospital / ED use). The literature in this area is roughly evenly split between designs in which outcomes are unlagged (92, 98, 119, 121, 128, 131, 132, 134, 139) and lagged (91, 93, 97, 122, 123, 126, 127, 129, 137, 138). In some cases the distinction is less clear (e.g. Comino et al. (118) and Chen et al. (133)). The potential issue with this literature is that papers reporting unlagged designs are likely to be susceptible to reverse-causation, as a hospitalisation or ED presentation (the outcome) is likely to have an impact on subsequent GP contacts (the exposure). This is explicitly demonstrated in Andersen's 2014 framework for health services utilisation (Figure 2-3), whereby patient health outcomes are theorised to influence upstream factors such as perceived need and personal health practices (86). Although researchers in the health sciences might refer to these designs as cross-sectional and longitudinal, this terminology could be unclear to readers with backgrounds in econometrics, where the term longitudinal usually refers to panel data. There is also potential for confusion with the concept of longitudinal continuity. The terms unlagged and lagged are used throughout this thesis.

Despite the risk of reverse confounding, it should be noted that the unlagged designs cited here do not necessarily report larger effect sizes than the lagged designs. For example, some papers using lagged designs report very large effect estimates; Gill et al. report an odds ratio (OR) of 0.62 (96) while Jung et al. report an extreme risk ratio (RR) of 27.17 (127). However, the potential for these design issues to lead to a biased body of evidence is enhanced when considered in the context of publication bias as a perverse incentive which may influence the research conducted and submitted for publication (148). Given that these studies use generally administrative data and hence do not require active follow-up of patients, it is likely that most of the studies which use unlagged designs could feasibly have adopted a lagged design either as the primary study, or as a sensitivity analysis to assess the robustness of the unlagged analysis.

Only one paper has explicitly compared results of an unlagged to a lagged design. Gill et al. found that when ED presentations were measured through the same year as continuity a significant, negative association existed, though when ED presentations were measured in the following year this relationship disappeared (96). This supports the view that a body of evidence in which a large number of papers report only unlagged methods, is potentially problematic.

Table 2-3: Characteristics of papers assessing associations between continuity of care and hospitalisation / ED use outcomes (ordered by author name)

Author / year	Setting / cohort	Exposure	Outcome	Design / time periods	Main result	Analysis methods
Barker et al. 2017 (92)	England, n=230,472	UPC index, measured as a change of 0.2	Admissions for ACSCs	Unlagged, both measured through a two year period	0.2 unit change in UPC associated with 6.22% reduction (95% CI 4.87–7.55%)	Multivariable negative binomial regression
Bazemore et al. 2018 (119)	USA, n=1.4 million Medicare beneficiaries < 65	COC index, in quintiles	All-cause hospitalisation and total Medicare expenditures	Unlagged, exposures and outcomes measured through 2011	Odds of admission lower in highest continuity quintile vs lowest (OR 0.839 95% CI 0.787 – 0.793). Costs lower in highest quintile (\$8,092 v \$6,958)	General linear models – multilevel (patients within physicians)
Burge et al. 2003 (98)	Canada, n=8,702 cancer patients at end of life	Modified modified continuity index (MMCI), in three levels	All-cause ED visits	Unlagged, exposure and outcome measured through last six months	Those with low MMCI had 3.9 times more ED visits than those with high MMCI (RR 3.9, 95% CI 3.57–4.34)	Multivariable negative binomial regression
Chen et al. 2011 (133)	Taiwan, n=48,107 patients with diabetes	COC, in three levels	Diabetes-related hospitalisation and ED presentation	Unclear: methods discuss a longitudinal design but this may refer to panel data	High COC (ref low) associated with lower hospitalisations (OR=0.26, 95% CI 0.25–0.27) and ED visits (OR=0.34, 95% CI 0.33–0.36)	Generalised estimating equation with logit link and binomial distribution

Author / year	Setting / cohort	Exposure	Outcome	Design / time periods	Main result	Analysis methods
Cheng et al. 2010 (134)	Taiwan, n=30,830	COC categorised as low / medium / high	Avoidable hospitalisation	Unlagged, both measured through 6 years	In age 19–64, OR for high group (ref low) of 0.41 (95% CI 0.35–0.48), similar relationship for those >65	Random-intercept logistic regression models using a longitudinal technique that could consider the unobserved time-invariant characteristics for patients (specific technique not stated)
Christakis et al. 1999 (138)	USA, n=785 children	COC, in tertiles	ED use	Lagged	High continuity (ref low) associated with reduced ED use (HR 0.65, 95% CI 0.50–0.80)	Multiple event survival analysis
Comino et al. 2015 (118)	Australia, n=20,433 diabetic patients	UPC, binary based on 0.8 cut-off	All-cause hospitalisation	Mixed: exposure measured through fifteen months, outcomes for twelve months, seven months of overlap	High continuity associated with reduced admissions, IRR 0.92 (95% CI 0.89–0.96)	Multivariable zero-inflated Poisson
Fung et al. 2015 (128)	Hong Kong, n=3,148	Self-report of having a regular doctor	Self-report of ED presentation or hospital admission	Unlagged	Having regular doctor associated with less use of ED (OR 0.48 (95% CI 0.33–0.70)) and hospital	Multivariate logistic / Poisson regression

Author / year	Setting / cohort	Exposure	Outcome	Design / time periods	Main result	Analysis methods
			for last episode of illness		admission (OR 0.46 (95% CI 0.27–0.79))	
Gill et al. 1998 (97)	USA, n=13,495 patients aged 0 to 64	MMCI, in seven groups	All-cause hospitalisation	Lagged, exposure measured year 1 and outcome measured year 2	High continuity associated with reduced hospitalisation (OR=0.56, 95% CI 0.46 – 0.69)	Multivariable logistic regression
Gill et al. 2000 (96)	USA, n=11,474 patients aged 0 to 64	MMCI	ED use (single or multiple)	Unlagged (exposure year 1, outcome year 1) and lagged (exposure year 1, outcome year 2)	Unlagged analysis: high continuity associated with reduced likelihood of single ED visit (OR 0.81, 95% CI 0.68–0.96) and multiple visits (OR 0.62, 95% CI 0.51–0.76). Lagged analysis: high continuity associated with increased likelihood of multiple ED visits (OR 1.25, 95% CI 1.06–1.46).	Multivariable logistic regression
Hong et al. 2013 (91)	Hong Kong, n=68,469 patients with type 2 diabetes	COC, in five categories	All cause hospitalisation	Lagged, exposures through three years and outcomes in the fourth year	Group with COC<0.4 (ref – group with COC = 1) had higher hospitalisation risk (OR 1.37, 95% CI 1.28–1.47)	Multivariable logistic regression

Author / year	Setting / cohort	Exposure	Outcome	Design / time periods	Main result	Analysis methods
Ionescu-Ittu et al. 2007 (131)	Canada, n=95,173 people aged 65+	UPC, split into five categories	ED utilisation	Unlagged, both measured through two years	Low continuity (ref high) associated with increased ED use (RR 1.46, 95% CI 1.44–1.48).	Multivariable Poisson regression
Jung et al. 2018 (127)	Korea, n=131,566 patients with osteoarthritis	COC, divided into four groups	Hospital admission	Lagged: exposure through nine months, hospitalisation in following three	Low continuity (ref high) associated with increased admissions: RR 27.17 (95% CI 24.08–30.68)	Multivariable logistic regression
Katz et al. 2015 (93)	USA, n=243,881 patients aged 65+	UPC, in four categories	ED visits and hospitalisations for ACSCs	Lagged, exposure through two years and outcomes in the third year	Low UPC (ref very high) was associated with higher ED presentations (OR 1.06, 95% CI 1.03–1.09) and hospitalisations (OR 1.04, 95% CI 1.01–1.07)	Multivariable logistic / negative binomial regression
Kohnke et al. 2017 (132)	Sweden, n=8,185 general population	UPC, COC and SECON, treated as continuous	ED presentations and out-of-hours GP visits	Unlagged, exposures and outcomes measured through three years	Negative associations reported, IRRs for UPC, COC and SECON 0.59, 0.56 and 0.50 respectively (p<0.01 for all)	Negative binomial regression

Author / year	Setting / cohort	Exposure	Outcome	Design / time periods	Main result	Analysis methods
Lin et al. 2010 (135)	Taiwan, n=6,476 diabetic patients	UPC in tertiles	Diabetes-related ACSC admission, short-term and long-term complications analysed separately	Unlagged, exposures and outcomes measured 1997 through 2002	Patients with low UPC (ref high) had increased risk of long-term ACSC hospitalisation (RR=1.34, 95% CI 1.02–1.75) (no significant association for short-term complications)	Multivariate Cox regression
Lin et al. 2017 (137)	Taiwan, n=2,199 patients with COPD	COC index in tertiles, assessed as short-term (one year measurement) and long-term (two-year measurement)	COPD-related hospitalisation	Lagged, hospitalisation measured in year following end of COC measurement	Low long-term COC (reference high) associated with increased COPD admissions (OR 2.03, 95% CI 1.05–3.94)	Multivariate logistic regression
Mainous et al. 1998 (123)	USA, n=13,495 patients aged 0 to 64	UPC, binary based on 50% cut-off. Measured at	Acute hospital admission	Lagged, exposure year 1, outcome year 2	High site / high clinician continuity (ref high site / low clinician) associated with reduced	Multivariable logistic regression

Author / year	Setting / cohort	Exposure	Outcome	Design / time periods	Main result	Analysis methods
		the physician and practice level.			hospitalisation, OR 0.75, 95% CI 0.66 – 0.87)	
Marshall et al. 2016 (130)	Canada, 1,424 residents of ten long-term care facilities	Implementation of new model of care promoting continuity	Ambulance transport from care facility to ED	Pre-post design	Ambulance transports to ED reduced by 36% (p=0.01)	Chi2 tests used to compare proportion of emergency calls resulting in ambulance transport
McCusker et al. 2012 (129)	Canada, n=311,701 adults	Affiliation with a family physician, UPC index	All-cause ED presentations	Lagged, two-year baseline and one-year follow-up	ED use higher among those not affiliated with a family physician (IRR 1.11, 95% CI 1.05 – 1.16). UPC only significant in most unwell subgroup.	Multivariate negative binomial
Menec et al. 2006 (139)	Canada, n=1,863	UPC, binary based on 0.75 cut-off	Admissions for ACSCs	Unlagged, both measured through two non-consecutive years	High continuity associated with reduced admissions, OR 0.67 (95% CI 0.51–0.90)	Multivariate logistic regression
Raddish et al.	USA, 12,997 patients with	Number of primary care providers seen	Number of prescriptions and costs, number of	Unlagged, all measured through year 1992	Increased numbers of primary care providers associated with increased utilisation and costs; relationship	Multivariate linear regression

Author / year	Setting / cohort	Exposure	Outcome	Design / time periods	Main result	Analysis methods
1999 (121)	chronic conditions		hospital admissions		varied by condition (e.g. pharmacy costs in otitis media increase \$58 annually for each additional provider)	
Romaire et al. 2014 (122)	USA, n=613,471 Medicare beneficiaries	COC index in tertiles	All-cause and ACSC hospitalisations and ED presentations	Lagged; COC through year 1, outcomes through year 2	Higher continuity associated with fewer all-cause hospitalisations (IRR 0.91, 95% CI 0.90–0.93) and ED presentations (IRR 0.85, 95% CI 0.84 – 0.86)	Multivariate negative binomial and generalised linear models

2.2.2.5 Continuity of care studies using more complex designs / analyses

The paper by Gill et al. (96) that reports both unlagged and lagged designs provides one example of researchers in this area attempting to more explicitly use different research designs to prevent one potential source of bias (reverse causation). As displayed in Table 2-3, most papers in this area use multivariable regression which may mean that although observed covariates are controlled for, risks of confounding by unobserved variables may remain. Some papers in this area describe more advanced statistical approaches which attempt to further reduce the likelihood of unobserved confounding and hence provide estimates which come closer to describing a causative relationship (149), described here.

In rare cases, changes in policy provide an opportunity to examine the effect of changes in continuity on patient outcomes. In these cases, as changes in continuity are the result of an exogenous process (the policy change) which is unlikely to influence the outcome through other means, the risk of reverse-causation or confounding by unobserved factors is minimised. One such policy change was assessed by Barker et al. (150). A policy requiring practices to assign a named, accountable provider to patients aged 75 and older came into effect in the UK in 2014, allowing the authors to examine patterns of continuity and markers of patient management. These authors found that although the policy did lead to a dramatic shift in the number of patients with a named accountable GP, there were no changes in continuity of care or the measures of patient management. Tammes et al. assessed the effect of the same policy on unplanned hospitalisations and similarly found no effect (151). A similar policy change introduced in California in 2010 was assessed by Pourat et al. (152). This study found that the policy led to dramatic increases in continuity of care, and this resulted in reduced ED and hospital use, though the reductions in these outcomes were modest in comparison to much of the literature described in Table 2-3. The major point of difference between the two policies was that while both required practices to assign each patient to a named provider, only the Californian policy imposed a financial penalty where patients were seen by a doctor other than their named provider. Usually, policy changes that directly influence exposures of interest are not available, so other techniques are required.

Two studies have assessed relationships between continuity of care and outcomes using observational methods which aim to mimic randomised controlled trials by using instrumental variable (IV) analysis. In IV analysis, the randomisation taking place in an RCT is replaced by an IV which represents a mechanism for assigning treatment to patients, that is a quasi-randomly assigned variable thought to influence the exposure of interest (continuity) and hence influence the patient outcome (hospitalisation or other health measure) via the exposure (153). IV analysis depends on three assumptions: firstly that the IV should be strongly associated with the exposure, secondly the effect of the IV on the outcome should be only via the exposure, and thirdly the IV–outcome relationship should be unconfounded (154, 155). An advantage of IV analysis is that it addresses both measured and unmeasured confounding (153, 155), whereas multivariate modelling controls only observed variables. The major limitation of IV analysis is that no tests are available to confirm that assumptions two and three are met (153, 156).

An IV approach was adopted by Ettner in assessing the relationship between having a regular doctor and the use of preventive care services (pap smears, mammograms, breast examinations, and blood pressure tests) (157). In this study the instrument was the length of time each participant had spent living within the study area. The author argued this was a valid instrument for two reasons: firstly because the longer someone has lived in an area, the more likely they are to have established a relationship with a usual provider, and secondly there is no reason to think that the length of residence affects the timing of preventative services through other means. The use of IV in comparison to standard regression did change effect estimates, though the direction and magnitude of this change was not consistent for all outcomes tested. Previous research has suggested the onset of serious disease can reduce the likelihood of migration (158). This suggests that for some common outcomes (e.g. hospitalisation or other health status measures) this instrument might not be appropriate, a point noted by Ettner (157). Note also that this study used survey data and information on changes to address, which is not typically available in administrative data collections (159), limiting the potential use of this instrument.

An IV approach was also used by Pu et al. (136) in a study investigating the impact of continuity of care on ED use in Taiwan. This study investigated patients with hypertension and type 2 diabetes, and the instrument was the continuity of care among a family member with the same condition. The authors argued that family members tend to exhibit similar healthcare-seeking behaviour, while a family member's healthcare-seeking behaviour would not directly affect whether a person visits the ED. Participants could therefore be considered as dyads whereby one provides the exposure (continuity) data and the other the outcome (ED-use) data. There are two reasons to doubt the validity of this IV. Firstly the data on family relationships were from a health insurance database which captured family status only when one or more people were classified as dependent on another. The fact that in all cases the two members of each dyad had differing employment arrangements likely leads to different patterns of continuity of care between them, given employment status is known to influence GP use (160). This would violate the first assumption of IV analysis. Secondly there are likely to be other means by which the behaviours of a family member with the same condition influence ED use (e.g. exercise levels (161), medication adherence (162), and diet (163)), and any covariance between family members on these factors would violate the third IV assumption. The scarcity of papers using an IV approach may indicate that finding appropriate instruments is challenging, in particular in examples such as this where use of health services makes up both the exposure and outcome of interest.

An alternative approach was used by Ride et al. to resolve potential issues of unobserved confounding in a study assessing associations between continuity and unplanned hospital use for people with serious mental illness (125). These authors used a correlated random-effects model (164) using panel data, under which the means of time-varying variables were calculated for each participant and these means included as explanatory variables. These within-patient mean variables capture confounding by any unobserved time-invariant patient characteristics which may influence continuity and unplanned hospitalisations. This provides results which are unbiased by observed or unobserved patient-level variables, as long as these are time-invariant (165).

Xu (166) examined the association between having a usual provider and use of preventive services. In this work it was theorised that unobservable patient characteristics (such as risk aversion) would influence both the exposure (having a usual doctor) and outcome (use of preventive services), leading to confounding. This was resolved through a two-stage estimation process, whereby a selection model analysed the probabilities of having a usual source of care based on observable information and in the second stage, the use of preventative services was estimated based on the predicted probabilities of having a usual doctor from the first stage.

This literature demonstrates that although multivariate regression models are the most common designs to assess associations between continuity and patient health outcomes, alternatives are possible to reduce the likelihood of certain biases. Even in studies using these approaches researchers have options regarding the timing of measurements and the choices made are not generally justified within the articles. Where administrative data are used, as is the case for most of these studies, the data would generally be able to support lagged measurement of outcomes. The only paper that explicitly compared a lagged to an unlagged design did find that this made substantial difference to effect estimates, suggesting the choice of design is an important one, and this is an issue that can be fairly easily explored. Alternative designs are also available to address the potential for confounding by unobserved variables, though these are applied rarely. In the case of IVs this may reflect difficulty in finding appropriate instruments. Other designs discussed here could likely be applied in many cases to the administrative data used.

The relative lack of consideration of different study designs presents a substantial limitation of the literature on continuity of care. Relatively few studies have assessed these issues by applying alternative designs / analytic methods and those which have done so have found that choice of design / analysis is influential, suggesting that certain biases may in fact influence the reported relationships. There is a need for a fuller investigation of the robustness of associations between regularity / continuity and downstream outcomes. The demonstration of associations which are in fact robust to differences in design and analysis would provide a strong incentive for policy in this area.

Within this thesis alternative designs are used to assess the robustness of associations tested to choices of study design and analysis. This is captured in Objective 3c: Determine the sensitivity of estimates of these associations to study design and statistical analysis. By doing so, a significant contribution to the literature is made by providing clear evidence of the likely value of regularity / continuity to patient health, and hence the potential value of policies targeting these factors. A significant contribution is also made in terms of future research by highlighting to researchers in this area the importance of conducting multiple analyses to evaluate robustness of estimates.

2.2.2.6 Measures of continuity

Information on the measures used to assess continuity of care mostly comes from two reviews of the literature. These were published by Saultz in 2003 (83) and by Jee and Cabana in 2006 (99). Saultz's review identified 21 continuity measures, while Jee and Cabana conducted a broader review and identified 32 measures of continuity.

In both cases, the majority of indices identified were based on observation of visit patterns, using administrative data, chart reviews or similar. A smaller portion were based on patient surveys or questionnaires. Saultz categorised visit-based measures into those that do and do not require an assigned provider (83). For example, the Continuity of Care (COC) index assesses the spread of visits across providers, whereby a larger number of visits to a smaller number of providers results in a higher score. In contrast the UPC index requires that there is a record of the patient's usual provider and measures the proportion of visits made to this provider (though commonly the usual provider is assumed to be the provider that the patient records most visits with, in the absence of a variable stating the usual provider (122)).

Jee and Cabana provided a useful classification of measures that is now commonly referenced in the literature. Indexes were classified into measures of duration (capturing length of relationship with provider), density (proportion of visits to usual provider), dispersion (spread of visits across all providers), sequence (whether consecutive visits are to the same provider) and subjective or miscellaneous measures. The most common were density (n=17) and dispersion (n=8) measures.

The most common density index was the UPC index, first published by Breslau and Reeb (167), and the most common dispersion measure was COC, published by Bice and Boxerman (168). These measures are defined in section 3.3.1.

One recent study has derived an alternative measure as an alternative to those based on visitation patterns. Ride et al. (125) separately measure relational and informational / management continuity. Measures of relational continuity were the COC and UPC indexes described above. Informational / management continuity was measured based on the documentation of a care plan by the family physician in the previous 12 months, captured in general practice information systems. In Australia, the preparation of a care plan in relation to a patient's care is captured in Medicare data, as there is an MBS incentive item for this activity under the CDM program described in section 2.1.2.3. This is consistent with a recent policy brief from the World Health Organisation (WHO) which highlighted multi-disciplinary care planning as an element of management continuity, and shared care records as an element of informational continuity (79).

As to which choice of measure should be used in a given study, substantial literature has discussed the conceptual differences between measures, and the advantages and disadvantages of different measures for different purposes. Density indices such as UPC have the advantage that they are the simplest to calculate, though have the disadvantage that aside from capturing whether visits are / are not to the usual provider, they do not capture any information on the dispersion among other providers (99); some researchers consider these measures crude (138). The dispersion indices do characterise the care received across a greater number of providers, though are more complex to calculate. Sequence indices may be useful in the sense that they can identify recurrent management of an acute problem (169), but with the disadvantage that they will not recognise consistent providers if these are not seen sequentially (99) (i.e. a patient who consistently visits two providers for different purposes may have a very low continuity score according to these measures if the visits happen to alternate between providers). In terms of calculation, it is common across most measures that a value of 1 indicates perfect continuity, though beyond this, the degree to which the continuity score changes in response to a given change in visit pattern, is inconsistent (169). Similarly, for only some measures is there a specific interpretation of a given continuity value. For example, on the UPC index a value of 0.5 would indicate that 50% of visits were to the usual provider, though for COC there is no specific interpretation for the value of 0.5 except in comparative terms (169) (i.e., there are multiple possible patterns of care which may result in a value of 0.5). Despite the conceptual differences and differences in calculation of these different measures, recent empirical work has demonstrated that in fact the most commonly used measures are highly correlated with each other (170) and as a result the choice of measure may have little impact on inferences drawn from analyses. The choice of measure may instead depend on practical considerations such as the data required for calculation of each, or conceptual concerns (170).

2.2.2.7 Regular GP contacts as a measure of continuity of care

Although Saultz (83) and Jee and Cabana (99) identified a substantial number of visit-based measures, each with different calculations, a common feature is that almost all of these measures essentially capture whether a patient is consistently seeing the same provider for their care, or alternating between different providers. The exception is one duration index identified by Jee and Cabana measuring the duration of the patient's relationship with their primary provider, though this provides relatively little detail on temporal aspects of continuity (99). This relatively narrow range of measures appears to contrast with the most commonly accepted definitions of continuity provided by Saultz and Haggerty et al., each of which are broad, describing multiple dimensions of continuity (83, 84). Several authors have discussed the inability of the majority of these measures to capture any temporal information on visit patterns, meaning that patients having regular visits will appear to have equal continuity to patients having extended periods without contact, as long as all contacts are made to the same provider (171-173). As early as 1980 some researchers had discussed longitudinality as being a distinct concept from continuity of care (174). More recently, the WHO has discussed proactive, regular care as a component of management continuity (79). These issues have prompted the development of a small body of work aimed at explicitly capturing the temporal pattern of visits to the GP or other primary care provider. This is referred to here and in other literature as regularity of care.

2.2.2.7.1 Associations between regularity and patient outcomes

A small body of work has assessed the impacts of regularity of GP / primary care contacts on patient outcomes. Work from the USA has demonstrated that where patients have regular primary care contacts, breast cancer detection occurs earlier (172) (which presumably improves care outcomes, though this was not explicitly tested). Australian work has demonstrated regular GP contacts to be associated with reduced risk of mortality and hospitalisation among patients 65 and older with chronic respiratory disease (175), and similar associations have been observed among seniors with IHD (176). Among older people with epilepsy a negative association was reported for mortality outcomes, though there was no effect on hospitalisation (177). These studies used lagged designs, so the potential for reverse causation bias is limited.

Other work has been published on the development of measures of regular GP contacts and drivers of regular contact with the GP, though these works have not extended to understanding associations with any patient outcomes (171, 178).

2.2.2.7.2 Indexes used to capture regularity

As discussed in section 2.2.2.6, some authors have noted that measures of continuity most commonly used are generally limited in that they fail to capture any information on temporal aspects of visit patterns (171, 172). Some measures have now been developed which incorporate these temporal aspects. This section describes first some measures which have been used in the literature but were unsuitable for the current study, then briefly describes the measures used in this thesis, which are more fully described in the methods chapter, section 3.3.2.

Measures described in literature, not used in this thesis

A continuity index developed by Wolinsky et al. incorporated temporal aspects of care by defining continuity of care as being present where, across a two-year period, a patient saw the same primary care physician, with a visit at least every eight months (173). Notably in the comparison of visit-based to self-reported continuity measures published by Bentler et al. discussed in section 2.2.2.2, this index reported stronger associations with all self-reported continuity measures than the other visit-based measures assessed, suggesting that the temporal pattern of visits matters to patient perceptions of continuity (112). This index is generally considered a measure of continuity rather than a measure of regularity, however.

Of those measures that focus explicitly on regularity, the most basic measure is described by Evans et al., who assessed the impact of regular visiting of GPs to aged care homes (178). In this case regularity was measured via a survey in which care home managers indicated whether there was a regular GP visit to the care home by any practice, with no further detail.

A substantially more complex method was developed by Spooner (171), who noted that repeated visits to the same provider are not necessarily reflective of continuity of care, if these visits are not timed appropriately. The complexity of the measure described stems from defining what is meant by appropriate timing, which depends on having data incorporating some clinical detail, and having pre-defined values specifying what an appropriate interval between visits may be for patients at different ages and with different sets of conditions (171). The index developed by Spooner has not been used in applied work beyond the paper describing its development, which may be a result of its complexity.

Measures used in this thesis

There are two measures published which directly measure the regularity of contacts with the GP / primary care provider, using information on visit dates that would typically be available in administrative data collections, and hence are used in this thesis. The first is based on the dates of contacts with any GP, with a score calculated based on the variance in the numbers of days between an individual's GP contacts (176, 177, 179). A higher regularity score, indicating visits spread evenly over time, likely reflects care that is planned and proactive. In contrast, a low score, indicating clusters of visits, more likely reflects care that is episodic and reactive, whereby the patient has extended periods without visiting the GP interspersed with periods of activity in response to an exacerbation of their condition. More detail, including the formula to calculate the regularity score, is provided in section 3.3.2 of the Data Sources and Methods chapter.

The second measure, published by Camacho et al. (172), assessed regular primary care contacts across a two-year study period using an ordinal measure which categorised primary care contacts as none (no contacts in period), any (some primary care contact in period), annual (primary care contact in each year) and semi-annual (primary care contact in the first and second half of each year). The authors suggested that visits spread over a semi-annual basis represented a very different care pattern than the same number of visits clustered together at a single point in time, which would more likely represent episodic care (172). Camacho et al. suggest that such regularity measures may be more relevant than other narrow continuity measures, against a backdrop of increasingly complex care settings and reduced likelihood of seeing the same primary care provider, and relate this to the hierarchy of continuity defined by Saultz (83).

A potential limitation of both measures is a sensitivity to visit frequency, which will partially reflect health status rather than reflecting the approach to management of a condition by the patient / GP. That is, a patient who is more unwell and as a result requires a more contact with their GP overall, will much more likely have semi-annual contacts than a healthier patient. Similarly, the unwell patient with more GP contacts will have, on average, fewer days between GP contacts, which will also likely lead to a smaller variance in the number of days between contacts, and higher regularity score. These issues are discussed in more detail in manuscript 2, which is found in section 5.1.1.

Summary

The literature therefore seems limited in several key ways. Firstly, the vast majority of the empirical literature regarding continuity of care uses measures of continuity which do not capture any information on the temporal pattern of GP contacts, with a relatively small body of literature assessing regularity. Secondly, the measures of regularity that have been published (and which can be applied using typical administrative data collections) have not been compared and may be sensitive to the frequency of contacts, meaning the measures may be conflating multiple concepts. Thirdly, relationships between measures of regularity and continuity have not been investigated in terms of their associations with each other and impacts on outcomes.

This thesis addresses each of these limitations. Firstly, “objective 3b: Investigate contemporary associations between regularity and hospitalisation / ED outcomes across conditions” contributes to the literature by assessing associations between regularity and downstream outcomes. Although such associations are often reported in studies of continuity of care, the evidence regarding regularity is more limited and this objective makes a significant contribution by providing information on the likely value of regular contacts as an intervention target.

Secondly, objective 2a: “Assess two previously published measures of regularity in comparison to a newly developed measure” makes a significant contribution by introducing an updated measure of regularity, designed to be less correlated with the frequency of GP contacts, and comparing this measure to the previously published measures in terms of their suitability to assess hospitalisation outcomes. This presents a significant contribution to future research by informing researchers in continuity of care as to how temporal aspects of care patterns can be better assessed.

Thirdly, objective 2b: “Compare regularity to commonly used measures of continuity by investigating interactions between exposures in influencing outcomes” makes a significant contribution by assessing the relationships between measures of continuity and regularity, which is informative in terms of understanding the value of capturing regularity in measures of continuity.

Note that throughout this thesis, the terms regularity and continuity are often presented together (as “regularity / continuity” or “regularity and continuity”). This is not intended to indicate that the terms are interchangeable, as the two measures are designed to capture different aspects of the patterns of care between patient and GP, and are conceptually different. These terms are instead presented together as they are thought to influence similar sets of outcomes, and through most of this thesis, are both used as exposure variables simultaneously in models assessing relationships with these outcomes, so their effects are generally described alongside each other.

2.2.2.8 Studies assessing intermediate outcomes

Section 2.2.1.3 outlined the mechanisms of action that researchers assessing continuity typically describe, that is that continuity of care leads to improved processes of care or health behaviours, then leading to improved patient health outcomes. These processes of care and health behaviours can be described in terms of being intermediate outcomes or mediators of relationships between continuity and downstream tertiary health service use outcomes. However, in contrast to the research assessing associations between continuity and downstream health service use, there is relatively little research assessing associations with these health behaviours or intermediate outcomes (92).

The Andersen framework of health services utilisation provides a useful way to view this issue (Figure 2-3), with Figure 2-4 below more clearly indicating how continuity of care fits within the framework. Continuity of care, as an organisational characteristic of healthcare, at either the individual or contextual level, is hypothesised to influence personal health practices or processes of medical care such as monitoring of the patient's condition, the medications prescribed, and patient adherence with medication regimens and advice. These improvements in health practices and processes of medical care are then thought to improve patient health and reduce use of tertiary health services. Researchers are typically interested in understanding the impacts of continuity of care on hospital and ED use (as the result of changes in patient health) and measure associations with these services, and assume that health practices and processes of care sit on the causal pathway of relationships observed (but do not assess these). As Figure 2-4 indicates, there is potential for confounding by other contextual or individual characteristics which can influence both individual enabling factors, and health service use outcomes. Problems may occur where these confounders are not measured, and understanding of these pathways can potentially be improved by incorporating measures of health behaviours into studies. Note that although 'use of personal health services' is defined in the framework as a health behaviour, hospital use (and to a lesser extent ED use) are considered here as reflections of patient health and hence are outcomes; while other more discretionary health services may be considered health behaviours.

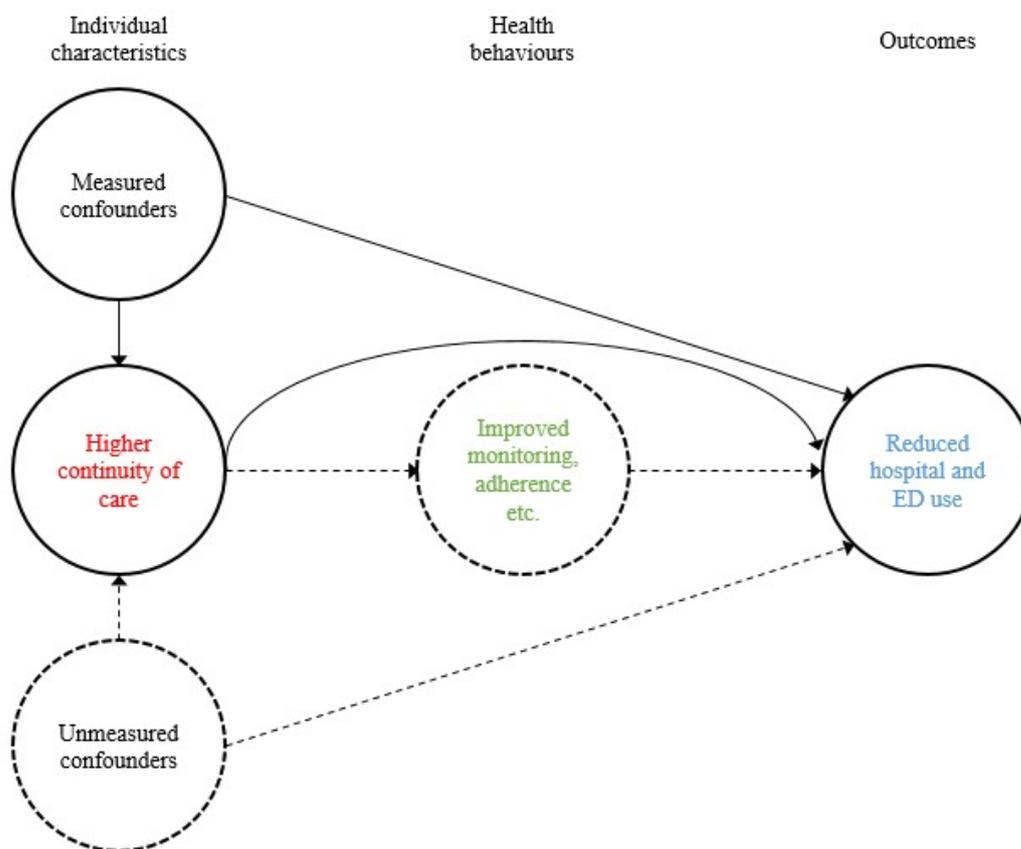


Figure 2-4: Continuity of care within the Andersen model of health service use

There has been some research investigating effects on these intermediate outcomes, though this is much less common than research assessing downstream hospitalisation and ED outcomes, and the results of these investigations have been mixed, as noted by previous authors (142).

Among papers assessing medication use, results have generally been positive. Cheng et al., in a study of patients with chronic conditions in Taiwan, reported that higher physician continuity was associated with a reduced likelihood of medication duplication (180). The same researchers also assessed the prescribing of potentially inappropriate medications among a Taiwanese cohort of people aged 65 and older, finding a protective effect of continuity (181). Higher continuity has also been associated with improved medication adherence among patients taking statin medication in one Australian study (182), though in a study in the USA continuity of care was not associated with improved statin use among a population with diabetes (183).

More research has assessed the associations between continuity of care and monitoring activities. Among a general population cohort in the USA, having a usual source of care was associated with improvements in testing blood pressure, cholesterol, pap smears, mammograms and flu shots (166). This has also been demonstrated in the Australian context, where attendance at a single practice was associated with improved preventive care including blood pressure and cholesterol testing (184). Another study in the USA observed that higher continuity was associated with increased rates of mammography (89). Two further studies set in the USA assessed monitoring activities among patients with diabetes in terms of completion of pathology tests, with one finding that continuity of care contributed to a greater frequency of monitoring (185), while the other found no association (186).

A smaller set of papers have assessed associations between continuity and objective measures of disease control, all among patients with diabetes, and these have reported mixed findings. O'Connor et al. reported associations between higher continuity and lower glycosylated haemoglobin (HbA1c) (185). Mainous et al., using a self-reported continuity measure among people with diabetes, found continuity to be associated with improved glycaemic control, but no improvements in blood pressure or weight (187). Similarly Gulliford et al. investigated the effects of continuity using a self-reported measure, and found that higher continuity was not associated with HbA1c, blood pressure or lipid control (188), a finding also reported by Overland et al. in an assessment of duration of time with the provider (189). Most concerningly, Hanninen et al. used a survey-based measure and found that HbA1c control was worse among patients with higher continuity (190).

Note that of the studies outlined above only three were set in Australia. These studies included one study demonstrating improved adherence with statin medications, one demonstrating improvements in blood pressure and cholesterol testing, and one finding no association with HbA1c. Furthermore, although there is a wider body of literature assessing associations of continuity with hospital / ED use outcomes, there appears to be no studies which assess the role of these intermediate patient outcomes as mediators and explicitly assess hospitalisation / ED use outcomes. The results of these studies are mixed in comparison to the larger body of literature assessing hospitalisation and ED use which routinely reports negative associations with continuity, with the most objective measure (health status based on pathology test results) showing the least promising results.

In recognition of these limitations, and the fact that none of these studies assess regularity, this thesis explores the associations of regularity and continuity with these intermediate outcomes.

These gaps in the literature are addressed firstly by objective 4a: “Investigate associations between regularity and appropriate use of pathology testing and patient health as indicated by results on pathology tests.” This objective represents a contribution to the literature by assessing impacts of these exposures on both processes of care, a hypothesised intermediate factor, and evaluated patient health (glycosylated haemoglobin (HbA1c)) as factors likely to sit on causal pathways between regularity / continuity of care, and hospital / ED use outcomes.. These gaps are further addressed by objective 4b: Investigate associations between regularity and the appropriate use of preventive medications, and 4c: “Assess appropriate medication use as a mediator of relationships between regularity and hospital / ED outcomes.” These objectives further contribute to the literature by providing a stronger understanding of likely causative pathways by which downstream outcomes may be affected. These analyses add substantially to the literature by providing a clearer understanding of potential causal pathways that underpin relationships with outcomes of main interest, which is essential to understanding the value of regularity and continuity as intervention targets. Note that although in clinical research these intermediate outcomes (in particular HbA1c, as the only biomedical measure assessed) are sometimes used as “surrogate” markers of patient health, their use in this thesis differs. Surrogate markers are patient observations, laboratory tests, imaging studies or similar measures which are used as outcomes of clinical trials in place of actual measures of patient health or clinical events, commonly as a means to reduce costs or time required for a clinical trial (191-193). The use of surrogate markers of health in research or clinical practice is problematic in cases where there are potentially multiple causal pathways or the surrogate itself does not have a strong causal relationship with the clinical outcome of interest, and experts suggest caution in their use (191, 192). However, even markers which are problematic as surrogate outcomes may be usefully investigated for other purposes such as elucidating mechanisms of action (193), which is the purpose of investigating HbA1c in this thesis.

2.2.2.9 Potential drivers of changes to continuity / regularity of care

Investigating the effects of regularity and continuity of GP contact is relevant only if there is potential for these metrics to be modified, whether by deliberate intervention or as an unintended consequence of other changes in the primary health care sector. According to the Andersen framework of health services use, enabling factors, which includes the patient–physician relationship, are considered highly modifiable (85).

Researchers and commentators across the world have discussed health system changes which threaten continuity of care. Some authors have discussed maintenance of continuity of care as being under threat from other principles such as rapid access to care (84, 92) and access to a plurality of providers (94), or more simply that continuity is “going out of style” (194). Growing practice sizes have impacts for clinic schedules leading to declines in continuity as observed in the USA and England (92), while a trend towards larger practice sizes is also occurring in Australia (195).

Previous Australian research has demonstrated that where GPs claim certain Medicare incentive items (the EPC / CDM items outlined in section 2.1.1.2) in relation to a patient’s care, GP contacts became more regular in the following year (179), furthermore this occurred without any increase in the frequency of GP contacts (that is no increase in resource utilisation) (196). Other work in the USA has demonstrated regularity of care to be lower among people living in more rural areas, leading to later cancer diagnosis (172), which suggests that the geographical distribution of GPs may be a driver of regular GP contacts. The geographical distribution of GPs is a potentially modifiable factor and is relevant in Australia where the geographical distribution of GPs is known to favour metropolitan areas over rural areas (197). Payment incentives and policies do attempt to address this in some cases. For example, there are incentives provided to GPs via Medicare’s fee-for-service payment system to encourage GPs in rural and remote areas to “bulk bill” (i.e. claim payment for services directly from the government, charging patients no out-of-pocket fee) (198). This incentive intends to encourage vulnerable patient groups in rural and remote areas to access their GP more often, and may encourage a redistribution of GPs towards rural and remote areas. Additional government policies have been introduced to encourage GPs and allied health providers to visit rural areas (199, 200).

Other work set in residential aged care homes has found that visiting GPs were more likely to attend a home more regularly if they had higher numbers of registered patients there. Again, this is a potentially modifiable factor. The authors of this study suggested that regularity could be enhanced via care home managers encouraging newly admitted residents to change GP to a provider already known to the home (178). In the Australian context, practice incentives have been introduced via Medicare, offering GPs an additional reimbursement for providing a minimum number of services in residential aged care facilities in a year (201). Note that this incentive does not explicitly require GPs to have a certain number of patients registered at a single aged care home, as was the exposure in the study cited in this paragraph, though GPs aiming to claim this incentive would likely aim to treat multiple patients at each care facility they visit.

Outside of Australia, the policy changes described in section 2.2.2.5 provide further guidance as to how continuity of care may be encouraged. A policy introduced in the USA which provided a financial incentives for providers to allocate all patients to a primary care physician, and imposed a financial penalty for visits by patients to physicians other than their own, resulted in increased continuity (152). In contrast, a policy in the UK required general practices to allocate patients to specific providers but imposed no penalty for visits by patients to other providers, and saw no change in continuity as a result (150, 151). Though Australia's fee-for-service system does have disadvantages, it does facilitate the introduction of financial incentives such as these to influence practice. Incentive payments are available via Medicare for general practices which register Aboriginal / Torres Strait Islander patients, and provide the majority of care to these patients in a calendar year, though there are no specific incentives to encourage continuity with the same GP at the practice (200). Such incentives have not been made available for other population groups.

Health policies, including GP funding via Medicare, undergo routine change and often these changes will have potential to affect continuity and regularity of care. In 2015, the Federal Government announced the introduction of a \$7 co-payment for all general practice visits with the aim of reducing government expenditure (202). This proposal led to criticism from the Australian Medical Association and Royal Australian College of General Practitioners which voiced concerns about access to services (203, 204). Critics have highlighted the risk that patients missing check-ups (that is reduced regularity) may lead to missed opportunities for early detection of serious illness (205). The proposed co-payment was scrapped prior to implementation due to political opposition. Similarly, a temporary freeze on the usual indexation of Medicare fees paid to GPs was in place from 2014 until 2018 and other providers for different date ranges (206). This raised similar criticisms, that the freeze on indexation would result in GPs charging higher out of pocket services above the government fee-for-service reimbursement (207), with similar effects on preventive services as described for the \$7 co-payment. The rhetoric from the Government proposing / implementing these policies was that many Australians visited the GP more often than was necessary, a view in line with the theory of moral hazard – that is, the notion that patients will be more likely to use health care when they are not the payer, resulting in the use of care that is worth less to consumers than it costs to produce (208). Note that although commentators were concerned that these increases in out-of-pocket payments would reduce delivery of preventive care, the evidence regarding this is less clear. The famous RAND health insurance experiment tested the impact of co-payment levels on the use of health services in the United States in the 1970s. This randomised controlled study found that a higher co-payment level led to fewer doctor visits and reduced hospitalisation. Overall this did not affect participant health, though among the poorest and sickest there were some adverse impacts observed (209); considering that this study excluded those older than 65, there may be a risk that a policy of co-payment increases might lead to adverse outcomes among older people with more comorbid conditions and complex care needs. Similarly the Oregon health insurance experiment found that among a low-income population randomly allocated to receive Medicare benefits, health-care utilisation increased (including the use of preventive services) and self-reported mental and physical health improved (210). Although these studies did not explicitly assess patterns of GP contact, they do suggest that increased out-of-pocket costs may discourage regular contacts with the GP.

In summary, there are many avenues by which policy can influence continuity and regularity of care, and potentially ultimately affect downstream outcomes. Although policies have been introduced in Australia to improve aspects of primary care, these have not generally been articulated in terms of intentions to improve continuity or regularity of care. These have generally been policies intending to improve the availability of primary care to specific population groups with poor access, where improved continuity and regularity may be expected to result even if these are not stated aims. In other cases changes to payment mechanisms (both proposed and implemented) may have secondary negative effects on regularity and continuity of care. There are examples internationally of policies which are specifically aimed at increasing the continuity of care, and in Australia's fee-for-service framework the implementation of such policies is practical. All of this provides some impetus to research the impacts of continuity and regularity on patient outcomes, to firstly better understand potential impacts of future policy decisions that may have deliberate or unintended effects on regularity of patient visits to GPs, and secondly to consider the value of developing policies aimed specifically at improving the continuity and regularity of care provided.

The impact of policy change is assessed in objective 3a: "Determine impacts of historical changes to primary care policy on regularity and the associations between regularity and outcomes in patients with diabetes." Although previous research has demonstrated that, at the individual level, claiming of incentive items under the EPC program was followed by more regular GP contact, it is unclear whether population-level changes to regularity occurred, considering the initially low program uptake. Furthermore it is unknown how the introduction of this program may have altered associations between regularity of GP contacts and patient hospitalisation outcomes. Addressing these points will provide a clearer understanding of how policies may be used to influence GP contact patterns and ultimately patient health.

2.2.3 Section summary

Following an overview of the Australian health system, this chapter has provided an overview of key concepts concerning continuity of care and discussed much of the literature in this area. Continuity of care was defined and its role as a key aspect of primary care was discussed. The mechanisms by which continuity is theorised to influence downstream health service use were described in relation to Andersen's model of health service utilisation. The empirical literature on continuity of care was discussed and some limitations of this literature highlighted. The concept of regularity was introduced. The general study designs used in this area were discussed and critiqued. The thesis objectives were introduced with respect to gaps in the current literature on continuity of care.

The following chapter will describe the data collections and key measures used through the thesis.

Chapter 3 Data sources and methods

This chapter outlines the data collections used in this study. The concept of data linkage is firstly described as this underpins several of the data collections utilised. Key features of the four data collections used are then described along with the ethical and data access approvals facilitating the study. Finally the measures of continuity and regularity used in the study are defined.

3.1 Data linkage

3.1.1 Overview of data linkage

The concept of linkage of administrative data collections has its origins in a 1946 manuscript by H.L. Dunn (211). Dunn described the idea as follows:

Each person in the world creates a Book of Life. This Book starts with birth and ends with death. Its pages are made up of the records of the principal events in life. Record linkage is the name given to the process of assembling the pages of this book into a volume.

Dunn wrote of the key challenges in assembling the book of life, most of which persist today: the events of importance (pages) are recorded in different places as a person moves through life, and usually no cross-index exists to all of a person's records. Dunn also suggests that assembling these pages into volumes is not necessary, that the creation of a "Life Records Index" which directs people to the location of the important records can achieve the same goal. The potential uses of such record linkage are hinted at by Dunn, including the potential for organisations to better understand the health and social status of their program members, foreshadowing the evaluation and research purposes which modern data linkage facilities support.

Computing technology has resulted in the development of data linkage systems that are very different in practice to those proposed by Dunn, although there are high-level similarities in principles. There are two commonly used approaches to linking data. The simplest is deterministic linkage, whereby there exists one or multiple unique identifiers across records and data collections, allowing the same individual to be identified across records and datasets where there is a perfect match on this identifier. Examples include the NHS number in the United Kingdom (212) and national identity numbers that exist in some countries (213).

In Australia no such unique identifier exists. As a result, data linkage is performed using probabilistic linkage. Probabilistic linkage involves matching records using multiple, partially identifying, non-unique variables. These include names, addresses, and dates of birth (212). The use of multiple fields allows for the calculation of probability weights that two different records concern the same person, taking into account misspellings, name changes and other issues.

In Western Australia probabilistic linkage has historically been performed by the WA Department of Health's Data Linkage Branch (DLB) (214) which administers the WA Data Linkage System (WADLS) established in 1995 (215). The approach described by Dunn of using a life records index is adopted, with participating databases remaining decentralised and the DLB generating and maintaining a master links file acting as a reference point to connect these (215). This approach has important implications for patient privacy as it allows the separation of data necessary for linkage (that is personal identifying information) from the clinical content data required for research, a practice known as the separation principle (214). On a routine basis custodians of individual data collections (such as the Hospital Morbidity Data Collection (HMDC) or the death registry) extract personal identifiers and provide these to the DLB. The DLB adds these to the master links file along with the date the record was generated and the database from which the record came. Deterministic linkage is performed on an ongoing basis so that all records in the master links file belonging to the same person are linked and the same randomly generated linkage key is applied to these. When data are required for research purposes, the DLB can flag all records belonging to the relevant individuals from all relevant data collections, and the custodians can extract the content data, without identifying information, to provide to the researcher. A simple fictional example is provided below to more clearly describe the data flows typically involved between data custodians, the DLB and the researcher.

Step 1: Custodians of individual data collections routinely provide personal identifiers to the WA DLB, along with references to the records within their own databases, with content data removed



Step 2: The WA DLB maintains and stores the Master Links File, flagging where records belong to the same individual

WA Data Linkage System Master Links File		
Hospitalisation	Record 4005	Joe Brown DOB 19/09/1944
Hospitalisation	Record 4006	Jane Smith DOB 15/02/1965
Hospitalisation	Record 4007	Jess Green DOB 01/03/1990
Mortality	Record 5187	Joe Brown DOB 19/09/1944
Mortality	Record 5188	Tim Wells DOB 25/05/1932
Mortality	Record 5189	Sue Smith DOB 12/09/1941

Step 3: A researcher defines a project cohort using International Classification of Disease (ICD) codes or similar (in this case, the cohort is made up of individuals who have had lung reduction surgery for a study of mortality), the custodian then flags the relevant records within their database

Hospital data	Record 4005	Joe Brown DOB 19/09/1944	Lung reduction on 01/07/2014
	Record 4006	Jane Smith DOB 15/02/1965	Chemotherapy on 08/01/2013
	Record 4007	Jess Green DOB 01/03/1990	Gave birth on 21/03/2014

Step 4: The custodian of the hospitalisation data informs the DLB that record 4005 belongs to a cohort member. The DLB flags all records belonging to that person which are required for the project as defined by the researcher

WA Data Linkage System Master Links File		
Hospitalisation	Record 4005	Joe Brown DOB 19/09/1944
Hospitalisation	Record 4006	Jane Smith DOB 15/02/1965
Hospitalisation	Record 4007	Jess Green DOB 01/03/1990
Mortality	Record 5187	Joe Brown DOB 19/09/1944
Mortality	Record 5188	Tim Wells DOB 25/05/1932
Mortality	Record 5189	Sue Smith DOB 12/09/1941

Step 6: The DLB inform the custodians of the relevant collections which records from their databases are required for the project and provide a project-specific person number

Hospital data	Record 4005	Joe Brown DOB 19/09/1944	Lung reduction on 01/07/2014	ID ABC123
Mortality data	Record 5187	Joe Brown DOB 19/09/1944	Died on 05/12/2016	ID ABC123

Step 7: The researcher is provided with files including content data, stripped of personal identifying information and with the project-specific person number attached to allow records to be matched

ID ABC123	Lung reduction on 01/07/2014
ID XYZ789	Lung reduction on 09/01/2014
ID XYZ789	Readmission on 21/07/2014
ID EKF195	Lung reduction on 19/09/2014
ID ABC123	Died on 05/12/2016
ID EKF195	Died on 15/02/2017

The DLB is no longer the only linkage facility in Western Australia. In 2009 the Centre for Data Linkage (CDL) was established at Curtin University (216). The CDL provides ad hoc linkage services to researchers in addition to conducting research into linkage methods. Notably, while the WADLS maintains ongoing linkage between a range of databases under the jurisdiction of the Western Australia (WA) Department of Health, the CDL has the ability to perform cross-jurisdictional linkages using its custom Linxmart software (217); this is a vital capacity for many projects given the federated nature of Australia's health system.

3.1.2 Privacy-preserving record linkage

The example above is simple in that two data collections are involved and both of these collections fall under the jurisdiction of the WA Department of Health. As Australia is a federation with health, social, aged care, disability and other services provided by different levels of government (16), often researchers will need datasets linked which are under the custodianship of different governments. This creates challenges in that personal identifiers must be released from one agency to another so as to allow for linkage (218). Similar challenges may be faced when attempting to link data held by private providers such as general practices to other collections (219). Difficulties in data access and sharing across agencies have been the subject of a 2016 report from the Senate Select Committee on Health which highlighted the complex approvals process and departmental approach to custodianship (220). The necessity for release of personal identifiers from one agency to another can present an insurmountable challenge, considering data custodians may often perceive the potential risk of privacy breaches (in terms of risks to themselves and to the individuals whose data is involved) to outweigh the potential benefits of a research project (221).

In this thesis and larger National Health and Medical Research Council funded project under which the thesis began, the challenge of sharing of identifiers between agencies was overcome through the use of privacy preserving record linkage (PPRL). PPRL refers to a range of techniques that allow for the linkage of large databases across organisations while preserving the privacy of the individuals stored in those databases (222). Typically, this involves the transformation of personal identifying information into other forms prior to any release to linkage units. The most basic form of privacy-preserving linkage is the usage of statistical linkage keys (SLKs). An SLK is a variable derived from components of an individual's personal identifying information. One commonly used SLK in Australia is SLK-581 which combines letters two and three of the first name, letters two, three and five of the surname, the full date of birth and sex. For example, David Youens, a male born 19 September 1986, forms the SLK `ounav190919861`. The deficiencies of this approach include the fact that the key retains identifying information and that there is loss of information in generating the key which effects linkage quality (223).

More complex and modern PPRL methods provide an improved level of anonymisation while still supporting probabilistic linkage. A method used in the current project is the Bloom filter method developed by Schnell et al. (224). Under this method, a field such as surname is split into sets of consecutive letters (called bigrams, as the set contains two letters). These sets of bigrams are then irreversibly encrypted using a Bloom filter, meaning the bigram cannot be reconstructed. Provided that all the records were encrypted using the same algorithm, each (encrypted) pair of records can be compared to generate similarity scores based on the number of encrypted bigrams across the two records which match (224). The use of similarity scores supports probabilistic linkage as tolerances for disagreement between two records can be set to allow for misspellings. Even with PPRL used the separation principle remains important and information flows remain similar to those outlined in section 3.1.1. However, the role of the linkage unit is expanded to include the provision to data custodians of the specialised software, metadata specifications (the characteristics of the fields to be used in linkage) and encryption specifications, to ensure that all custodians perform identical encryption and extraction before returning data to the linkage unit. These methods do not reduce linkage quality in comparison to traditional probabilistic linkages (225).

3.2 Data sources

The current project used four different datasets. Each of these datasets involved linkage of multiple collections, though data are not linked across these four datasets for both technical and ethical reasons. The following text and Table 3-1 outline the different data collections used in the current project. This section outlines the types of data contributing to each data collection, the data linkage techniques used by the data providers, the datasets and key variables making up each collection, and population sizes.

3.2.1 WA population data 1990–2004

This is a collection of linked administrative data, including both WA Health data and Medicare data. The data were linked and provided via the WA Data Linkage System (215). This collection includes data covering Western Australian Medicare enrollees aged 18 and older at any time between 1 January 1990 and 31 December 2004. For this cohort, the collection includes hospital separations (all separations from public and private hospitals in WA from 1981 to 2004), all Medicare claims for services rendered in Western Australia from 1990 to 2004, deaths from 1990 to 2004, and electoral roll records (including all recorded changes in address, including migration to and from WA, from November 1988 to October 2006).

3.2.2 45 and Up data

The 45 and Up Study consists of a large-scale survey of over 250,000 people aged 45 and older in New South Wales (NSW), administered by the Sax Institute (226). Individuals who were resident in NSW and aged 45 and older were randomly sampled from the Medicare Australia enrolment database. Eligible participants were mailed a survey and consent form, which included consent to have survey data linked to administrative data collections including Medicare Benefits Schedule, Pharmaceutical Benefits Scheme, hospitalisation, emergency department and mortality and other health records. The study over-sampled individuals aged 80 and older and people in rural and remote areas. The survey captured a range of information including socio-demographic characteristics, health status and medical and surgical history, lifestyle and social factors, functional status and more. The response rate for the study was about 18% (227). The data extracted for the current study included NSW hospitalisation data (all separations from NSW hospitals from July 2001 to June 2017), NSW ED data (all presentations to NSW EDs from 1 January 2005 to June 2017), deaths from February 2006 to June 2017, Medicare claims and PBS records originating in NSW from July 2005 to December 2016.

3.2.3 MedicineInsight data

The MedicineInsight data collection (228) is a large-scale general practice dataset originally established to support quality improvement in Australian primary care and post-market surveillance of medicines. The program is administered by NPS MedicineWise. The MedicineInsight program collates routinely collected electronic health record information from the clinical information systems of consenting general practices (229). As of July 2017, MedicineInsight had recruited more than 650 general practices, collecting information on more than 3,300 general practitioners and 3.6 million patients. The data are accessed on application to MedicineInsight's independent Data Governance Committee which is comprised of consumer advocates, data security experts, GPs and researchers (229).

General practices which choose to participate in MedicineInsight volunteer to provide patient data (excluding identifiers such as name, date of birth and address), though patients may opt out of having their information included in data extracts and practices are required to display posters in waiting rooms informing patients that their de-identified data are being shared with MedicineInsight. When practices join MedicineInsight whole-of-practice electronic health record information is made available, both current and historic, and data extracts continue periodically, allowing for longitudinal follow-up of patients (within an individual practice). The data collected include patient demographic and clinical data (conditions, vaccines, allergies, etc.), pathology data reported automatically from labs to practice CISs, patient encounters, information on the site and GP, and patient prescriptions. Prescription data are coded using Anatomical Therapeutic Chemical Classification System Codes where possible, pathology data are coded using the Logical Observation Identifiers Names and Codes (LOINC) system, while some diagnosis entries can be mapped to the Systematized Nomenclature of Medicine – Clinical Terms system (228).

For the current study, MedicineInsight data were accessed including data from all practices in WA and NSW. The data provided include diagnoses, observations recorded at the practice (such as blood pressure, body mass index (BMI) and other recordings commonly made at general practices), pathology test orders and results, prescriptions (current and historical), encounter records, patient characteristics (sex, age group, geography etc.) and practice characteristics (geographical socioeconomic status, rurality).

3.2.4 WA population data 2000 - 2017

The WA population 2000 to 2017 dataset is a collection of linked administrative data covering all Western Australian adults aged 18 and older, who were enrolled with Medicare in WA between the years 2005 and 2017. The year 2005 is used to define the cohort although data going back to 2000 is included for cohort members to allow for variables relating to historical health service use. The data were provided by WA Health and the Commonwealth Government Department of Human Services and linkage was performed by Curtin's CDL using privacy-preserving record linkage techniques (225). For this cohort the data included all Medicare claims from January 1999 to February 2017, separations from all public and private hospitals in Western Australia from January 1999 to June 2017, presentations to all WA EDs from January 2002 to June 2017, and death records.

3.2.5 Comparison of data collections

Table 3-1 provides a comparison of key features of the four datasets accessed for the study.

Table 3-1: Summary of datasets used in current project

Collection	WA population data 1990–2004	NSW 45 and Up	MedicineInsight	WA population data 2000–2017
Cohort definition	Western Australian Medicare enrollees aged 18 and older at any time between 1 January 1990 and 31 December 2004	Participants of the Sax Institute’s 45 and Up study. This includes residents of NSW sampled via Medicare enrolments.	All patients at all practices in WA and NSW participating in the NPS MedicineInsight program	People enrolled with Medicare, resident in WA, and aged 18 years and older at any time from 1 January 2005 to 31 December 2017
Cohort size	2,025,770	267,153	640,293 patients 214 practices	2,868,749
Datasets and date ranges	Medicare claims 1990–2005 Electoral roll 1988–2006 Hospital separations 1981–2004 Mortality 1981–2004	Self-report survey data completed 2006–2009 Medicare claims 2001–2016 PBS dispensations 2004–2016 Hospital separations 2001–2016 Emergency department presentations 2005–2017 Mortality 2006–2017	<u>Practice</u> Location information (rurality, socioeconomic status) <u>Patients</u> Diagnoses up to 2017 ^a Observations (recorded at practice) 2011–2017 Pathology results 2011–2017 Prescriptions 2011–2017 Prescription history 2011–2017 Services 2011–2017 Patient demographics	MBS claims 1999–2017 PBS dispensations 2002–2019 (unavailable at time thesis completed) Hospital separations 1999–2016 ED presentations 2002–2017 Mortality 1984–2018

Collection	WA population data 1990–2004	NSW 45 and Up	MedicineInsight	WA population data 2000–2017
Linkage	Probabilistic linkage performed by the WA Department of Health DLB	Survey data linked to hospital, ED and death data by NSW Health Centre for Health Record Linkage, MBS and PBS data linked by the Sax Institute, both using probabilistic linkage	Deterministic linkage of records belonging to the same individual within each practice only, using internal patient IDs – no linkage between practices.	Probabilistic PPRL performed by the Curtin University CDL, using encrypted identifiers provided by the WA DLB and AIHW Linkage unit

<p>Key variables (patientID available in all cases)</p>	<p><u>Medicare claims</u> Sex, age, item claimed, service date, MBS group, provider postcode, benefit paid, copayment</p> <p><u>Hospitalisations</u> Admission date, separation date, diagnosis codes, diagnosis-related group (DRG), procedure codes, indigenous status, age, sex, postcode, hospital type (public / private, teaching / non-teaching), separation type (transfer, discharge, deceased, etc.,\.)</p> <p><u>Electoral roll</u> Date of addition to / removal from roll / change of address, postcode, sex, age</p> <p><u>Deaths</u> Country of birth, age, sex, indigenous status, date of death, cause of death (ICD code), postcode</p>	<p><u>Self-report survey</u> Age, weight, height, ancestry, qualifications, country of birth, language, smoking, alcohol intake, housing, relationships, exercise, family history of disease, medications, diagnoses, limitations, carer status, diet, screenings, work status</p> <p><u>Medicare claims</u> ProviderID, service date, item claimed, MBS group, provider postcode, benefit paid, co-payment</p> <p><u>Pharmaceuticals</u> PBS code, ATC, dispensing date, prescribing date, quantity supplied, new / repeat prescription, patient contribution</p> <p><u>Hospitalisations</u> Admission date, separation date, diagnosis codes, DRG code, procedure codes, condition onset flag, care type (such as acute, rehabilitation,</p>	<p><u>Patient</u> Sex, age, rurality, year of death, indigenous status, smoking, location (statistical area / PHN)</p> <p><u>Practice</u> Rurality, socioeconomic status, location (statistical area / PHN)</p> <p><u>Diagnoses</u> Diagnosis, date recorded, onset date</p> <p><u>Observations</u> Date, observation type (BMI, blood pressure, pulse etc.), observation value, provider performing observation)</p> <p><u>Prescriptions</u> ATC, prescription date, reason for prescription, medication name, quantity, number of repeats, strength, formulation</p> <p><u>Pathology</u></p>	<p><u>Medicare claims</u> Service date, item claimed, MBS group, age, postcode, in hospital flag, bulk-billing flag, benefit paid, schedule fee</p> <p><u>Hospitalisations</u> Admission date, separation date, diagnosis codes, age, sex, indigenous status, country of birth, marital status, hospital category, care type, mode of separation, postcode, procedure codes</p> <p><u>Emergency presentations</u> Presentation date and time, age, sex, marital status, indigenous status, country of birth, hospital type (tertiary / other), triage code, visit type, arrival type, referral source, discharge category, destination, diagnosis code, postcode</p> <p><u>Deaths</u> Date of death</p> <p>Indigenous flag</p>
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Collection	WA population data 1990–2004	NSW 45 and Up	MedicineInsight	WA population data 2000–2017
		<p>palliative etc.), separation type, referral source</p> <p><u>Emergency department presentations</u> Arrival date, departure date, referral source, triage code, visit type (emergency, planned, etc.), mode of arrival, mode of separation, UDC</p> <p><u>Deaths</u> Date of death, causes of death</p>	<p>Test date, test name, test result, units used, LOINC code</p> <p><u>Service</u> Service date, MBS item, practice and provider</p>	

^a Diagnoses prior to 2011 are available in some cases but accuracy of onset dates appears unreliable – onset dates appear to default to 2011 in many cases, likely reflecting the date that data were extracted for provision to the NPS rather than the actual date of diagnosis.

3.2.6 Data access and ethical approvals

This section outlines the process for each collection to gain approval and access to the data, and my role / the principal supervisor's (Rachael Moorin) role in accessing each collection.

The WA whole population data 1990–2004 were accessed under a memorandum of understanding (MOU) which existed between the WA Department of Health and the Commonwealth Department of Health in the 2000s to support cross-jurisdictional linkages. Access to these data were negotiated by the principal supervisor who was the principal chief investigator for a large cross-jurisdictional program of work evaluating the impact of an ageing population on changes in health system cost, access, utilisation patterns and outcomes. Ethical approval for the broader study (which the analyses undertaken using these data for this PhD was covered by) was provided by The University of Western Australia's Human Research Ethics Committee.

Access to the NSW 45 and Up data required approval from the Sax Institute (access to survey, Medicare Benefits Schedule and Pharmaceutical Benefits Scheme data), the New South Wales Population & Health Services Research Ethics Committee (NSW Health data), the ACT Human Research Ethics Committee (ACT Health data), the NSW Centre for Health Record Linkage and custodians of individual data collections. For security purposes, these data are accessed via the Secure Unified Research Environment (SURE), a remote-access data research laboratory (230). The applications for these data were led by the principal supervisor, though I provided substantial input into the content (background, analysis plans and variable lists requested). Since the data have been provided I have largely been responsible for preparing annual reports to the Sax Institute and ethics committees

Access to MedicineInsight data required a two-stage review involving an expression of interest to assess project feasibility followed by a full data application assessed by MedicineInsight's external Data Governance Committee. The application was assessed in terms of feasibility, significance, capability of the researchers to complete the work, and security of the working environment and computer systems. I led this data application and the annual reporting required to maintain access.

The WA whole population data 2000–2017 were the most difficult to access. Although the technology to support PPRL was available via the CDL, this technology was not well understood by the various ethics committees, linkage branches and custodians involved. Substantial negotiation was required for all parties to understand the process, and approve the data flows required for linkage to proceed. These negotiations were led by CDL and researchers (Rachael Moorin and me). Ultimately approval was granted by the WA Health Human Research Ethics Committee (HREC), the Australian Institute of Health and Welfare HREC, the WA Health DLB, the AIHW linkage unit and custodians of all data collections. The approval granted did not initially include the provision of PBS data because at the time the approval was negotiated, key personnel at the AIHW and / or Commonwealth Department of Health erroneously believed that legislation prevented the provision of MBS and PBS data as part of the same project using the waiver of consent process (the process typically used for population–based studies). After initial approval was granted, interpretation of legislation changed such that these data collections could both be provided. Following this a new data application was submitted to the AIHW HREC and the PBS data governance committee to allow the inclusion of PBS data to the existing project. This data collection is accessed via SURE, in a separate workspace to the NSW 45 and Up data. The initial data application was led by Rachael Moorin, though I provided substantial input into application documentation and contributed to meetings with data custodians and others. I led the subsequent application, to incorporate PBS data, involving several rounds of negotiation with data providers.

All data sets involve the completion of annual reports to the relevant ethics committees and / or data providers, outlining project progress and detailing any ethical or security concerns that have occurred.

3.2.6.1 Approvals for the thesis

Larger NHMRC grant

Curtin HREC RD-42-14

PhD project

Curtin HREC HRE2017-0579

WA Population data 1990–2004

UWA HREC RA/4/1/1239

MedicineInsight data

MedicineInsight Data Governance Committee DG 2017-012

WA Population data 2000–2017

WA Health HREC 2016/61

AIHW HREC EO2015/4/192, now superseded by EO2020-2-1138

NSW 45 and Up data

Sax Institute project CPC-17007

ACT Health HREC 8.17.175

NSW Health Population & Health Services Research Ethics Committee 2017/HEW1001

3.3 Measures of GP contact derived from administrative data

Different analyses within this thesis use different measures depending on the objective being addressed. All indices used in analyses are described in this section for completion and to avoid repetition. Further, more specific details on how each was constructed using the administrative data is provided within the methods section of the relevant chapters and published manuscripts.

3.3.1 Measures of continuity

As detailed in section 2.2.2.6, two of the most commonly used measures of continuity of care used in the literature are the UPC and COC indices; each of these are used in this thesis.

Equations for these are provided below:

Usual Provider of Care (UPC)

$$UPC = n_i/N$$

Where N is the total number of GP visits made by the patient through the study period

n_i is the number of visits to the patients usual GP, i .

Note that the UPC index as originally defined relies on the patient's usual provider being known, this is not generally stated in the administrative data commonly used in this area. Instead, the usual provider is typically assumed to be the provider who the patient visits most frequently through the measurement period.

Continuity of Care (COC)

$$COC = \frac{\sum_{i=1}^k n_i^2 - N}{N(N - 1)}$$

Where k is the number of providers

n_i is the number of visits to provider i

N is the total number of visits to all providers through the study period

An alternative measure of continuity is an indicator that care plans accessible to a patient's various providers have been developed. This is in line with the 'informational' level of continuity defined by Saultz and by Haggerty et al. (83, 84) and has been used as a measure of informational continuity previously (125). In the Australian setting indicators of the use of care plans can be derived via MBS data. The CDM program described in section 2.1.2.3 includes fee-for-service incentive items claimable by GPs for preparing or reviewing a management plan for a patient, co-ordinating team care arrangements, or contributing to a care plan developed by another provider (67). The claiming of any of these items in the care of a patient is taken as an indicator of informational continuity.

3.3.2 Measures of regularity

Two measures of regularity published in the existing literature are used in this thesis.

The first is based on the dates of GP contacts within a given ascertainment period (176, 177, 179). For each of an individual's GP contacts within the measurement period, the number of days since the prior contact is counted, and the variance in this number of days calculated. The regularity score is calculated as follows:

$$R = \frac{1}{1 + \text{var}(\text{days})}$$

Where *days* is the number of days since the prior GP contact. The regularity score, *R*, ranges from 0 to 1. A higher regularity score, indicating visits spread out over time, likely reflects care that is planned and proactive. In contrast, a low score, indicating clusters of visits, more likely reflects care that is episodic and reactive, whereby the patient has extended periods without visiting the GP interspersed with periods of activity in response to an exacerbation of their condition.

The second, published by Camacho et al. (172), assessed regular primary care contacts across a two-year study period using an ordinal measure which categorised primary care contacts as none (no contacts in period), any (some primary contact in period), annual (primary care contact in each year) and semi-annual (primary care contact in the first and second half of each year). The authors suggested that visits spread over a semi-annual basis represented a very different care pattern than the same number of visits clustered together at a single point in time, which would more likely represent episodic care (172).

These measures differ in that the first provides a continuous value (though this is often converted into quintiles for analysis) while the second only produces a categorical value.

As previously mentioned, although the terms regularity and continuity are frequently used alongside each other in this thesis, this does not intend to imply that the terms are interchangeable. The terms relate to different aspects of the relationship between patient and GP and are calculated differently. The terms are generally presented together because they are usually being assessed simultaneously in terms of their associations with health service use outcomes.

3.4 Summary

This chapter has provided an overview of the data sources and main measures used throughout this thesis. The following chapters detail outputs produced during the course of the thesis.

Chapter 4 Use of general practice data for research in Australia

4.1 Chapter overview

In section 2.2.2, some limitations of the literature on continuity of care were discussed. This included a relative lack of consideration of intermediate outcomes of continuity (care practices) in comparison to the assessment of downstream tertiary health service use. This may in part reflect the types of information generally available in administrative data collections. Increasing availability of the clinical information collected via general practice may provide a greater ability to assess intermediate factors. Notably, general practice clinical information system data can improve on typical administrative data in terms of the diagnostic information captured, information on observations recorded during general practice encounters, information on pathology tests requested including results of these tests, prescription information and other clinical information. In the context of the Andersen framework, while administrative data can be informative regarding personal enabling characteristics (regularity and continuity of care) and health service use outcomes (hospital and emergency department use), GP data have potential to provide information on the health behaviours (prescribing, monitoring, patient adherence to advice) that sit on the pathway between these in addition to providing information on evaluated health.

Manuscript 1 (which I led and have reproduced below) provides a commentary on the current availability of general practice data for research in Australia. This manuscript is presented to fulfil objective 1: “describe the availability of general practice data in Australia for observational research.” The manuscript outlines Australia’s history as a leader in the development of data linkage infrastructure and the conduct of research using administrative data. General practice CISs are outlined in terms of the data they capture and their research potential. Means of accessing these data for research are discussed, including access via direct collaboration with general practices, and access via third-party collections of general practice data. Comparisons are made to developments internationally. The full citation for this manuscript is:

Youens, D., Moorin, R., Harrison, A., Varhol, R., Robinson, S., Brooks, C., Boyd, J., (2020). Using general practice clinical information system data for research: the case in Australia. *International Journal of Population Data Science* 5(1). DOI: 10.23889/ijpds.v5i1.1099.

4.2 Manuscript 1

Using general practice clinical information system data for research: the case in Australia

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Abstract

General practice is often a patient's first point of contact with the health system and the gateway to specialist services. In Australia, different aspects of the health system are managed by the Commonwealth Government and individual state / territory governments. Although there is a long history of research using administrative data in Australia, this split in the management and funding of services has hindered whole-system research. Additionally, the administrative data typically available for research are often collected for reimbursement purposes and lack clinical information.

General practices collect a range of patient information including diagnoses, medications prescribed, results of pathology tests ordered and so on. Practices are increasingly using clinical information systems and data extraction tools to make use of this information. This paper describes approaches used on several research projects to access clinical, as opposed to administrative, general practice data which to date has seen little use as a resource for research.

This information was accessed in three ways. The first was by working directly with practices to access clinical and management data to support research. The second involved accessing general practice data through collaboration with Primary Health Networks, recently established in Australia to increase the efficiency and effectiveness of health services for patients. The third was via NPS MedicineWise's MedicineInsight program, which collects data from consenting practices across Australia and makes these data available to researchers.

We describe each approach including data access requirements and the advantages and challenges of each method. All approaches provide the opportunity to better understand data previously unavailable for research in Australia. The challenge of linking general practice data to other sources, currently being explored for general practice data, is discussed.

Finally, we describe some general practice data collections used for research internationally and how these compare to collections available in Australia.

Keywords

General practice; administrative data; big data; health information systems; medical records systems

Introduction

Health systems produce large volumes of data and these data are increasingly created and stored in digital formats [1]. Such data can be an invaluable tool both for patient care and research. In Australia the administrative data generated in hospitals has supported research for decades [2], however general practice data has to date seen limited use as a research resource [3].

This paper adds to a limited body of evidence regarding the utility and availability of clinical general practice data for research in Australia. This is based on our experience of working with different sources of general practice data, which we have accessed through different approaches. We describe these approaches in terms of access, usage, challenges and linkage to other collections. We describe the approaches our research

group is familiar with in detail, and provide an overview of other Australian data collections and leading examples internationally.

Background

The Australian Health System

General practices are entrenched in communities and are usually the initial interaction people have with the health system. While general practice provides health promotion, prevention, treatment and support; it is also the gateway to specialist services that support a growing population with chronic and complex comorbidities [4].

In Australia primary care and specialist services are pro-

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vided largely by private providers who are reimbursed by the Commonwealth (Federal) Government on a fee-for-service basis [5]. Australia's universal public insurance system, Medicare, ensures that all citizens and permanent residents have free access to public hospitals and reimburses general practitioners, specialists and other providers for services rendered (though providers may charge additional out-of-pocket costs [6]). It also provides reduced cost access to pharmaceuticals via the Pharmaceutical Benefits Scheme (PBS) [6]. In contrast, public hospitals in Australia are managed and operated by state and territory governments and are funded jointly by these state / territory governments and the Commonwealth Government. A significant recent development is the establishment in 2015 of 31 Primary Health Networks (PHNs) covering the country. These are not-for-profit companies independent of government, established to organise health services in their region. The main roles of the PHNs are to commission services to address gaps and meet prioritised local needs; to work closely with general practitioners and other health professionals to build capacity and the delivery of high quality care; and to integrate services at the local level to improve the patient experience and eliminate duplication [7]. Their key objectives are to improve the efficiency and effectiveness of medical services for patients, particularly those at risk of poor health outcomes, and to improve the coordination of care. The PHNs work with public and private services (including general practice) in their region but do not directly provide services [8].

Administrative data supporting research in Australia

Administrative data regarding ambulatory care services (including general practice) and medication dispensations are routinely collected in Australia. The Medicare Benefits Schedule (MBS) captures data on all services rendered attracting reimbursement through Medicare [9] and hence includes almost all general practitioner contacts, many diagnostic tests, therapeutic procedures and specialist visits. PBS data include records of all medicines dispensed under the scheme [9]. These data are collected for reimbursement meaning that while they have very good coverage and quality, they often lack detail important for research. For example the PBS records medications dispensed with no information on prescribing, meaning important information needs to be estimated (for example dosage prescribed or the reason for prescription) and there is no information on unfilled prescriptions [10] (relevant if trying to understand, for example, primary non-compliance). The MBS records item numbers indicating reimbursable activities such as general practice consultations, procedures, the completion of pathology tests and so on [9, 11] without any information on context. For example, a record indicating a general practice consultation will not include information on the reason for the visit, the advice offered, or any condition(s) diagnosed. Similarly, a record may indicate the completion of a pathology test but will not hold any information on the results of that test, and in many cases may indicate the completion of any one of a range of tests, which attract the same reimbursement but are otherwise unrelated. Furthermore, where multiple pathology tests are ordered, only the three attracting the highest reimbursements are captured meaning a test which is relevant to a research question may not appear in MBS data. While these

administrative data have certain strengths in their suitability for research (including completeness, whole population coverage, oversight by a single custodian) the limitations described, in particular the lack of clinical and patient information, make them unsuitable for many research questions.

General practice data

Beyond this administrative data there is a substantial gap in the general practice data available for research in Australia [12]. Previously survey data has provided insight into general practice activity [13] although these surveys were not intended to facilitate whole-sector research linking with data from other sources or longitudinal follow-up of patients.

More suitable clinical data for many research questions is collected through the clinical information system (CIS) software increasingly used by general practitioners since their introduction in the 1990's [14] to manage their patients [3]. This software initially focussed on collecting administrative and business related information, such as billing and scheduling, to assist with daily practice processes. These systems have expanded considerably to also collect clinical information including referrals, prescribed medications, development of patient management plans, pathology tests and other data. As the use of clinical information systems have increased over the past decade, tools to extract the data captured with these systems have been developed. These aid providers through clinical audits of patient cohorts and can highlight opportunities for improvement in business processes and patient care. These tools can extract de-identified patient information from clinical software and aggregate these data into measures related to patient visits, demographics, diagnoses, immunisations, pathology and so on. Many of these provide useful dashboard approaches and have been shown to enable quality improvement within general practice [15]. The development and use of these tools facilitates the extraction of clinical general practice data for research purposes, the focus of this paper.

Development of data linkage in Australia

Data linkage capabilities within Australia are shaped by the division of health services [16]. Individual states have developed their own linkage centres over several decades and many of these have supported large numbers of research projects [17, 18]. These state-based systems link hospitalisation data with emergency records, disease registries, large surveys, community services and so on. These state-level data can be linked to MBS and PBS (Commonwealth) data on a project by project basis, though as such linkages require the release of linkable fields by one jurisdiction to another the approvals process becomes more complex. The Commonwealth Government established the Population Health Research Network (PHRN) in 2008 to provide Australian researchers with access to linkable de-identified data from a diverse and rich range of health datasets, across jurisdictions and sectors. Meanwhile the Australian Institute of Health and Welfare has been designated an Integrating Authority, meaning that it has the authority to undertake linkage including Australian (Commonwealth) Government data [19]. Through the PHRN Australia now has

a dedicated capability for linkage of administrative and research data across all states and territories [20], though the approvals process for such linkages remains very challenging for researchers [21].

In summary, despite a strong tradition of linked data research in Australia using administrative (predominantly billing) data there are currently major limitations including the lack of information on the clinical management of patients in general practice, and obstacles to research using data from multiple sectors, making research capturing the patients journey through the health system challenging.

Current approaches to accessing general practice data

Our research group currently accesses general practice data for research through three methods. The first involves working directly with individual practices. The second is through working with general practices in partnership with one of our researcher teams working with the Primary Health Networks (PHNs) in Western Australia. The third is via a centralised collection of general practice clinical information system data collected, maintained by and accessed via the MedicineInsight program run by NPS MedicineWise [22], which is an authority on the quality use of medicines in Australia. We describe the practicalities, benefits and challenges of each of these approaches.

Working with general practices, directly and via Primary Health Networks

Access to general practice data for research relies in part on the CIS and associated data extraction systems, so a brief overview of these is warranted. As the clinical data collected in general practice has increased in scope, software vendors have developed their clinical information systems largely independently, without standardisation, resulting in a disparate array of methods to store and report information. For example, Best Practice and Medical Director, the two most common general practice management tools in Australia, use the incompatible medical terminology and health coding systems Pyefinch [23] / DOCLE (Doctor Command Language) [24] and the Medical Director termset, a derivative of SNOMED CT (Systematized Nomenclature of Medicine – Clinical Terms) [25]. Other applications such as PractiX, ZedMed and Genie use ICPC-2+ (International Classification of Primary Care) [23].

There is also diversity in the data extraction tools in use in Australia. The most popular is CAT4 (Clinical Audit Tool 4) developed by PenCS [26], which is provided to general practice through subsidised means by most (28 of 31) PHNs. Some PHNs provide POLAR GP (Population Level Analysis & Reporting) [27] as an alternative clinical auditing tool. Individual practices can select alternatives, with some choosing to use the Canning Tool [28] or to participate in the MedicineInsight program, which uses the GRHANITE (GeneRiC HeAlth Network Information Technology for the Enterprise) extraction tool [29, 30] and a customised version of cdmNet.

Access to general practice data

Firstly, we describe experiences in accessing general practice data through working directly with practices.

There are some general steps that researchers can follow if wishing to access data from general practices. Ideally, the project should already have ethical approval from the researcher's institution. Practices should be approached individually and invited to participate in the project. A brief information sheet is important, and practices may be invited to a workshop or information session where the researcher explains their project. For specific low-risk projects that have received ethics approval which require the participation of a cohort of patients (i.e. extraction of de-identified data), the Practitioner and the Practice Principal may consent on behalf of the patient depending on the practice's registration form for new patients. Building trust with general practitioners is crucial for long-term data sharing. Regular sharing of data can be fostered where organisations or researchers are able to provide value to practices, through providing data summaries to practices either as in-person data summary reviews or via data dashboards or other visualisations. These approaches can help practices to increase data literacy and identify areas to target quality improvement activities.

Involvement of Software Vendors

Some recent developments in patient privacy [31] have prompted clinical software vendors to require oversight of how data captured via their software is used. A data application including the project description and evidence of ethical approval will usually be reviewed by the vendor's committee, and the data request will usually incur a cost. Data extraction can occur in multiple ways. The simplest form of extraction is through predefined templates specific to each clinical software platform, though a unique extraction protocol is required for each platform as there is no agreed standard for extracting data. These templates are limited to what the vendor provides with requests for specific reports often associated with a financial outlay. Where these predefined templates are unsuitable, a customised extraction from the CIS database may be possible, though this requires SQL (Structured Query Language) expertise and governance approval from both the General Practice Principal (owner) and the software vendor. Software vendors are increasingly involved with data extraction requests by restricting data access to only general practice staff. It is becoming commonplace for researchers to work with CIS vendors to obtain data, as vendors want to ensure that data are being used in accordance with ethical approvals and to minimise risks of data breaches [31]. Accessing data this way therefore requires the research team to have sufficient technical skills to extract and store comparable data from across practices, substantial relationship and trust building with practices and administrative work to navigate approvals. These challenges will of course increase the more practices the research involves.

Involvement of Primary Health Networks

Where researchers need general practice data for their project the PHNs could (though do not necessarily need to) be approached. By involving the PHNs the researchers may get additional support if the project aligns with the PHNs health

initiatives in the region. With the establishment of the PHNs there has been a renewed awareness of the importance and capability of data collected in general practice to improve both patient outcomes and operational efficiencies (i.e. workflows and practices). Prior to this, data extraction across the general practice continuum was sporadic and uncoordinated, making consistent quality improvement a challenge. Routine data extraction is now becoming commonplace in most general practices, with data extracts scheduled at a frequency and time identified by the practice and coordinated by the PHN and the extraction software vendor.

To ensure only approved individuals have access to the data, comprehensive terms of agreement and governance frameworks are defined and applied at both the practice and PHN. These facilitate the reciprocal exchange of data from general practice to PHNs in return for practice specific reports detailing comprehensive insights into practice performance that often include regional comparators. As secondary data custodians, the PHNs may, depending on the agreed governance, further use the aggregated information to help inform population health service planning and policy. Decisions relating to data access for research will depend on the nature of the research project. For example, an ecological analysis of a chronic disease, utilising data aggregated across patients before release from the practice, may be viewed differently from a project requiring longitudinal follow-up of patients and hence individual patient data. For data that are de-identified at the general practice, aggregated and shared with PHNs for continuous quality improvement, the Practice Principal will decide whether information is shared with the PHN.

Strengths of general practice data

Despite the immediate shortcomings of data collected in general practice, these can provide a diverse range of information to inform policy and practice which are not available elsewhere. The information collected in general practice, ranging from diagnostic, therapeutic, prescription, disease control data and so on, has the potential to complement the data generated in hospitals and elsewhere (e.g. allied health, aged care etc.) to provide a comprehensive view of the patient journey. When combined, these sources offer tremendous opportunities in improving, for example, prevalence and incidence estimates, health services evaluations, outcomes research and economic analyses.

Working with general practices via the means described above involves substantial work in building relationships to facilitate trust and the sharing of data (whether by researchers themselves or by the PHNs). Though this can involve a significant time investment, the building of these relationships can have the added advantage of facilitating the dissemination of research findings back into practices and hence informing the clinical care of patients.

Challenges in accessing data via general practices

The lack of standardisation in patient information management tools and data extraction tools used across general practice results in substantial variability and inconsistency in the data captured. The variability in the information captured by general practitioners, and between patient information systems

/ extraction tools in the type and coding of information, may not be an issue for individual practices using data for business improvement purposes but can be problematic for researchers aiming to use information aggregated across practices or make comparison between practices.

In addition to the technical aspects mentioned above, there is apprehension from health providers regarding the sharing of data with third parties, including de-identified data. This includes concerns about maintaining patient and provider privacy; a lack of confidence relating to information accuracy and completeness in the data collected; and, in our experience, an uneasiness in providing regulatory bodies with such data. This uneasiness follows examples such as the controversial Quality and Outcomes Framework (QOF) implemented in the United Kingdom (UK) [32] and Care.data which was abandoned over privacy concerns [33].

In the Australian context, the ability of the PHNs to provide data extraction software to practices and to provide snapshots of practice data in comparison to local or regional averages may encourage practices to share their data for quality improvement purposes. However, for individual researchers or research groups working in, for example, the university sector, challenges around data sharing may be more difficult to overcome. One of the advantages of partnering with the PHNs, where this is possible, is that many of the challenges outlined above may have been fully or partially resolved through the prior work of the PHNs. For example, most PHNs that have existing relationships with the practices in their region are providing snapshot reports back to practices, which may encourage data sharing and may have existing governance processes in place.

External linkages

With the exception of a few exploratory endeavours [34, 35] patient data are not typically linked between practices [35] or to other areas of the health system (e.g. tertiary care) [34] and, as such, the data collected by general practices in Australia cannot currently be used to fully understand patients' interactions with the health system. International examples have demonstrated the power of using data from across the continuum of care in understanding, for example, associations between body-mass index and cancer [36], and risks of myocardial infarction and stroke following acute infection and vaccinations [37].

Although data linkage is not new, it is new to the field of general practice in Australia. The challenges described above in relation to data sharing also apply to data linkage, though given the reliance of data linkage on patient identifiers these issues can be more challenging to overcome. For example, a general practitioner or practice principal who is willing to provide access to de-identified data to support a research project may become much more hesitant where patient names and addresses are required to allow for linkage. Linkage may be facilitated through privacy preserving record linkage, whereby patient identifiers are irreversibly encoded prior to extraction from the practice, and linkage then performed on these encoded data [38]. Even with a technological solution such as this the steps of gaining the confidence and trust of practices remains vital, along with the necessity for a research team to have the technical skills to apply such methods. Of course,

if the data are to be linked to hospitalisation or other data sources, separate applications will also need to be made to the custodians of those data collections which adds further complexity.

Obstructions to data sharing can be the result of legal or legislative barriers but are more often related to understanding the options around data sharing by data custodians. These barriers can often be dismantled by mitigating risks associated with the data sharing process through careful planning, secure protocols and legal agreements. Given the sensitivity of the information involved, and the growing desire to link a broader number of datasets, any risk mitigation models that facilitate broader sharing of data are valued by researchers, data owners and the public.

In cases where linkage to other data sources is desired, the patient is generally required to provide consent for linkage; although the National Health and Medical Research Council provide criteria under which an ethics committee may approve the use of patient data under a waiver of consent, considering the risk to patients and benefits of the research, practicality of obtaining consent for the given project, privacy protections and more [39]. Data linkage can be performed in Australia by linkage facilities under state [40] or Commonwealth Governments [19] or at university-based centres [41]; for a given project the party to perform the linkage will depend on the datasets being linked and the jurisdictions responsible for these data collections.

NPS MedicineWise MedicinesInsight Data

NPS MedicineWise was established twenty years ago in 1998 with the aim of promoting the quality use of medicines. The MedicinesInsight program was established in 2011 as a quality improvement program to allow consenting general practitioners to assess their patterns of prescribing and patient care and to allow benchmarking at multiple levels [42]. This program involves practices signing up to share clinical data from their clinical information systems to MedicinesInsight monthly, which allows MedicinesInsight to provide insights into aggregated clinical data and provides practices the means to review their own activities. The extracted data includes information on patient demographics, reasons for encounters, conditions, prescriptions, observations, immunisation history and pathology tests, including results where available. Progress notes are not available. NPS MedicineWise has made MedicinesInsight data available to external researchers to support primary health care research following ethical approval. As of July 2017 the program had recruited over 650 practices, which included information from over 3,300 general practitioners and 3.6 million regular patients [43].

Access

Data are accessed by application to NPS MedicineWise. Liaison staff including biostatisticians and epidemiologists work with researchers to discuss data requests. The release of data requires approval from MedicinesInsight's external independent Data Governance Committee. This committee includes general practitioners, consumer advocates, privacy experts and researchers. Practices enrol in the MedicinesInsight program without the express consent of patients, though participating

practices are provided with information to keep in waiting areas and patients may opt out of having their data reported from the practice to MedicinesInsight.

Strengths

Practices are only enrolled if they use the patient management systems Medical Director or Best Practice. MedicinesInsight staff perform data cleaning and coding of important information. This includes work to de-duplicate patients with multiple records at a single site, separate 'clinical encounters' from records that are administrative only and identify 'active' and 'regular' patients. Similarly, MedicinesInsight apply geographical information such as remoteness and socioeconomic status using the Australian Statistical Geography Standard Remoteness Areas [44] and the Socio-Economic Indices for Areas [45], respectively. Researchers still need to do additional cleaning of their own as apparent errors remain in the data (for example, impossible values in various free-text fields including clinical observations in some cases). Clinical codes are used for some important fields including Anatomic Therapeutic Classification codes [46] being used for the medicines prescribed and the Logical Observation Identifiers Names and Codes (LOINC) system [47] which is used for pathology data.

A data book and a data dictionary are provided to aid interpretation of data [43, 48]. These provide background information on the collections, data elements (with explanatory notes), governance and ethics, data quality and some worked examples of how the data can be used. Although these are extensive, they lack some detail in comparison to data dictionaries that might be provided by data linkage branches with more substantial experience working with academic researchers. In some cases, the data book and data dictionary lack explanations on data that are automatically coded by the patient information management systems of the practices, such as some clinical observations and pathology requests and results. However, enough information and support is available to help researchers decide if this is a suitable source of data for their project.

Data include a scrambled patient identifier [22], allowing service, pathology, prescription and other data belonging to a single patient to be linked and importantly, allowing for patients to be followed longitudinally. The program has been running since 2011 and, once a practice joins, the full clinical history of patients is available. Information on representativeness of the patient population in the MedicinesInsight data in comparison to the general Australian population is provided for some important fields [48].

MedicinesInsight provides some derived variables on request, notably including patient diagnostic flags for a number of important chronic conditions. These are likely to be useful to many researchers whether aiming to understand prevalence within a population of interest, prescribing within specific cohorts or countless other research questions. While the generated diagnostic flags may not always reflect the cohort a researcher is interested in or the level of detail needed (e.g. a researcher may need the date a diagnosis was made rather than a flag of its presence), detail of the data available gives researchers a great deal of flexibility in constructing their own cohorts and indicators.

Challenges

As NPS MedicineWise seeks to recover the cost of data provision, researchers are required to pay data access fees, which may present a barrier for some researchers, although this is typical for any researcher wishing to access an existing dataset.

Most of the limitations of Medicinesight data reflect the fact that it is a collection of the data generated across millions of encounters at hundreds of practices. Inconsistencies in the data captured and / or coded by general practitioners, or at any other step of the data generating process prior to Medicinesight receiving the data, will ultimately be reflected in the data provided to researchers.

Some important data are provided as free-text fields, for example patient diagnoses and reason for encounter. This can result in a substantial time investment for researchers to identify clinical cohorts of interest, particularly when compared to collections such as hospitalisation data where this information is provided as International Classification of Disease (ICD) codes. The possibility of spelling errors and incorrect use of fields by general practitioners, for example the diagnosis field being used to record symptoms or family histories, can add to the time required to clean the data. This does, however, provide researchers with a high level of control over how they use the data. Medicinesight do also offer a service of providing cohorts of interest which may save researchers significant time, albeit with added cost.

There are issues in some cases with missing data, for example, pathology test results with no unit of measurement recorded (approximately 8% of tests in the data checked by the authors) and prescription records with no information on medicine strength (approximately 1% of prescriptions) and no Anatomic Therapeutic Class code (4% of records), issues which ultimately reflect the recording of information by general practitioners.

As the Medicinesight program staff continue to work with both general practices and researchers the data available and supporting documentation will continue to improve.

Linkage to other data sources

Linkage of Medicinesight data is currently in its infancy, both in terms of linking general practice data between practices and linking to other data collections. Identifying information such as name, date of birth and address is not collected by Medicinesight and data linkage can only be implemented using encoded versions of person-identifying information. These cryptographic hashes of the person-identifying information are performed within the practice so no identifying information leaves the practice [22]. Linkage is being explored using the GRHANITE key and Statistical Linkage Key (SLK) matching algorithms. Research is occurring in Victoria to link Medicinesight data with cancer registry data. The issue of patient identifiers that do not link between practices, meaning that patients who visit multiple providers will appear multiple times in the data, has been explored using algorithms by the University of Melbourne. Longitudinal research is possible for patients who receive their care through a single practice. Medicinesight are planning work to identify records across practices belonging to the same patient, which will facilitate improved longitudinal research.

Comparisons to other systems

The need for reliable linkage services in SA was first clearly articulated by the research community and Government of South Australia in 2002, through the 'Clients-in-Commons project'. This led to the linkage of records from several state government agencies, i.e. public hospitals, housing and community services, and the creation of an anonymised dataset of 1.5 million records for 410,000 clients allowing We present here brief comparisons to other relevant general practice data collections. We describe other Australian collections that we are aware of; and provide comparisons to the UK's Clinical Practice Research Datalink (CPRD) and Wales' Secure Anonymised Information Linkage (SAIL) databank, which represent 'gold standards' in general practice data collections. We also describe systems in Canada at a similar level of development to the approaches described above. Canadian examples provide useful points of comparison on account of the two countries similar federations, and similarities in access to both public hospitals and medical services [49, 50].

Australian examples

The Melbourne East Monash General Practice Database (MAGNET) presents another collection of general practice data to support research in Australia [51]. This database includes practices within a single region in Melbourne. Practices which agree to participate have their data encrypted and extracted to a data warehouse (without identifying information) where it can then be used for research. Data are fed back to practices for quality improvement, which is the primary purpose of the underlying infrastructure. The data include patient demographics, episodes of care, diagnoses, medications prescribed, observations, investigations ordered and received, immunisations and more, while some practice data is also included. This collection is much smaller than Medicinesight in terms of practice and patient numbers included. The MAGNET database includes a SLK which allows the same patient to be identified at different practices and hence duplication avoided and may also support linkage to external data collections. MAGNET has been used as the basis for research investigating service use [52], prescribing [53], cohort characterisation [54] and more.

More recently, the Data for Decisions project has been established through the University of Melbourne [55]. This program has been recruiting practices since only 2017 and is described as being in its start-up phase. De-identified data are transferred to a data repository using GRHANITE, and the program may facilitate linkage to different datasets. The data extracted appears comparable to other data collections; with initial projects assessing antimicrobial prescribing, chronic disease programs and disease detection [56]. Data is accessed following approval by an independent Data Governance Committee, and a practice opt-in, patient opt-out model has been adopted.

Australia's earliest collection of CIS data is the General Practice Research Network, administered by the Health Communication Network, publishers of Medical Director. This system extracts information on medications, conditions, history, imaging and pathology tests ordered, observations taken, basic patient demographics and risk factors [57]. This repository

is restricted to practices which use a single CIS (Medical Director) and operates on a GP opt-in, patient opt-out model. The dataset includes information for approximately 3 million unique patients of 1,100 GPs [58]. Since 1999 this network has supported publications examining prescribing and vaccination [59], though publications using this resource appear to be rare, particularly in the last decade.

International examples

Internationally, one of the most comprehensive sources of primary care data used for research is the Clinical Practice Research Datalink (CPRD) in the UK [60]. The CPRD has provided data and services to support research investigating pharmacovigilance and the use of medicines, informing of health policy and healthcare delivery and exploring disease risk factors for more than thirty years. The CPRD is a primary care database of de-identified medical records from general practices in the UK including over 11 million registered patients split across two datasets [61]. The CPRD has been designed to provide a representative population dataset and is linked to a number of other sources to provide a rich data resource. The CPRD includes information on encounters, immunisations, tests, therapies and patient socio-demographics. Data including diagnoses are recorded using version 2 Read codes. One of the major strengths of the CPRD is linkage to external data sources including hospitalisation, mortality and disease registries for a subset (over half) of practices [60]. Furthermore, the CPRD has a broad ethical approval for observational research using the primary care data and established linkages simplifying data access. Referrals to secondary care, and information fed back from secondary care are also included. Data quality is promoted through the Quality and Outcomes Framework in place in the UK which provides financial incentives for recording of important data items [62]. Similar financial incentives are currently being planned in Australia, which will reimburse practices for participating in quality improvement practices and sharing a minimum dataset demonstrating this with their local PHN [63], however the implementation of these incentives has been subject to delays and it is as yet unknown how data recording and quality may change as a result of the incentives [64].

The SAIL (Secure Anonymised Information Linkage) databank is based in Swansea University Medical School. SAIL works in partnership with researchers and health professionals, aiming to maximise the value of routinely collected individual level data through record linkage and to enable and support health related research [65]. Linked data from different sources is created by the NHS (National Health Service) Wales Informatics Service using the NHS number. The Welsh Demographic Service [66] provides personal information of all persons who have registered with a general practice or received care from health services in Wales [67, 68]. SAIL links a wide range of data including general practice, hospitalisation, national screening programmes, the national cancer registry and more [65]. The primary care dataset contains information on patient encounters with primary care; capturing the signs, symptoms, test results, diagnoses, prescribed treatment, specialist referrals and social aspects relating to the patient's home environment [69]. Similar to NPS MedicinesInsight, SAIL recruits general practices to voluntarily share data;

practices sign up to share data without the express consent of patients, though practices are provided with information to keep in waiting areas and patients may opt out of having their data reported to SAIL. As of November 2018, SAIL had recruited 334 general practices (76% of all Welsh practices) which relates to information for over 2.5 million patients. SAIL has now been used to support a range of research including follow-up of clinical trials [70], evaluation of medication use [71], epidemiological studies [72] and policy evaluations [73].

Currently the general practice data available for research in Australia is comparable to the CPRD and SAIL systems in some ways, including the breadth of data captured, the centralised data application and practice opt-in / patient opt-out consent model. The key point on which these UK systems are further developed than any system in Australia is the availability of linkage between general practice and other data sources, though this capability is developing with regards to the MedicinesInsight data collection and other collections within Australia.

There are also examples of developing primary care linkages in Canada. These include the Electronic Medical Record Administrative Data Linked Database (EMRALD) in Ontario, and the Canadian Primary Care Sentinel Surveillance Network (CPCSSN), which includes practices across most provinces. Like MedicinesInsight, these programs recruit general practices to voluntarily report data, based on their use of CISs. Each of these captures some information on patient encounters with physicians, medications prescribed, laboratory investigations and so on. The EMRALD database includes linkage to other health related administrative, survey, registry, demographic data and more through the comprehensive data holdings of the Institute for Clinical and Evaluative Sciences [74]. This provides a more complete picture of patient's care than is possible through the primary care data collections in Australia, although the system is confined to a single Canadian province [75]. The CPCSSN is larger than EMRALD in the number of practices and patients captured, with over 200 practice sites and 1.5 million patients as at May 2016 [76] though is smaller than the MedicinesInsight collection on these measures. Furthermore, the CPCSSN has recently begun to be used for research projects linking primary care data to other sources such as hospitalisation and census data [76, 77]. Case definitions are applied for a number of chronic conditions, similar to the MedicinesInsight collection, though in the case of the CPCSSN these are supported by the use of ICD-9 codes in Canadian CIS data. The scope of the data collected is otherwise similar. One problem common to both the CPCSSN and general practice data in Australia, is that when patients visit multiple providers they will exist in the database more than once and duplicated patients cannot be differentiated.

The road ahead

Despite the increased use of CISs in general practice, and extensive collections of administrative data, research covering the whole health system has been hampered by jurisdictional issues obstructing linkages [3, 21], and until relatively recently, the lack of any centralised collections of general practice data. Such collections are now becoming available, and technological advances are developing to help resolve challenges around

sharing of patient data for linkage to other sources. Even with technological solutions available, it remains important to build trust among general practitioners that any patient data shared remain confidential and that evidence generated is fed back to practices to support patient care and practice processes. Though evidence on the Australian public's views on data use is scarce, opinion polls suggest that a vast majority are supportive of health records being used for research [78]. Meanwhile most GPs are supportive of general practice research though there are barriers to involvement [79]. Data sharing models that maintain patient and provider privacy are therefore likely to be valued by all. These data sharing challenges were the focus of an Australian Productivity Commission inquiry (under the Productivity Commission Act 1998) into the benefits and costs of options for increasing the availability and use of public and private sector data by individuals and organisations. The resulting report prepared by the Productivity Commission [80] proposes a new legal and policy framework to allow public and private sector data to flow. The recommendations in the report provide good foundations to build future data sharing and data linkage models.

Conclusion

Within Australia there is extensive population-level administrative data captured on the use of health and other services. However, the delivery of services by different levels of government, and hence the holding of data by different levels of government, presents challenges to researchers aiming to perform whole of system research. Furthermore, administrative data covering primary care services are generally limited to basic information gathered for reimbursement purposes. Where research questions require the use of more detailed primary care data including patient diagnoses, the ordering of and results of pathology testing and measurement of observations, the prescribing of medications and so on, there are limited options available to researchers. We have described three avenues to access this data from general practices, though there are limitations to each of these methods. One limitation of the approaches described here is the limited ability to link the detailed clinical data from general practices to other sources of information such as hospital admissions and even other general practices although this capacity is emerging.

International examples demonstrate that comprehensive individual-level data capturing primary, secondary and tertiary care can be linked and made available to researchers, though these countries have universal unique identifiers for patients. We hope that the data available to Australian researchers can continue to improve, following these examples.

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Statement on Conflicts of Interest

Two of the authors, JB and SR, are currently working on a research project with NPS MedicineWise. RM sits on NPS

MedicineWise's General Practice Insights advisory group.

Ethics statement

As this is a commentary paper, ethical approval is not required.

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Abbreviations

AIHW	Australian Institute of Health and Welfare
BEACH	Bettering the Evaluation and Care of Health
CAT4	Clinical Audit Tool 4
cdmNet	Chronic Disease Management-Net
CHeReL	Centre for Health Record Linkage
CIS	Clinical Information System
CPCSSN	Canadian Primary Care Sentinel Surveillance Network
CPRD	Clinical Practice Research Datalink
DOCLE	Doctor Command Language
EMRALD	Electronic Medical Record Administrative Data Linked Database
GP	General Practitioner
GRHANITE	GeneRic HeAlth Network Information Technology for the Enterprise
ICD	International Classification of Diseases
ICPC	International Classification of Primary Care
LOINC	Logical Observation Identifiers Names and Codes
MAGNET	Melbourne East Monash General Practice Database
MBS	Medicare Benefits Schedule
NWIS	NHS Wales Informatics Service
NHS	National Health Services
NPS	National Prescribing Service
PBS	Pharmaceutical Benefits Scheme
POLAR	Population Level Analysis & Reporting
PHN	Primary Health Network
PHRN	Population Health Research Network
QOF	Quality and Outcomes Framework
SAIL	Secure Anonymised Information Linkage
SLK	Statistical Linkage Key
SNOMED	Systematized Nomenclature of Medicine
SQL	Structured Query Language



4.3 Chapter summary

This chapter has provided a summary of Australia's history as a leader in the development of data linkage infrastructure and the conduct of research using administrative data, and an overview of the current availability of general practice CIS data to support research. CIS data were discussed in terms of the types of information captured, the strengths of these data and potential challenges in their use, and potential methods to access CIS data for research. This chapter demonstrated that while CIS data are potentially a very useful resource for research, and the availability of these data to researchers in Australia is improving, there is still potential for improvement in access / availability, and in linkages between CIS data and other data sources. The clinical information in these data present a potentially valuable resource to develop a stronger understanding of the potential causal pathways underlying relationships with downstream health service use, and have the potential to add important evidence on the topic of continuity of care and health services research more broadly. General practice CIS data are utilised in later chapters to provide evidence of associations between regularity / continuity, processes of care and tertiary health service use outcomes.

Chapter 5 Measures of regularity

5.1 Chapter overview

As discussed in section 2.2.2.7.2, two measures of regularity have been published which can be applied using typical administrative data collections. These measures are referred to as the variance index and interval index. A limitation in the previous literature is that these measures have not been compared to each other so there is uncertainty over which should be utilised in studies of regularity and patient outcomes. Furthermore, each of these measures is likely to be associated with frequency of GP contacts (discussed in more detail in manuscript 2).

In manuscript 2 below, these two measures were compared to each other and an updated measure (called the relative variance index), designed to be independent of frequency of GP contacts. Using the WA population data 1990–2004, comparisons between the three measures of regularity were made in terms of their associations with frequency, and in their associations with hospitalisation outcomes. This work was conducted in a cohort at risk of diabetes-related hospitalisations. The manuscript demonstrates that the newly developed modified variance index was less correlated with frequency of GP contact than the two previously published measures, and that this has implications for the measurement of associations with hospitalisation outcomes.

This chapter also includes supplementary analyses not included with the published manuscript which provide further comparisons between the regularity measures. The first of these assessed the responsiveness of each measure to changes in the regularity of GP contacts. In this analysis simulated GP visit data were generated in which some irregularity was stochastically introduced (that is, multiple datasets were created in which the regularity of contacts was known to differ). The three regularity measures were then assessed in terms of how sensitive they were to changes in regularity. The analysis found that the previously developed variance index was most sensitive to changes, the previously published interval index the least sensitive, with the newly developed modified variance index in between. The second supplementary analysis, in Appendix B, consists of two sensitivity analyses that test the associations between the different regularity indices and frequency of contacts. These sensitivity analyses support the findings reported in the manuscript, that the previously published indices are associated with frequency of contacts while these associations are substantially smaller with the relative variance index.

This chapter addresses objective 2a: “assess two previously published measures of regularity in comparison to a newly developed measure.”

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5.1.1 Manuscript 2: Regularity of contact with GPs: Measurement Approaches to improve valid associations with hospitalization

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Research Methods

Regularity of contact with GPs: Measurement approaches to improve valid associations with hospitalization

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Abstract

Background. Studies examine longitudinal continuity of GP contact though few consider ‘regularity of GP contact’, i.e., the dispersion of contacts over time. Increased regularity may indicate planned ongoing care. Current measures of regularity may be correlated with the number of contacts and may not isolate the phenomenon of interest.

Objectives. To compare two published and one newly developed regularity index in terms of their ability to measure regularity of GP contacts independently of the number of contacts and the impact on their association with hospitalization.

Methods. A cohort at risk of diabetes-related hospitalization in Western Australia from 1990 to 2004 was identified using linked administrative data. For each regularity index, relationships with number of GP contacts were assessed. Hospitalization was then regressed on each index with and without number of contacts as a covariate.

Results. Among 153,414 patients the new regularity index showed a reduced association with number of contacts compared with existing indices. Associations with hospitalization differed between measures; for previously published indices, there were no significant associations between regularity and hospitalization, whereas on the new index, most regular GP contact was associated with reduced hospitalization (IRR = 0.90, 95% CI = 0.88–0.93). When number of contacts was added as a covariate, point estimates for this index showed little change, whereas for existing measures this addition changed point estimates.

Conclusion. A new measure of regularity of GP contact was less correlated with the number of contacts than previously published measures and better suited to estimating unconfounded relationships of regularity with hospitalization.

Key words: Continuity of patient care, diabetes mellitus, general practice, health policy, health services research, research design.

Introduction

Continuity of care has been the focus of much research in expectation that it may improve patient satisfaction and health outcomes (1–3),

and reviews have identified dozens of measures of continuity (4,5). Most of these measures aim simply to summarize whether patients consistently receive care through the same provider(s), contrasting

KEY MESSAGES

- Regularity of GP contact is the visit pattern over time
- A pattern of regular contacts may indicate planned ongoing care
- Papers on this topic have measured regularity of GP contacts differently
- These measures are correlated with the frequency (number) of visits to the GP
- This correlation can confound the association of regularity and hospital use
- A newly developed regularity index provided unconfounded associations

with the breadth of definitions of continuity of care (4,6). Most measures of continuity do not consider temporal aspects, meaning that a patient seeing a single doctor sporadically would have a similarly high continuity level to someone seeing a single doctor regularly. This paper examines the dispersion of visits to providers over time, referred to as ‘regularity.’

A related concept is the number of times a patient visits the GP within a specified period, referred to as ‘frequency’ of contacts. While regular (rather than sporadic) GP contacts may indicate proactive or planned care for disease management, more frequent contacts might simply indicate poorer health or recent exacerbation of condition. From a policy perspective the difference is important. While policies could promote the regular management of chronic disease in primary care, a policy which increased the frequency of GP contacts might be undesirable due to increased costs incurred. Therefore, the ability to measure regularity and frequency separately is an important consideration. Figure 1A displays the difference between regularity and frequency of contacts.

One Australian study has assessed the impact of regular GP contacts on hospitalization and mortality in cohorts with chronic conditions (7,8), while American research assessed the impact of regular primary care on early breast cancer detection (9). The Australian researchers hypothesized that regular GP visits would allow early recognition of changes in condition and treatment adjustment, whereas the American research hypothesized that regular contacts would facilitate earlier cancer detection. These studies measured regularity of contact differently. The American research defined an ordinal variable with contacts over a 2-year period as none, any, annual, or semi-annual (at least one visit in each half of both years). The Australian researchers measured regularity by counting the number of days between consecutive GP visits and using the variance in this number of days to calculate a regularity score (see Table 1).

These measures may be associated with the frequency (number) of primary care contacts. For the ordinal score, this is because someone can only have, for example, semi-annual contacts if they have at least two contacts per year; hence, people in the higher regularity levels will generally have more GP contacts. The previously

used Australian score is based on the variance in the number of days between consecutive GP visits. Someone with few GP contacts will have a high mean number of days between them, and because variance is an absolute measure of variation (10), a high mean number of days between visits will generally result in higher variance in the number of days between visits. Therefore, the count of GP contacts (frequency) may be correlated with regularity. This could be problematic if attempting to understand relationships between regularity and health outcomes. For example, people in poorer health may see the GP more frequently and may be more likely to be hospitalized; hence, associations between regularity and hospital use may be confounded by frequency. This confounding is displayed in Figure 1B. In previous Australian research, frequency was included in models as a covariate to account for this. In the American study, this would unlikely be an issue, given the outcome of early breast cancer detection was asymptomatic by definition; however, confounding by frequency would make it impossible to isolate impacts of regularity and frequency, unless these are accounted for separately in the modelling process.

Objectives

This paper assesses two previously used approaches for measuring GP regularity and one newly developed index in terms of their associations with frequency of GP contacts and the potential for any such associations to confound the measurement of relationships with hospitalization.

Methods

Administrative data

Data included all adults aged 18+, enrolled with Medicare [Australia’s universal public insurance scheme, covering all citizens and permanent residents except prisoners (11)] and resident in Western Australia (WA) any time between 1 July 1990 and 30 June 2004. Person-level linked data included: WA mortality records (1980–2004); WA

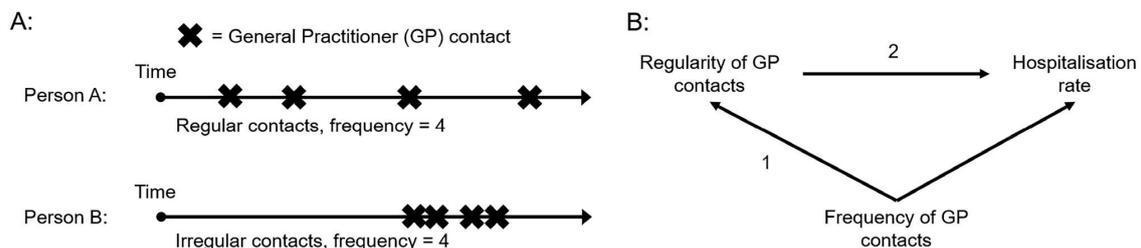
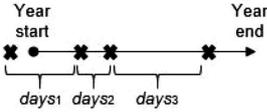
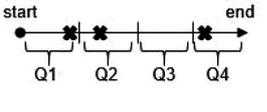
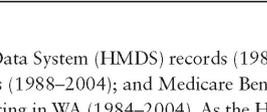


Figure 1. (A) Patterns of GP contacts over time for two fictional people. Person A has regular GP contacts over time and Person B irregular contacts, despite having the same frequency of GP visits. Part (B) displays the hypothesized relationships between regularity of GP contacts, frequency of GP contacts and hospitalization. Associations between regularity of GP contacts and hospitalization may be confounded by frequency of GP contacts.

Table 1. Details on the three indices used to measure regularity of GP contact

Index	Method	Notes
Variance index	<p>✱ Indicates date of GP contact</p> 	$r = \frac{1}{1 + var(days)}$ <p>At least two GP contacts per year required to calculate. Produces a score from 0 to 1 with 1 indicating perfect regularity. Analysed in quartiles with 1 = least regular 4 = most regular (7,8,15).</p>
Relative variance index		$r = 1 / \left(1 + \frac{sd(days)}{mean(days)} * 100 \right)$ <p>Differs from the variance index in that the coefficient of variation in the days between GP contacts is used rather than the variance. At least two GP contacts per year required to calculate. Analysed in quartiles.</p>
Interval index		<p>1 = Annual contact; 2 = Bi-annual contact; 3 = Quarterly contact; 4 = Bi-monthly contact. Diagram represents bi-annual contact as contacts occur in the first and second half of the year, but the next level (quarterly contacts) has an interval without contact.</p>

Hospital Morbidity Data System (HMDS) records (1980–2004); WA Electoral Roll records (1988–2004); and Medicare Benefits Schedule (MBS) claims originating in WA (1984–2004). As the HMDS records all separations from public and private hospitals (12) and the MBS records all Medicare-funded services, which includes all GP services, all relevant service contacts are captured. The electoral roll captures address changes which informed time within the study area (13). WA data were provided and linked via the WA Data Linkage System (WADLS) and MBS data by the Commonwealth Department of Health and Ageing. The WADLS has error rates of 0.11% for both false-positive and -negative linkages (14).

Cohort at risk of diabetes hospitalization

A cohort at risk of diabetes hospitalization was identified as described previously (13). Individuals were classified into one of two mutually exclusive risk groups annually: confirmed diabetes or likely to have diabetes. Confirmed diabetes was identified by any of the following: (i) diagnosis in hospital, (ii) diabetes cycle of care consultation in MBS data or (iii) quantitation of HbA1c in MBS data twice within 6 months. Likely diabetes was identified by (i) diagnosis of impaired glucose function in hospital, (ii) an oral glucose tolerance test outside of pregnancy in MBS data, or (iii) HbA1c quantitation once within 6 months. Codes are detailed in Supplementary Table 1.

Individuals exited a risk group upon moving from WA, death, study end, or for 'likely' diabetes patients, moving into the confirmed group. Individuals were included if they had two or more GP visits in a year, the minimum required to calculate the variance and relative variance indices.

GP contact

Three regularity indices were calculated as four-level ordinal variables, detailed in Table 1.

The 'variance index' was based on the variance in the number of days between consecutive GP visits (7,8,15). The newly developed 'relative variance index' was similar, using the coefficient of variation (CoV) in the number of days between consecutive GP visits rather

than the variance. The CoV describes variation as a percentage of a variable's mean so does not systematically differ with changes in mean (10) (hence should not differ between those with a high mean number of days between GP contacts compared with those with a low number of days). As the mean number of days between GP contacts depends on the number of visits a person has, this aims to measure regularity independently of the frequency of GP contact. The 'interval index' was based on a previously reported index (9), with annual regularity of GP contact defined as 'any', 'biannual', 'quarterly' and 'bi-monthly'. Indices were measured annually for each cohort member. Frequency was defined as the annual count of GP visits. Since all measures were annual, there were repeated observations for each cohort member.

Hospitalization outcomes

Outcomes were diabetes-related hospitalizations, including potentially preventable hospitalizations (16) and other hospitalizations where diabetes increases risk (17). Codes are listed in Supplementary Table 1. A hospitalization which resulted in an individual joining the study cohort could not contribute to outcomes; outcomes were measured after an individual had entered the cohort at risk and GP contact had been ascertained for at least 1 year.

Covariates

The administrative data listed sex, age and Indigenous status. Socioeconomic status and residential remoteness were obtained from national indices based on postcodes (18,19). Comorbid status was determined using the Multipurpose Australian Comorbidity Scoring System (MACSS). The MACSS was developed among medical, procedural and psychiatric patients in WA using administrative hospitalization records and compared with the Charlson index resulted in improved correction of mortality and hospitalization outcomes (20). Comorbidity was recorded as the count of MACSS conditions in each patient's hospitalization records in the preceding 5 years (21), updated annually. Diabetes risk level was a covariate in models. Further details are provided in Supplementary Table 2.

Descriptive statistics

Analyses were performed using Stata SE version 14.2 (22).

Sex, age, Indigenous status, socioeconomic status, remoteness, diabetes risk level, annual hospital use and primary care contacts were summarized. Crosstabs were used to indicate correlations between the regularity indices.

Associations between regularity and frequency

For each index, frequency was regressed on regularity of GP contact (path 1 in Figure 1B). Models included the variables listed under the heading 'covariates'. The coefficients of the regularity levels were compared to understand how associations between regularity and frequency differed between indices.

This comparison of coefficients is impacted by group sizes at each level of regularity differing between indices; hence, the groups being compared are not completely equivalent. As a sensitivity analysis, the Bayes Information Criterion (BIC) values of these three models were compared with a model with no regularity index where frequency was regressed on the set of covariates. Where inclusion of an index caused BIC to reduce compared with the model with no regularity index, this indicated that it added information to the estimation of frequency, i.e. the index was associated with frequency.

Assessment of confounding

The potential for frequency to confound associations between regularity and hospitalization was assessed by regressing the number of diabetes-related hospitalizations on each regularity index.

Diabetes-related hospitalization was regressed on regularity of GP contact in the previous year. Six models were estimated, for all

three regularity indices with and without frequency included as a covariate. Where associations between regularity and hospital use (path 2 in Fig. 1B) differed for models with and without frequency, this indicated that that frequency was confounding associations between regularity and hospital use for that index.

An alpha level of 0.05 was considered significant. As the outcomes in each regression analysis were count outcomes (frequency of GP contacts or count of diabetes-related hospitalizations), negative binomial regression models were used. As there were multiple records (years) per person, random-effects models were used.

Results

Cohort characteristics

Of 2,129,552 Medicare enrollees, 88.1% had no diabetes hospitalization risk, 1.8% had no electoral records, 2.7% had no full years alive and within the study area and 0.3% had no years with two or more GP contacts. The 153,414 remaining individuals contributed on average 4.5 (SD 3.1) years to the study each; Table 2 presents characteristics of the 685,623 records in the dataset. Most individuals lived in highly accessible areas (86.8%) and were non-Indigenous (96.4%), half were female (51.8%) and approximately half were in the 'Confirmed diabetes' group (47.1%). People spent on average 1.2 (SD 10.7) days in hospital and visited the GP 10 times annually.

Table 3 presents relationships between the relative variance index and the two published measures. On the variance index, half (50.5%) of those people in the least regular quartile and 45.1% of those in the most regular quartile were in the equivalent quartiles according to the relative variance index. Similarly, on the interval

Table 2. Characteristics of the cohort at risk of diabetes-related hospitalization identified via administrative data in Western Australia from 1990 to 2004

Variable		All records <i>n</i> (%) ^a
Sex	Female	354,797 (51.75)
	Male	330,826 (48.25)
SEIFA quintile ^b	Highest disadvantage	129,224 (18.98)
	High disadvantage	182,935 (26.88)
	Moderate disadvantage	98,595 (14.48)
	Less disadvantage	107,027 (15.72)
	Least disadvantage	162,891 (23.93)
ARIA category ^b	Very remote	14,910 (2.19)
	Remote	10,854 (1.59)
	Moderately accessible	30,502 (4.48)
	Accessible	33,933 (4.98)
	Highly accessible	590,575 (86.75)
Indigenous status ^b	Indigenous	23,633 (3.64)
	Non-Indigenous	625,447 (96.36)
Risk status	Confirmed diabetes	322,705 (47.07)
	Likely diabetes	362,918 (52.93)
	Mean (SD) ^c	
	Age	59.09 (14.29)
	Frequency	10.36 (9.19)
	Diabetes-related hospital separations in year	0.31 (4.78)
	Comorbid condition count	1.18 (2.47)
	Bed days associated with diabetes-related separations in year	1.19 (10.74)
Total		685,623

^aNumber and percentage of all person-years in category.

^bMissing data accounting for 0.7% of records for socioeconomic index for areas, 1.1% for accessibility/remoteness index of Australia and 7.2% for Indigenous status excluded from table and from denominators of percentages.

^cMean and SD values for all person-years.

index, 62.9% of those in the least regular (annual) group and 35.2% of those in the most regular (monthly) group were in the least and most regular quartiles on the relative variance index, respectively.

Associations between regularity and frequency of GP contact

Frequency was regressed separately on each regularity index to understand associations between regularity and frequency. For all

indices, this showed significant associations between regularity and frequency and these followed a dose-response type pattern, i.e. each increase in regularity was associated with a greater change in frequency (Fig. 2A–C). For the variance index and the interval index, these associations were positive (Fig. 2A and C, respectively), i.e. frequency increased with greater regularity, whereas the relative variance index showed the reverse. Coefficients were smallest for the relative variance score indicating the weakest association between

Table 3. Crosstabulations of values on the relative variance index with the (A) variance index and (B) interval index, relating to 685,623 person-years.

Relative variance index	A: Crosstab of relative variance index and variance index				Total
	Variance index				
	Least regular	2	3	Most regular	
Least regular	50.47	26.59	16.23	6.71	100.00
2	25.17	29.16	27.63	18.04	100.00
3	16.27	24.43	29.12	30.17	100.00
Most regular	8.09	19.81	27.02	45.08	100.00
Total	25.00	25.00	25.00	25.00	100.00

Interval index	B: Crosstab of relative variance index and interval index				Total
	Variance index				
	Least regular	2	3	Most regular	
Least regular	62.85	31.19	19.51	8.55	100.00
2	15.69	26.28	29.32	22.35	100.00
3	9.31	20.33	28.23	33.91	100.00
Most regular	12.15	22.20	22.94	35.19	100.00
Total	9.20	38.43	25.15	27.23	100.00

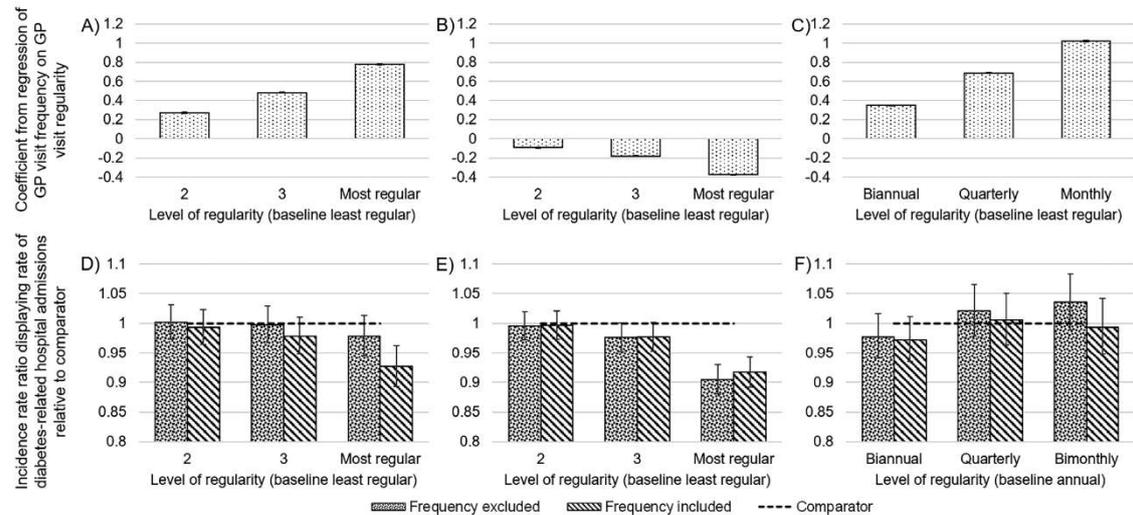


Figure 2. Outputs of regression models displaying relationships between regularity of GP contact, frequency of GP contact and diabetes-related hospitalization for three regularity indices. Parts (A to C) display regressions of frequency on the variance index, relative variance index and interval index, respectively, with the least regular group as the baseline in each case. Parts (D to F) display associations between regularity and diabetes-related hospitalization for the same three indices, respectively, for models with and without frequency included as a covariate. All analyses were negative binomial regression models among a cohort of 153,414 Western Australian adults at risk of diabetes-related hospitalization from 1990 to 2004. Covariates in all models include age (continuous), gender, Indigenous status (Indigenous/non-Indigenous or unknown), socioeconomic status (quintiles based on the socioeconomic status for areas – index of relative social disadvantage), accessibility (based on the accessibility/remoteness index of Australia), count of specialist contacts, count of comorbid conditions in previous 5 years, and group (within person) means of age, count of specialist contacts and 5-year comorbid condition count.

regularity and frequency (Fig. 2B). Coefficients at each level were less than half the absolute value of the other indices (e.g. coefficient for most regular group of -0.374 compared with 0.776 and 1.020 for the variance and interval indices, respectively).

Results of sensitivity analysis showed that adding any regularity index caused BIC to reduce compared with a model with no regularity score, i.e. each was associated with frequency. However, this association was much weaker for the relative variance index than previously published indices (data not shown), supporting these findings.

The effect of frequency on associations between regularity and hospital use

Relationships between regularity of GP contact and hospital use differed between indices, as displayed in Figure 2D–F). When using the variance index (Fig. 2D) being in the most regular group was associated with a small, non-significant reduction in the hospitalization rate in the following year compared with the least regular group. When frequency was included as a covariate, this relationship changed; the IRR for the most regular group became significant (IRR 0.93 , CI 0.89 – 0.96) though the middle two categories remained non-significant. The relative variance index (Fig. 2E) being in the most regular group was associated with a significant reduction in hospitalization compared with baseline (IRR 0.90 , CI 0.88 – 0.93), though the second and third levels were not; furthermore, this relationship showed very minor changes when frequency was a covariate. When the interval index was used (Fig. 2F), there were no significant differences observed between any level of regularity and hospitalization. Following the addition of frequency as a covariate, there were small, non-significant changes in IRRs [change in IRR for ‘annual’ group from 1.04 (CI 0.99 – 1.08) to 0.99 (CI 0.9 – 1.04)].

Discussion

The relative variance index used the coefficient of variation in place of the variance in the number of days between GP visits, which should theoretically produce regularity values independent of the frequency (number) of visits. For this index, associations between regularity and frequency reduced substantially, though did not disappear completely. Given the cohort size, even weak associations are likely to be statistically significant.

Differences between indices matter if they influence associations with outcomes. Relationships between regularity and hospitalization rate were assessed, as hospitalization is important to patients and funders and analysed often (23–25). For the relative variance index, most regular GP contact was associated with reduced hospitalization in the following year compared with least regular contact. The inclusion of frequency made little difference to this relationship, suggesting it was not a confounder. When the variance index was used most regular GP contact was associated with reduced hospitalization, though this was only significant when frequency was included as a covariate. When frequency was included in this model rate ratios were similar to those for the relative variance index, suggesting that including frequency as a covariate, as in previous work (7,8) resulted in unconfounded estimates of associations with hospitalization. For the interval index, associations were not significant in any case, though including frequency caused these to change similarly to the variance index, consistent with the positive associations between regularity and frequency observed for these indices.

The ability to distinctly measure different markers of primary care contact may matter in understanding drivers of health or hospitalization outcomes. Where policy impacts need to be understood, the ability to measure regularity and frequency independently could be important as the resource and cost implications of changes in each differ.

For researchers interested in measuring regularity, there are additional considerations. The interval score provides categories with more direct meanings than the variance or relative variance index which may aid interpretation. However, such a score provides only an ordinal indicator (rather than continuous) which might prevent certain analyses being used. An interval score could be calculated using data where dates have been perturbed or aggregated to protect confidentiality (26), whereas the others require accurate GP contact dates.

This analysis is not intended to critique previous works assessing regular GP contacts, some of which derive from our research group; the methods reported previously have been changed substantially here to contrive comparisons between approaches. This work simply represents the first attempt at comparing possible measures of this concept.

Strengths and limitations

For comparisons between scores, the only difference was the index included; each was a four-level ordinal variable; hence, comparisons are internally valid. The variety of data available meant that statistical features of the indices could be assessed and applied to an important outcome.

A limitation of this observational work is that unobserved factors may influence outcomes and hence causation cannot be considered. However, such factors would likely have similar effects for each index; hence, comparisons between scores remain informative.

The observation period for this study ended in 2004. Diabetes prevalence has increased since (27) and use of health services may have also changed. Associations reported here between regularity of GP contact and hospitalization should be interpreted with this in mind, though understanding these associations was not the main aim of the study and in methodological work comparing indices age of the data is less of a concern. When comparing the ability of the indices to estimate relationships with hospitalization, the major assumption was that sicker people are more likely to visit the GP and to be hospitalized. We believe that this assumption is valid regardless of the time frame considered; furthermore, the statistical issues at the centre of the paper will hold regardless of the time period.

Finally, these analyses are limited to a single cohort and we cannot state how findings might translate to different populations or outcomes.

Conclusion

This work demonstrates that when measuring regularity of GP contacts, the choice of index used can impact on findings. In future work, we intend to further validate the relative variance index described here in place of the existing variance index and would recommend that other researchers interested in this concept do the same unless they consider an interval index easier to calculate or interpret. Much research has examined the impact of provider continuity, researchers examining continuity of care should consider measuring regularity as an additional component of continuity of care.

Supplementary material

Supplementary material is available at *Family Practice* online.

Declaration

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5.1.2 Manuscript supplement (published)

Supplementary table S1: Diagnosis codes flagged in hospitalisation data for identification of the cohort at risk of diabetes-related hospitalisation, and to flag diabetes-related hospitalisation outcomes. Outcomes include potentially preventable hospitalisations as defined by the National Health Performance Authority (231) and hospitalisations where diabetes is known to increase risk are those reported by Davis *et al* (232).

Part A: Cohort identification		
Diagnosis	ICD-9-CM codes	ICD-10-AM codes
Diabetes	250	E10-E14
Impaired glucose function	790.2	E09, R73, O24.5
Part B: Outcome identification		
Diagnosis	ICD-9-CM codes	ICD-10-AM codes
Diabetes Complications	250.1-250.9	E10.0-E10.9, E11.0-E11.9, E13.0-E13.9, E14.0-E14.9
Circulatory disorders	401-405, 410-414, 430-438, 362.64, 784.3, 428, 429.2-429.3, 429.9, 440, 443, 459.8-459.9, 444, 447.1	I10-I13, I15, I20-I22, I24, I25, I60-I67, I69, G45, H34.0, R47.0, I50.0-I50.1, I50.9, I51.6-I51.7, I51.9, I70, I73, I87.2, I99, I74, I77.1
Visual disorders	365, 366, 369	H40, H42.8, H25-H26, H28.0, H54
Nephropathy	580-583, V45.1, V56	N00, N01, N03-N05, N07, N08, N16-N19, Z49, Z99.2
Other renal complications	590, 595, 599.0, 791.0, 354, 355, 356.8, 729.2, 707, 785.4, 84.1, 84.3	N10, N11.8-N11.9, N12, N15.1, N15.9, N28.8, N30, N39.0, R80, G56-G57, G58.7, G60.8, M79.2, M54.10, M54.11, M54.19, L89, L97, L98.4, R02; procedure codes 44338-00, 44358-00, 44361-00, -01, 44364-00, -01, 44367-00, -01, -02, 44376-00
Other complications	112.1, 730.17, 681, 682	B37.3+N77.1, M86.37, M86.47, M86.57, M86.67, M86.87, L03

Supplementary table S2: Sources and details of covariate information

Covariate	Source	Format and notes
Age	Electoral Roll	Continuous, updates annually
Sex	Electoral Roll	Binary, static
Indigenous status	HMDS	Binary, static. Coded 1 if person ever flagged as indigenous, 0 otherwise. Unknown for people with no hospitalisation data, coded 0 in these cases.
Socio-economic status (SEIFA-IRSD)	Electoral Roll	Derived based on postcode recorded on Electoral Roll. Socio-economic status grouped into quintiles based on the Socio-Economic Index For Areas – Index of Relative Social Disadvantage (SEIFA-IRSD). Updates with changes in postcode. Unknown in 0.5% of cases (coded as “missing” to allow inclusion in models)
Remoteness (ARIA)	Electoral Roll	Derived based on postcode recorded on Electoral Roll. Categories of Highly Accessible, Accessible, Moderately Accessible, Remote and Very Remote based on Accessibility and Remoteness Index of Australia (ARIA). Updates with changes in postcode. Unknown in 0.5% of cases (coded as “missing” to allow inclusion in models).
Comorbidity	HMDS	Applied based on the Multipurpose Australian Comorbidity Scoring System (MACSS) (233) and characterised as the count of MACSS conditions, excluding ‘endocrine, metabolic or

Covariate	Source	Format and notes
		immune disease', on any HMDS diagnosis field in the 5 years prior to each study year.
Count of specialist contacts	MBS	Updates annually
Risk status	MBS and HMDS	As described under "Cohort at risk of diabetes hospitalisation"
Mean of regularity level	MBS	Group-means of time-varying variables were included to relax the assumption in the random-effects estimator that observed variables were uncorrelated with unobserved variables (164)
Mean of age	MBS	As above
Mean of frequency	MBS	As above
Mean of count of specialist physician contacts	MBS	As above
Mean of count of comorbid conditions	HMDS	As above

5.1.3 Manuscript supplements (unpublished)

Several additional analyses were performed which are not included in the manuscript. These were omitted from the manuscript on account of space constraints and their technical nature, as the journal has a clinical focus. These include two sensitivity analyses of the associations between the each of the regularity measures and frequency, and these are presented in Appendix B. The third is an assessment of the three measures in terms of their responsiveness to induced changes in regularity of GP contact, which is detailed here.

5.1.3.1 Introduction

Manuscript 2 focused on how different measures of regularity of GP contact may be correlated with frequency of contacts, and how as a result, measures of the impact of regular GP contacts on hospital use or other health outcomes may be confounded. A second consideration, not included in the manuscript, is how well each of these measures responds to changes in regularity. A measure which is not responsive to changes in regularity and hence does not discriminate between patients with different GP contact patterns would have limited use.

This analysis uses simulated GP visit data to assess the responsiveness of the different measures of regularity to changes in contact patterns. Simulated data are used because (1) there is no 'gold standard' measure against which to compare the three measures assessed using real data, and (2) the use of simulated data allows for visit data to be deliberately manipulated to reflect regular / irregular contacts. This means that the expected responses of the regularity measures (i.e. they are expected to return higher / lower values when applied to regular / irregular data, respectively) can be compared to observed responses. For some measures of continuity straightforward interpretations of values are possible. For example, a UPC index of 0.75 indicates that a patient has 75% of their contacts with their usual provider. For the variance and modified variance indexes described in Manuscript 2, a specific value (for example 0.1) cannot be interpreted as simply, though can be compared against other values (e.g. another patient with a regularity value of 0.5) to rank patients as having more or less regular care in analysis. Assessing the responsiveness of these measures to changes in regularity introduced into simulated data can support this interpretation of these measures.

5.1.3.2 Methods

Development of simulated data

A dataset was generated with 5000 rows, each representing one year of service data (general practitioner visits) for one person. Each record was given a randomly generated number of GP visits (n) following an exponential distribution with a mean of 10.4 (rounded to the nearest integer), derived from the mean and distribution of annual GP visit frequencies among the cohort at risk of diabetes-related hospitalisation described in manuscript 2. The dataset was expanded to form a panel where people had multiple records, each representing one visit. Visit dates were generated as perfectly regular in the first instance, that is, they were applied to dates spread equally through the year with $365/n$ days between visits (rounded to the nearest integer). Irregularity was then introduced by dropping randomly selected visits (selected using the `–runiform–` command in Stata) and by adjusting the dates of remaining visits following a random normal distribution (using the `–rnormal–` command in Stata). This alteration was performed twice to produce sets of visit dates reflecting high regularity (5% of visits dropped, normal distribution with a mean of 0 and standard deviation of 3) and low regularity (20% dropped, normal distribution with a mean of 0 and standard deviation of 14). As one year of service data was required for each simulated person in the dataset, visit dates which ended up in the previous / following year following adjustment were dropped.

Analysis

The responsiveness of each index to changes in regularity was assessed using the simulated data. Each simulated person present in the simulated data had two values derived using each regularity index, calculated based on the high and low regularity data. For each index the percentage of people allocated to the same regularity level in both the high and low regularity data was calculated. Though each index had four levels of regularity, the numbers of people at each level differed between indices and as such the expected (random) agreement between the high and low regularity data differed between indices. Kappa statistics were therefore generated for each measure to indicate agreement on regularity levels between the high and low regularity data. A high Kappa score for any of the regularity indices would indicate that people did not generally change regularity groups when the pattern of GP visits changed, suggesting the measure was less responsive, and vice versa.

5.1.3.3 Results

Table 5-1 displays, for each index, the percentage of people who were allocated to the same level of regularity according to the high and low regularity data. According to both the crude comparison and the Kappa scores, the variance index showed the lowest agreement and the interval index the highest. That is, the variance index was most responsive to changes in visit patterns, while the interval index showed the least responsiveness to changes.

Table 5-1: Agreement between regularity levels derived from simulated high and low regularity data, according to three regularity indices

Comparison	Regularity index		
	Variance index	Relative variance index	Interval index
Percentage of records with same regularity level	34.87	45.20	59.45
Kappa value	0.14	0.28	0.39

5.1.3.4 Summary

Results indicated that the existing variance index was more responsive to changes in regularity than either the interval index or the relative variance index. It is important to note that the adjustments made to the simulated data to produce high and low regularity variables were somewhat arbitrary and these results may differ in data drawn from different populations; and in populations with very high or very low rates of GP contact the responsiveness of the interval index in particular may change. For example, in a population where most people have only a small number of GP visits, the bimonthly group may capture very few people and the index may not discriminate well (unless of course different intervals were defined). The variance and relative variance indices however, being continuous, can be used to rank or group people into quintiles or other ordinal groupings regardless of the underlying distribution of regularity values.

5.2 Chapter summary

The major contribution of this work to the literature on continuity of care is in aiding future researchers who wish to assess regularity, alongside the more commonly used continuity measures. In addition to substantially contributing to the literature by introducing an updated measure which is well suited to estimating patient health outcomes, this work will help other researchers in deciding which regularity measure would be most useful for their own work. This analysis highlights a potential trade-off between the straightforward interpretation of the interval index and the reduced chance of bias when using the relative variance index. For the remainder of this thesis, the relative variance index is used predominantly. Researchers who wish to measure regularity in their work would generally be able to do so when administrative data are used, as visit dates are typically available in such collections.

There are also some policy implications to this work. The analysis in manuscript 2 suggested a negative association between regularity and diabetes-related hospitalisation, among a cohort with and at risk of diabetes. This association suggested an approximately 10% reduction in diabetes-related hospitalisation among the most regular quartile compared to the least regular. Note that later chapters in this thesis will further explore the sensitivity of such estimates to study designs and analyses used, in particular Chapter 7.

A note on terminology is required. Within manuscript 2 and through this chapter, the terms ‘variance index’ and ‘relative variance index’ were used. These titles made sense within the context of this manuscript which focused on how the different indices were calculated, as these names reflect the calculations used. In later work it was felt that names should reflect what the indices were measuring, rather than how they were calculated. The relative variance index is therefore referred to as the modified regularity index through the remainder of the thesis.

There are certain limitations to the analyses in this chapter. Firstly, in these analyses the measures of regularity could not be compared to common measures of continuity, as the data did not include a provider identifier. Comparisons to continuity measures are made in Chapter 9. As discussed previously, the lack of any gold standard measure of regularity means that the indices could only be assessed in comparison to one another. No truly objective measure of the quality of these indices could be produced. The study period ended in 2004. This mainly has implications for the reported associations between regularity and hospitalisation outcomes, as health system changes have occurred in the time since this work was performed which are likely to impact these associations. The comparisons between the indices, which is the major contribution of the chapter, are less likely to be adversely impacted by the age of the data.

Chapter 6 Associations between regularity of GP contact and hospitalisation in Western Australia 1990–2004

6.1 Chapter overview

This chapter consists of manuscript 3, published in *Health Services Management Research*, assessing changes in regularity and changes in the associations between regularity and hospital use during a period of substantial policy change.

This manuscript uses the WA Whole Population data 1990–2004 to investigate changes in regularity through a period of policy change in Australia amongst people with diabetes. As described in manuscript 3 and section 2.1.2.3, the Enhanced Primary Care program was introduced in Australia in 1999, with the intention of encouraging the management of chronic conditions in primary care. In this manuscript, changes in the regularity of GP contact are investigated prior to and following the introduction of the EPC program. Following this, the associations between regularity and diabetes-related hospitalisation are investigated, pre and post EPC. The analysis finds that leading up to the introduction of EPC there were slight reductions in regularity of GP contact, though this trend stopped following the program's introduction. Regularity was found to be associated with reductions in the rate and cost of diabetes-related hospitalisation, both prior to and following the introduction of EPC, and there was little evidence of change in these associations following the introduction of the program.

This chapter addresses objective 3a: “determine impacts of historical changes to primary care policy on regularity and the associations between regularity and outcomes in patients with diabetes.”

The full citation for this manuscript is:

Youens, D., Preen, D.B., Harris, M., Wright, C., Moorin, R., (2021). Regularity of contact with general practitioners and diabetes-related hospitalisation through a period of policy change: A retrospective cohort study. *Health Services Management Research*, online ahead of print. DOI: 10.1177/09514848211020866.

6.2 Manuscript 3: Regularity of contact with general practitioners and diabetes-related hospitalisation through a period of policy change: a retrospective cohort study

Primary Research

Regularity of contact with general practitioners and diabetes-related hospitalisation through a period of policy change: A retrospective cohort study

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Abstract

Background: This study evaluated changes in regularity of general practitioner (GP) contact (the pattern of visits over time) and the impact of regularity on diabetes-related hospitalisation following introduction of care co-ordination incentives.

Methods: Linked primary care, hospital and death records covered West Australian adults from 1991–2004. Different eras were evaluated based on incentive program changes and model fit, to assess changes in regularity. Changes in regularity, derived from the variance in the number of days between GP contacts, were evaluated using ordered logistic regression. The impact of regularity on hospitalisation rates and costs were evaluated.

Results: Two eras prior to program introduction (1991/92–1994/9 and 1995/96–1998/99), and one after (1999/2000–2002/03) were assessed. Among 153,455 at risk of diabetes-related hospitalisation GP contact became slightly less regular in the second era, though there was no change from the second to third era. The most regular decile had 5.5% fewer hospitalisations (95% CI -0.9% to -9.9%) and lower per-patient costs (difference AU\$115, CI -\$63 to -\$167) than the least regular. Associations were similar in each era.

Conclusions: Ongoing relationships between GPs and patients are important to maintaining health. Historical data provide the opportunity to assess the impact of care co-ordination incentives on relationships.

Keywords

general practice, hospital utilisation, incentives

Summary of findings and implications for managers

This analysis of historical data provides a unique opportunity to examine the impact of financial incentives designed to improve the general practice management of complex patients with chronic disease. Findings suggest that through the study period regular GP contact was associated with reductions in diabetes-related hospitalisation. Neither these associations nor GP regularity changed substantially over time nor following the introduction of the program, possibly due to a low initial program uptake. For service managers, this highlights the value of maintaining ongoing relationships with patients, using a different metric to the more commonly used continuity of care measures.

Background

Australian health expenditure over the last 15–20 years has been growing at 5% annually¹ and as a consequence Australia, like developed countries elsewhere, faces challenges in the funding and delivery of health care. One

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response to these challenges has been to shift service delivery from the acute to the primary health sector.

The Australian health system

In Australia universal health insurance is provided by the Federal Government via Medicare, covering all Australian citizens and permanent residents. General Practitioners (GPs) operate in private practices and are reimbursed for all services rendered on a fee-for-service basis via Medicare, though are free to charge patients additional co-payments.² GPs have a gatekeeper role with specialist care only accessible via GP referral, and referral to allied health and hospital also common. Patients are free to visit the GP of their choice and can change providers at any time.² Medicare also guarantees access to public hospitals and emergency departments (which are managed and partly funded by State governments²) free of charge, and many people additionally hold health insurance providing access to private hospitals. Hospitals are accessed via referral from a GP or specialist, or following presentation at an emergency department. Western Australia covers approximately 1/3rd of the Australian continent with a population of 1.88 million at the time of the study.³ 80% of this population live in Perth with the majority of the State being sparsely populated.

Policy context

Throughout the 1990s evidence developed suggesting that health could be maintained and hospitalisations reduced through sufficient access to physicians or GPs,⁴ according to insurance coverage,⁵ and by preparation of care plans,⁶ while further studies suggested that continuity of care between the patient and physician could reduce hospitalisation⁷ and emergency department presentations.⁸ Concurrently, the concept of Ambulatory Care Sensitive Conditions (ACSCs) was developed through clinical consensus panels.⁹

As a result, the Enhanced Primary Care (EPC) model was introduced in Australia from 1999. Under this model, fee-for-service items aimed at improving the continuity and quality of healthcare provided by GPs to older Australians and those with chronic diseases were made available through the Medicare Benefits Schedule (MBS). These were expanded and repackaged as Chronic Disease Management (CDM) items in 2005¹⁰. These items did not specify continuity of primary care in terms of continuity of provider.

While the cost of CDM items in the 2007/08 financial year was \$AUD203.8 million,¹⁰ little is known about their impact on potentially preventable hospitalisations (PPHs). Knowledge about the influence of patterns of GP contact on PPHs is needed to evaluate the effect of

shifting the focus from acute to primary care using a mechanism focused on ongoing, regular contact with a GP.

The role of regular GP contacts

In this paper continuity of care is assessed as “regularity” of GP contact. This refers to the timing of patients’ GP visits, to distinguish between those having regular and irregular care. We use regular contact as a marker for ongoing proactive care, likely to reflect disease management activities. Conversely irregular contact is a marker for reactive care (i.e. exacerbations of symptoms prompting GP contacts to have “the problem fixed”). We previously found that use of EPC/CDM items by those aged ≥ 65 years increased regularity of GP contact for the remainder of the year,¹¹ suggesting that regularity is a good marker of proactive care. Additionally, previous work has demonstrated associations between regularity and hospital/emergency department use which persist after controlling for provider continuity, indicating that regularity may be a meaningful measure distinct from continuity of provider.¹²

Uptake of EPC items in Australia was initially low. A qualitative analysis suggested that GPs were already undertaking activities like those encouraged by the EPC program due to changes in thinking about the management of chronic disease, but not claiming the items due to their administrative complexity.¹³ Thus, it is likely that at the same time or prior to the EPC items being implemented there was already a paradigm shift in primary care that may have resulted in more regular contact. Therefore, the additional cost burden to the health system of the new MBS items to encourage a change in practice may not have been warranted.

During a period of change in Australian primary care, this study aimed to evaluate: (i) whether regularity of GP contact changed (which may indicate shifts from reactive to more proactive care), and (ii) the impact of regularity on diabetes-related hospitalisation using a community-level analysis. Findings will be of interest to policy makers and service managers who may benefit from a clearer understanding of the relationship between patterns of GP contact and hospitalisation outcomes, and will also be of interest to researchers interested in assessing continuity of care. Though this analysis uses historical data, the use of incentives in primary care continues to have contemporary relevance in Australia and elsewhere.

Methods

This was a whole-population retrospective cohort study using linked administrative data. Reporting follows the RECORD statement.¹⁴ Approval was from the

University of Western Australia and Curtin University Human Research Ethics Committees (reference numbers RD-42-14 and RA/4/1/1239, respectively) which exempted the study from requiring individual patient consent.

Data sources

The cohort included adults aged ≥ 18 enrolled to vote in Western Australia (WA) at any time between 1 July 1991 and 30 June 2004. Person-level linked data covering 1980–2004 included:

1. WA mortality records;
2. WA Hospital Morbidity Data System (HMDS) records, including all private and public inpatient activity;
3. WA Electoral Roll records (1988–2004); and
4. MBS records originating in WA.

WA data were linked and extracted via the WA Data Linkage System (WADLS) and MBS data by the Commonwealth Department of Health and Ageing.

Cohort

Though programs such as EPC often target specific diagnoses, there may also be potential for benefit among those at risk of developing the condition, and hence being hospitalised. Therefore, this analysis extends beyond those people with diabetes, to include people at high risk of the condition. For each financial year (1 July–30 June) individuals were classified into one of two risk groups: confirmed diabetes or risk of diabetes. Confirmed diabetes was indicated by any of: (i) diagnosis on any hospital record (code 250 using ICD-9-CM and E10–E14 using ICD-10-AM); (ii) diabetes cycle of care consultation in MBS data (a reimbursement to the GP for completing a set of annual diabetes management activities); (iii) quantitation of fructosamine for diabetes management in MBS data; or (iv) quantitation of HbA1c in MBS twice within six months. Risk of diabetes was indicated by: (i) impaired glucose function in hospital data (790.2 in ICD-9-CM or E09, R73 or O24.5 in ICD-10-AM); (ii) an oral glucose tolerance test outside pregnancy in MBS data; (iii) HbA1c quantitation once within six months in MBS data; or (iv) the combination of being Indigenous, aged ≥ 45 and diagnosed as obese on any hospital record. ICD-9-CM data did not allow differentiation between diabetes types.

Individuals entered either risk group on the day they met the criteria for that group and exited upon permanent outward migration from WA, death or study end.

In Australia the Electoral Roll captures address changes once registered, and hence indicates residence

within the study area (WA).¹⁵ Cohort entry was 1 July in the first full year from 1990 in which an individual resided within WA and had entered one of the risk groups. Eligible person-time was restricted to full financial years individuals were in a risk group, alive and resident in WA.

GP contact

GP contact was captured via MBS claims for “Attendances by General Practitioners”, as described previously.¹¹ Briefly, for each GP visit within a financial year the number of days since the previous GP visit was calculated (which for the first visit in a given year, will have taken place in the prior year), and the coefficient of variation in this number of days was calculated. An annual index (R) was constructed using the formula $R = 1/(1 + \text{Coefficient of Variation}(\text{Days}))$, resulting in a score between 0 and 1 per person-year, with 1 indicating perfectly regular contact. Deciles were created from least to most regular. Calculation required at least two GP contacts within a financial year, person-years with fewer contacts were excluded.

Contact with GPs was also characterised in terms of frequency (i.e. the annual count of contacts) as this likely reflects health status and health-seeking propensity.

Outcomes

Diabetes-related PPHs¹⁶ and hospitalisations where diabetes was identified as a significant risk factor by Davis *et al.*¹⁷ were classified as diabetes-related hospitalisations using HMDS data. Hospitalisations where diabetes was a significant risk factor¹⁷ included certain circulatory disorders, visual disorders, renal complications, and others. Outcomes were the number and cost of these hospitalisations in each financial year, with inter-hospital transfers counted as a single episode. Costs were based on Australian-refined diagnostic related groups (AR-DRGs) which were first developed in 1992. They were developed by clinical colleges, derived from the DRGs previously developed in the United States,¹⁸ with a national costing study run to determine the appropriate cost weights for each AR-DRG. Cost weights are now updated annually based on a representative sample of hospital separations for each AR-DRG. For this sample, bottom-up costs are calculated, and the mean cost across the sample for each AR-DRG is used to reimburse hospitals for episodes of care.¹⁹ New AR-DRG versions are released every 4–5 years. In this study the costs applied to each separation in each year are specific to the AR-DRG version and cost weights which were in use in that year. Although separate cost-weights exist for public and private hospitals, public hospital cost weights have been applied to all separations in

this study so as to prevent health system changes (e.g. private health insurance incentives) influencing results.

Time periods (eras)

The study data cover a period of change in primary care practice and policy in Australia. As such, the study period was divided into eras to test for changes in regularity or associations between regularity and hospitalisation. The period from 1999/2000 to 2002/03 was treated as a separate era to the period from 1990/91 to 1998/99, reflecting the introduction of the EPC program. We additionally tested for changes prior to the program's introduction, following international experience. In the United Kingdom, the Quality Outcomes Framework (QOF) was introduced in 2004. This was a pay-for-performance scheme under which family practices were offered financial incentives to perform and record a range of chronic disease management activities. Evaluations have found that although there was improvement in these activities following the QOF, many of these improvements had begun prior to implementation of the framework.²⁰ We therefore tested for changes in regularity and associations of interest in the lead-up to the introduction of the EPC.

We considered several approaches with respect to the number and timing of eras, using Akaike and Bayesian Information Criterion (AIC/BIC) values. We considered firstly a two-era variable (the cut-point being the introduction of the EPC program) and then three-level era variables where the earlier cut-point was varied from 1993/94 to 1997/98. Additionally, a MEDLINE search was conducted to understand the development of relevant literature through this period to better understand potential changes in practice and patient management. The search included papers published from 1985 to 2004 assessing the impact of managed (as opposed to ad-hoc) primary care on hospitalisation for ACSCs (search strategy detailed in online Additional file 1, pages 1 to 4). Cut-off values were primarily based on AIC/BIC values, with published literature assessed to guide discussion of the likely 'face validity' of these in the context of discussion via published research.

Covariates

Sex, age and indigenous status were captured in datasets. Socio-economic status (SES) and service accessibility were based on the *Socio-Economic Index for Areas* (Index of Relative Socio-economic Disadvantage)²¹ and Accessibility/Remoteness Index of Australia²² applied annually, based on postcode. Comorbidity was ascertained using the Multipurpose Australian Comorbidity Scoring System (MACSS)²³ defined as the count of MACSS conditions, excluding diabetes,

on HMDS data in the previous five years, updating annually.

Frequency of GP and specialist physician contacts in each exposure year were included in models. We included measures of past health service use, as these are associated with future hospitalisation²⁴ including hospitalisations, the count of GP contacts and mean regularity decile in the 3 years prior to the exposure year.

The number of years available for identification of cohort members was captured as a count for each person based on time within the study area. Changes in the availability of tests was controlled for through the use of binary variables for each method of cohort identification, flagging which individuals had recorded each potential method of cohort entry prior to each study year.

Analysis

Stata SE Version 14.2 was used.²⁵ The data formed panels with multiple years per person. Panels were unbalanced and complex as individuals may have exited and re-entered the study area. Analyses related regularity to hospitalisation in the following year, preventing reverse causation. Descriptive statistics were generated for socio-demographics and service use across eras. Changes in regularity across eras was evaluated using multivariable random effects ordered logistic regression. The adjusted percentage change in the probability of being in each regularity decile was determined based on the predicted probabilities of each category and the marginal effects of era using the Stata margins command.

Hospitalisation data are typically characterised by high numbers of zero counts and right-skewed distributions, making Poisson regression models unsuitable.²⁶ Zero-inflated negative binomial (ZINB) models were therefore used for hospitalisation count outcomes, while Cragg-hurdle models were used for hospitalisation cost outcomes. Descriptions of these models are available in Jones *et al.* along with equations and discussion of the application of these models to health service use data.²⁷ In the ZINB model the zero component contained a constant term only. Appropriateness of the ZINB model, in comparison to a zero-inflated Poisson, was assessed based on the significance of the dispersion parameter reported by Stata's ZINB command, following Cameron and Trivedi.²⁶ The multivariable Cragg-hurdle model was clustered with robust standard errors, a lower limit of zero and no upper limit. The hurdle model combined (i) a selection model that determined if an individual had a diabetes-related hospitalisation, and (ii) an outcome model determining the cost for these hospitalisations. The covariates for the selection model were determined using logistic regression

with diabetes-related hospitalisation as the dependent variable. Significant covariates were used in the selection model while the outcome model used all covariates. Models were pooled versions with clustering at the person level, and employed Mundlak variables (i.e. group-means of time-varying variables: age, count of GP contacts, count of specialist contacts, comorbidity history, and regularity) to proxy the fixed effects, reducing potential bias introduced by unobserved heterogeneity.²⁸ A detailed description of this approach to using Mundlak variables is available in Schunck *et al.*²⁹ Analysis included interactions of regularity and the era variable to understand how associations between regularity and hospitalisation outcomes may have changed across eras.

Associations between regularity of GP contact and hospitalisation were ascertained using the margins command, with marginal effects produced at each level of the era variable.

Robustness check

A robustness check was performed to assess the potential influence of migration to or from the study area. Analysis examining the count and costs of hospitalisations were repeated, limited to those cohort members who did not migrate to or from the study area (though could exit the study due to death).

Results

Eras

In comparison to an era variable with one cut-point (in 1999/00, reflecting the introduction of EPC), AIC/BIC

values were lowest for the count model with three eras, the second of which started in 1994/95 (Figure 1(a)). The cost model had the lowest AIC score when the second era began in 1995/96 and the lowest BIC score for the two era model, followed by a three era model with the second era starting in 1995/96. All remaining analyses are based on three eras, with the second era starting in 1994/95, for consistency.

Care co-ordination literature

Results of the literature search on the topic of managed/co-ordinated primary care and hospital use are displayed in Figure 1. The search identified few publications on this topic appearing in the literature from 1993, with a substantial increase in the literature in the late 1990's and further increases in the early 2000's. More detailed search results are presented in online Additional file 1, pages 5 to 8.

Cohort characteristics

The cohort included 153,455 individuals and increased with successive eras (Table 1). Compared to the first era, cohort members in the last era were slightly younger, more likely to be male, less likely to be non-Indigenous (the remainder including Indigenous and unknowns), less likely to have diabetes (as opposed to high risk), less likely to have died during the study period, lived in areas of less disadvantage and which were more accessible. The median annual number of GP visits declined slightly across eras as did the likelihood of diabetes-related hospitalisation.

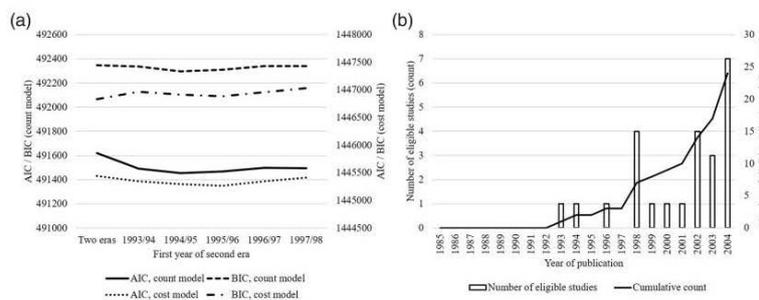


Figure 1. Changes throughout the study period informing the cut-points for the Eras analysed Part A displays AIC/BIC values of models regressing the count and cost of diabetes-related hospitalisation on clinical, sociodemographic and health service factors; Era variable cut-point varied from 1993/94 to 1997/98. Model covariates include age*, gender, indigenous status, socioeconomic status (Socioeconomic Index for Areas), remoteness (Accessibility/Remoteness Index of Australia), number of GP* and specialist physician contacts*, comorbid history*, history of diabetes-related hospitalisations, history of primary care contacts, diabetes risk level, years available for ascertainment of diabetes status, presence of individual diabetes status/risk indicators, regularity*, era, era-regularity interaction and group-means of time-varying variables (denoted by *). Part B displays growth in the number of peer-reviewed journal articles on the topic of managed primary care and potentially preventable hospitalisation published from 1985–2004 indexed in Medline.

Table 1. Cohort characteristics at first year in each era (A) and health service use across eras (B).

(A) Status of individuals at entry into era	Era 1 (1991/2–1993/4) Mean (95% CI) N (%)	Era 2 (1994/5–1998/9) Mean (95% CI) N (%)	Era 3 (1999/0–2002/3) Mean (95% CI) N (%)	Significance ³ p-value
Age ⁴	58.72 (58.55–58.90)	57.02 (56.91–57.12)	57.24 (57.17–57.32)	<0.001
Gender				
Female	14,620 (51.59%)	39,602 (50.39%)	70,080 (50.28%)	<0.001
Male	13,717 (48.41%)	38,990 (49.61%)	69,308 (49.72%)	
Indigenous				
No	26,123 (92.19%)	78,592 (90.88%)	124,016 (88.97%)	<0.001
Risk status				
High risk	9,663 (34.10%)	44,921 (57.16%)	89,258 (64.04%)	<0.001
Confirmed diabetic	18,671 (65.90%)	33,671 (42.84%)	50,130 (35.96%)	
Died during study	9,830 (34.69%)	12,470 (15.87%)	6,934 (4.97%)	<0.001
SEIFA IRSD ¹ quintile*				
Highest disadvantage	5,844 (20.62%)	14,857 (18.90%)	25,103 (18.01%)	<0.001
High disadvantage	8,996 (31.75%)	21,517 (27.38%)	34,965 (25.08%)	
Moderate disadvantage	4,260 (15.03%)	11,148 (14.18%)	19,996 (14.35%)	
Less disadvantage	3,504 (12.37%)	11,565 (14.72%)	22,792 (16.35%)	
Least disadvantage	5,632 (19.88%)	18,819 (23.95%)	34,966 (25.09%)	
Accessibility to services (ARIA ²)*				
Very remote	826 (2.91%)	2,043 (2.60%)	3,781 (2.71%)	<0.001
Remote	591 (2.09%)	1,347 (1.71%)	2,114 (1.52%)	
Moderately accessible	1,679 (5.93%)	3,461 (4.40%)	6,456 (4.63%)	
Accessible	1,586 (5.60%)	3,694 (4.70%)	7,462 (5.35%)	
Highly accessible	23,572 (83.18%)	67,381 (85.74%)	118,013 (84.67%)	
Total number of individuals in the cohort	28,337	78,582	139,388	
Use of health services	Era 1 (1990/1–1994/5) Median (IQR)	Era 2 (1995/6–1998/9) Median (IQR)	Era 3 (1999/0–2002/3) Median (IQR)	Significance P-value
Annual number of GP visits ⁵	9 (5–14)	8 (5–14)	7 (4–12)	<0.001
Probability of diabetes related hospitalisation	Proportion 11.87%	Proportion 8.32%	Proportion 7.29%	P-value <0.001

*Numbers in categories do not sum to the total cohort due to unknown (missing) information.

¹Socioeconomic Index for Areas, Index of Relative Socio-economic Disadvantage.

²Accessibility and Remoteness Index for Australia.

³Significance testing based on Chi-squared test unless otherwise stated.

⁴Significance testing based on ANOVA test.

⁵Significance based on Kruskal-Wallis test.

Changes in regularity

When changes in regularity across eras were evaluated, adjusting for confounders (Figure 2), there was a significant though small reduction in the probability of higher regularity categories and a similar increase in the probability of the lower regularity categories from era 1 to era 2. These changes were minor, with the proportion in deciles 5 or above decreasing by only about two percent. From era 2 to era 3 there was no change in the probability of each category.

Associations between regularity and hospital use

Only relationships between regularity and hospitalisation are presented here; for detailed outputs of the

hospitalisation count model see Table 1 in online Additional file 2, for the cost model see Table 3 in online Additional file 3.

Table 2 presents marginal effects of regularity of GP contact on (A) the rate and (B) the annual cost of diabetes-related hospitalisations. There were differences in the baseline annual costs over time, due to changes in funding algorithms and policies to reduce length of stay. Therefore, in Figure 4 outcomes are presented as proportional changes in hospitalisation costs (i.e. the marginal change relative to the predicted mean for the baseline group). Table 2 and Figures 3 and 4 display that overall there was a pattern of decreasing hospital use with increasing regularity, though there were some differences between count and cost outcomes.

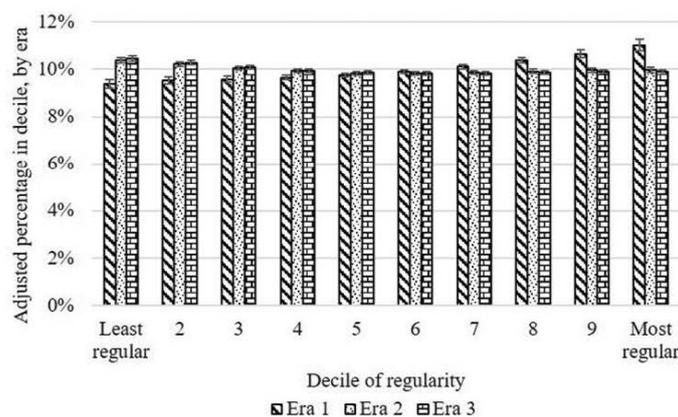


Figure 2. Adjusted# probability of regularity each level of regularity, by era. #Covariates included age*, gender, indigenous status, socioeconomic status (Socioeconomic Index for Areas), remoteness (Accessibility/Remoteness Index of Australia), number of GP* and specialist physician contacts*, comorbid history*, history of diabetes-related hospitalisations, diabetes risk level, years available for ascertainment of diabetes status, presence of individual diabetes status/risk indicators, regularity*, and group-means of time-varying variables (denoted by *). Error bars represent 95% confidence intervals

Results show that compared to the baseline (least regular) decile, increasingly regular GP contact was associated with significant reductions in hospitalisation. Compared to the least regular group, the second most regular and most regular groups had 6.9% (95% CI 2.8% to 10.7%) and 5.5% (95% CI 0.9% to 9.9%) fewer hospitalisations, respectively. In the first era there was no significant association between regularity and the hospitalisation rate due in part to a smaller group size and larger standard errors, though point estimates showed similar patterns. In the second era the second most regular and most regular deciles were associated with reductions of 9.8% (95% CI 3.0% to 16.2%) and 8.4% (1.3% to 15.0%) respectively. In the final era the second most regular decile was associated with a 5.5% lower (95% CI 0.1% to 10.7%) hospitalisation rate though the most regular decile did not differ significantly from baseline. The dispersion parameter, α , was significant (see Table 1 in online Additional file 2), indicating that the negative binomial regression adopted was more appropriate than a Poisson model.

Results for the cost outcome were similar to those for the hospitalisation rate (Table 2 and Figure 4), although in this case significant associations were observed at lower levels of regularity rather than only at the highest levels. Across the entire study period the most regular decile had lower costs by \$115 (95% CI \$63 to \$167). In the first era the most regular category was associated with a \$264 reduction in inpatient costs (95% CI \$96 to \$431). In the second era significant reductions were observed from the sixth decile onwards, and these reductions were similar in scale from the sixth to the most

regular decile, where a reduction of \$108 (95% CI \$22 to \$194) was observed. In the final era significant reductions were observed across all deciles except the second and fourth least regular; in the most regular decile a reduction of \$96 (95% CI \$33 to \$159) compared to baseline was reported. Figure 4 presents the same information, with costs at each decile instead presented as a percentage change from the adjusted baseline cost in each era, to allow a comparison in effects accounting for different baseline costs.

Robustness check

In the robustness check limited to those who did not migrate to or from the study area, the cohort size was reduced by approximately 25%. Incidence rate ratios for the hospitalisation count outcome did not change dramatically in comparison to the main analysis. Overall, the two highest regularity deciles had significantly reduced hospitalisations in comparison to the least regular, as was the case in the main analysis. These relationships attenuated across eras.

Negative associations between regularity and hospitalisation cost remained, though were slightly diminished. Overall, these negative associations were significant from the 5th most regular decile and above, compared to the main analysis where all deciles had significantly lower hospitalisation costs than the least regular reference group. The effect attenuated across eras, as with the main analysis. Results from the robustness check relating to the count model are in Table 2 in online

Table 2. (A) IRR¹ for hospitalisation count and (B) change in annual cost² (\$AUD2017³) by regularity category.

Regularity	N ⁴	A: Hospitalisation rate		B: Hospitalisation costs	
		IRR	95% CI	Change	95% CI
Full study period (1990/91–2002/03)					
Least regular	68,563	Reference category			
2	68,564	0.981	0.936, 1.029	–60.42	–108.22, –12.62
3	68,563	0.993	0.948, 1.040	–64.88	–112.10, –17.65
4	68,564	0.978	0.935, 1.023	–52.32	–100.17, –4.48
5	68,563	0.979	0.932, 1.028	–92.30	–139.34, –45.26
6	68,564	0.975	0.931, 1.021	–96.45	–144.12, –47.89
7	68,563	0.989	0.942, 1.037	–82.23	–129.96, –34.51
8	68,564	0.960	0.915, 1.007	–97.08	–145.71, –48.44
9	68,563	0.931	0.893, 0.972	–125.10	–174.53, –75.68
Most regular	68,564	0.945	0.901, 0.991	–114.91	–167.31, –62.52
Era 1 (1991/2–1993/4)					
Least regular	7,023	Reference category			
2	6,012	1.005	0.870, 1.160	–101.66	–281.54, 78.21
3	5,980	0.972	0.866, 1.091	–60.65	–236.82, 115.53
4	5,787	0.970	0.817, 1.150	–58.94	–239.11, 121.22
5	5,915	1.029	0.834, 1.270	–158.50	–329.34, 12.33
6	5,933	0.965	0.851, 1.093	–71.59	–248.22, 105.04
7	5,778	1.018	0.872, 1.189	–108.64	–281.20, 63.91
8	6,016	0.906	0.811, 1.012	–182.81	–348.09, –17.53
9	6,127	0.959	0.848, 1.086	–101.84	–275.16, 71.48
Most regular	6,477	0.900	0.802, 1.010	–263.54	–431.18, –95.90
Era 2 (1994/5–1998/99)					
Least regular	25,245	Reference category			
2	24,115	0.933	0.864, 1.007	–61.72	–145.30, 21.85
3	24,135	1.031	0.934, 1.138	–21.98	–105.64, 61.68
4	23,896	0.950	0.879, 1.027	–49.19	–130.83, 32.46
5	23,531	0.965	0.891, 1.050	–70.07	–151.10, 10.97
6	23,111	0.959	0.880, 1.046	–111.66	–193.57, –29.75
7	22,823	0.965	0.880, 1.060	–98.64	–179.16, –18.13
8	22,462	0.964	0.882, 1.053	–87.39	–169.21, –5.58
9	22,345	0.902	0.838, 0.970	–115.66	–197.67, –33.65
Most regular	21,832	0.916	0.850, 0.987	–107.85	–193.94, –21.73
Era 3 (1999/00–2002/03)					
Least regular	36,295	Reference category			
2	38,437	1.008	0.941, 1.079	–53.74	–114.63, 7.16
3	38,448	0.974	0.922, 1.030	–91.78	–150.80, –32.75
4	38,881	0.999	0.942, 1.059	–54.66	–114.70, 5.38
5	39,117	0.976	0.922, 1.034	–95.50	–153.87, –37.14
6	39,520	0.987	0.929, 1.050	–93.67	–152.31, –35.03
7	39,952	0.997	0.939, 1.059	–69.37	–128.34, –10.40
8	40,086	0.970	0.912, 1.031	–90.12	–149.63, –30.61
9	40,091	0.945	0.893, 0.999	–136.44	–195.61, –77.27
Most regular	40,225	0.975	0.909, 1.045	–95.78	–158.64, –32.92

Note: Models adjusted for age^{*}, gender, indigenous status, socioeconomic status (Socio-Economic Indexes for Areas - Index of Relative Socio-economic Disadvantage), remoteness (Accessibility/Remoteness Index of Australia), number of GP^{*} and specialist physician contacts^{*}, comorbid history^{*}, diabetes risk level, history of diabetes-related hospitalisations, history of primary care contacts, years available for ascertainment of diabetes status, presence of individual diabetes status/risk indicators, regularity^{*}, era, era-regularity interaction and group-means of time-varying variables (denoted by *).

¹Incidence Rate Ratio indicating change in the predicted rate per person-year from reference group, derived from negative binomial regression.

²Change in the predicted annual mean cost per person from reference group, derived from Cragg Hurdle regression.

³As updated inflation multipliers were released during the study, models were applied to data in \$AUD2014 and results later inflated to \$AUD2017.

⁴Crude count in category in each era.

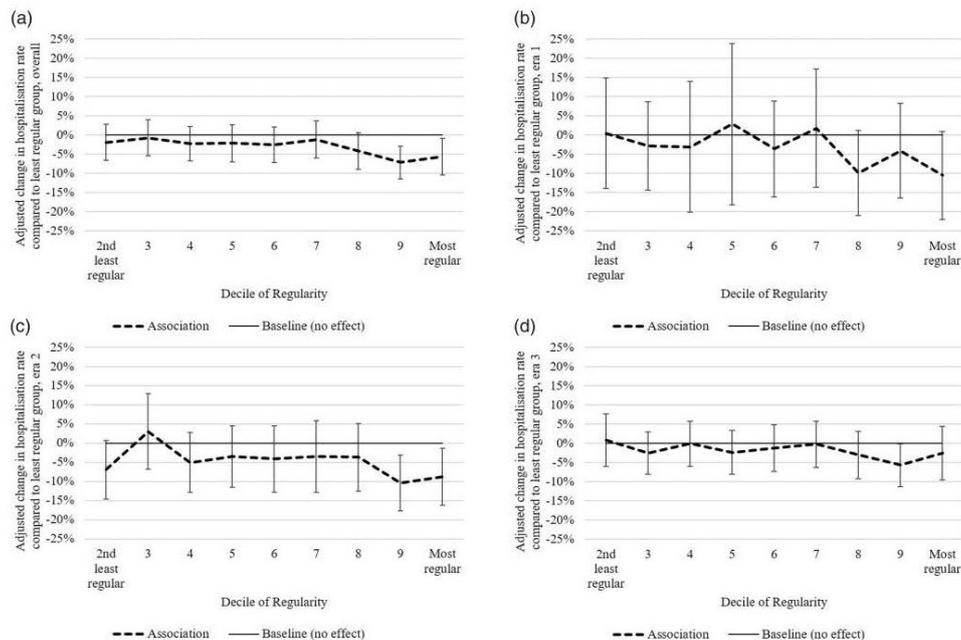


Figure 3. Associations between regularity of GP contact and diabetes-related hospitalisation rate. Associations are presented separately for the entire study period (a) and for eras 1, 2 and 3 (b to d). #Covariates included age*, gender, indigenous status, socioeconomic status (Socioeconomic Index for Areas), remoteness (Accessibility/Remoteness Index of Australia), number of GP* and specialist physician contacts*, comorbid history*, history of diabetes-related hospitalisations, history of primary care contacts, diabetes risk level, years available for ascertainment of diabetes status, presence of individual diabetes status/risk indicators, regularity*, era-regularity interaction and group-means of time-varying variables (denoted by *). Error bars represent 95% confidence intervals.

Additional file 2, and for the cost outcome are presented in Table 4 in online Additional file 3.

Discussion

Where a patient has regular GP contact, this may impact health by facilitating the detection of changes in health and treatment modification. Results here indicated that regular GP contact was associated with a reduction in the number and cost of diabetes-related hospital admissions, and this association was fairly similar across the periods prior to and following the EPC program introduction. While effect sizes were small at the individual level, they are significant from a practice perspective when considering the high prevalence of diabetes. There were slight differences in associations observed for hospitalisation count and cost outcomes. Reduced hospitalisation rates were observed only at the highest levels of regularity whereas with regards to costs, significant associations were observed from lower levels of regularity, compared to baseline. The different modeling techniques might account for this, though it is also

plausible that contact with the GP might mean that a change in condition is detected early which results in hospitalisation for management of the acute problem, preventing further deterioration which might otherwise have resulted in a more complex and costly admission. Similar findings have been observed in chronic care models previously.³⁰

Previous work has demonstrated that where GPs claim EPC items, regularity increased in the following year,¹¹ contrasting with the lack of change observed here following the introduction of EPC. It may be the case that the initial low uptake of the program meant that these individual level changes were outweighed in the current analysis by broader population trends. Practice sizes in Australia were increasing through the study period³¹ which is associated with lower interpersonal continuity (i.e. patients less likely to see the same provider).³² This could result in irregular contact if patients and doctors are less likely to schedule follow-up appointments, for example. Additionally, although the literature search in this paper identified only a few publications on the topic of managed care prior to the EPC program

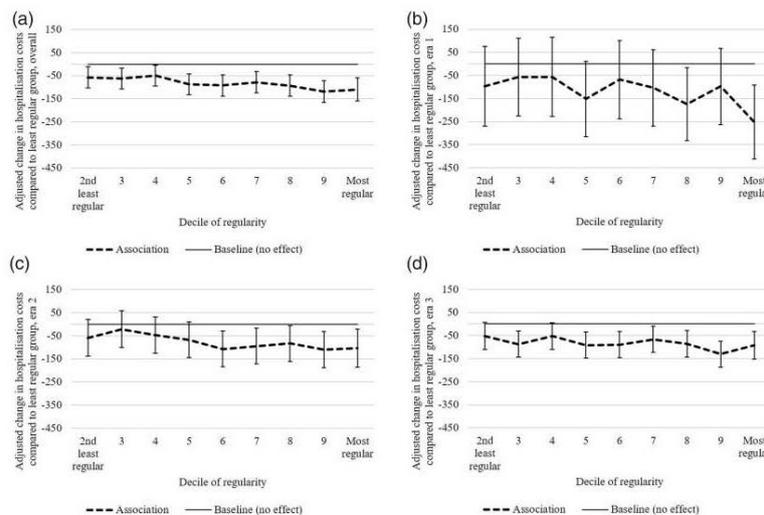


Figure 4. Associations between regularity of GP contact and diabetes-related hospitalisation costs. Associations are presented separately for the entire study period (a) and for eras 1, 2 and 3 (b to d). #Covariates included age*, gender, indigenous status, socioeconomic status (Socioeconomic Index for Areas), remoteness (Accessibility/Remoteness Index of Australia), number of GP* and specialist physician contacts*, comorbid history*, history of diabetes-related hospitalisations, diabetes risk level, years available for ascertainment of diabetes status, presence of individual diabetes status/risk indicators, regularity*, era regularity interaction and group-means of time-varying variables (denoted by *). Error bars represent 95% confidence intervals

introduction, through the 1990s various guidelines for diabetes management were developed.³³ It is possible therefore that the introduction of the EPC program represented policy catching up with changes in practice, rather than policy driving practice change.

In 2004 the EPC program was replaced by the CDM program and uptake increased. This may have resulted in shifts towards more regular contact, though the current study does not capture this period. The historical data used here provide a unique opportunity to inform about the utility of regularity of contact as a distinct domain (and potential policy lever) which may not be possible today due to the proliferation of policies encouraging ongoing contact. In recent years primary care policies have been proposed and introduced³⁴ with the potential to influence preventive contacts and therefore regularity of GP care, hence evidence regarding associations with hospitalisation outcomes remains relevant.

Similar efforts to promote the primary care management of diseases have been made internationally. In the United Kingdom the QOF was introduced in 2004. Though this is much broader in scope than any program attempted in Australia, the QOF has similarities to the EPC/CDM in that it provides financial incentives for practices and providers to perform and document a range of activities aimed at the prevention and management of chronic disease. Improvements in the

achievement rates of many QOF indicators were occurring leading up to introduction of the framework.²⁰ Any similar trend in Australia might partially explain the lack of change in associations observed here following introduction of EPC. In the USA financial incentives for disease prevention and management activities have been implemented via collaborations between health plans, physician organisations and purchasers,³⁵ though the incentives are inevitably different, reflecting different purchasing arrangements.

Strengths and limitations

The use of longitudinal, whole-population data and variety of datasets available have several major strengths. The use of administrative data prevents sampling or non-response bias. It also enabled a look-back prior to the study start date capturing potential heterogeneity on a range of factors. Address data allowed us to capture migration to/from the study area and correct person-time at risk of hospitalisation. The fact that the data were panel allowed for the group means of time-varying variables to be added to models as a means to control for unobserved time-invariant individual level factors.²⁸ Information on comorbidities, previous hospitalisation and frequency of GP contacts were included to control for health status and remove potential bias from effects of regularity.

A common issue in administrative data is the lack of clinical information available. Although we identified separate cohorts of people with and at risk of diabetes, detailed clinical data may improve adjustment for confounding. Similarly, MBS data provides little contextual information on services provided. We had no information on health service use outside of WA, so people diagnosed with diabetes elsewhere will not have entered the cohort until they used services within WA. As this study is observational we cannot make inferences regarding causation. A particular concern is unobserved variables which may influence associations. There are some differences in the cohort demographics between eras. To reduce the potential for changes in diagnostic practices to cause differences in associations between eras we included as covariates the length of time in the study population (i.e. available for entry in to the cohort) and variables for each method of cohort entry, flagging which indicators each person had recorded. Variables such as the comorbidity indicators should additionally control for potential changes in the overall health of the cohort between eras. The use of eras, though informative in understanding changes in relationships over time, should be interpreted with caution. In particular, the division between eras 1 and 2 was selected based on AIC/BIC values rather than reflecting a discrete practice change; the differences between these eras in reality reflects more gradual trends across this decade. Finally, findings may differ substantially for conditions other than diabetes.

Conclusion

Among a cohort at risk of diabetic related hospitalisation, more regular GP contact was associated with a small reduction in diabetes-related hospitalisation, and this association was fairly consistent in the periods prior to and following the introduction of policies aimed at improving the primary care management of chronic disease. The apparent protective effect of regular contacts is relevant to health service managers, and poses the question as to which component of continuity of primary care is the most important in further reducing potentially preventable hospitalisations. Given the significant financial investment in programs to improve the quality of chronic disease management in Australia and other developed countries, further investigation of this with contemporary data is warranted.

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Supplemental material

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6.3 Chapter summary

This chapter has demonstrated that during a period of primary care policy change, regularity of GP contact remained relatively constant, as did associations between regularity and hospitalisation outcomes. Previous literature has demonstrated that at the individual level the claiming of EPC items was followed by more regular GP contact (179, 196); the analysis in this chapter has provided some evidence for similar relationships at the population level (a trend of declining regularity prior to the program, which stopped following the program's introduction) though there was little evidence of changes to associations between regularity and hospitalisation (that is, little evidence of effect modification). Note that even in the absence of such effect modification a positive impact on regularity would indicate a beneficial impact, considering the negative associations observed with hospitalisation.

A limitation of this work is that the impacts of the policy change cannot be considered separately from other health system changes discussed within the manuscript (changing practices sizes, a developing evidence base, the publication of clinical guidelines through the study period). This stems from the introduction of the policy on a nation-wide basis. If the policy were introduced in specific states, for example, this would allow for unexposed states to be used as comparators, capturing differences introduced by other factors, and a more accurate estimate of impacts of the EPC program on regularity to be produced using difference in difference methods or similar.

Chapter 7 Associations between regularity and continuity and hospital / ED outcomes in Western Australia 2005–2015

7.1 Chapter introduction and overview

This chapter examines the impacts of regularity and continuity of GP contacts on hospital and ED use, among different clinical cohorts. This aims to provide information regarding both (i) the associations between these exposures and health service use, and (ii) the degree to which these associations may depend on the choice of study design and statistical analysis used, given the potential limitations of the analyses commonly used in the continuity of care literature described in section 2.2.2.4.

This chapter addresses objectives 3b: Investigate contemporary associations between regularity and hospitalisation / ED outcomes across conditions; and 3c: “Determine the sensitivity of estimates of these associations to study design and statistical analysis.”

Analyses in this chapter find that when the study design and statistical analysis reflect the methods most commonly used in the literature on continuity of care, substantial negative associations between regularity / continuity and hospital / ED use are observed, consistent with much of the literature in this area. However, when alternative study designs and analytical methods that reduce the risk of bias are used, these associations change substantially. Changes in the relationships according to research design and statistical methods are maintained across cohorts with different conditions. This analysis suggests that in studies of continuity of care, choices made regarding study design and analytic methods have major implications for the results observed and hence policy implications, and this has not been explored in the literature to date. These findings present a major contribution to the literature, with several implications. Firstly, from a policy perspective, the findings here suggest the beneficial effects of regularity / continuity of care are likely to be more modest than suggested by much of the existing literature. This of course has implications for the development of policies to improve patient health, and the suitability of these exposures as intervention targets. Secondly, these findings demonstrate that in future research into continuity of care it is imperative that alternative study designs be further utilised as sensitivity analyses to better understand the robustness of findings and potential biases influencing results, so as to produce a stronger evidence base for policy development.

7.2 Methods

The analyses in this chapter used the WA Population Data 2000–2017 described in section 3.2. This data captures all adults (aged 18 plus) living in Western Australia who were enrolled with Medicare at any point from 2005 to 2017. The individual-level linked data collections include all records for hospitalisations, all emergency department presentations, deaths, and all Medicare Benefits Schedule service data. In addition details of Medicare registration for all enrollees (regardless of whether they accessed health services) incorporating postcode of residence with updated records provided as people changed residence within WA or relocated out and into WA.. Being a whole-population data collection, including more than 2 million people, including those who have not interacted with health services (a group that are often missing from administrative data analyses), it is not subject to bias due to sampling inherent with cohort data.

For all analyses in this section the data were arranged as a panel from 2005 to 2015 with all exposures and outcomes measured on an annual basis. The panel began in 2005 to allow for five years of look-back to ascertain comorbid status, and ended in 2015 to allow lagging of outcomes (outcomes in 2016 were attached to exposures in 2015). As the Medicare registration data captured de-registrations and re-registrations (most commonly reflecting migration to / from the study area or periods of incarceration) the data were limited to include only person-years for which individuals were registered with Medicare in WA for the full year.

7.2.1 Clinical cohorts

Analyses were repeated across different clinical cohorts so as to understand potential effect modification, i.e. the extent to which associations between regularity / continuity and hospital / ED outcomes differed between patient groups. Patients with and at risk of diabetes were selected following the procedure outlined in manuscript 3. A cohort with confirmed diabetes was identified based on any of (i) a past hospitalisation with an International Classification of Disease, 10th revision, Australian Modification (ICD-10-AM) code for diabetes (E10–E14) on any diagnosis field, (ii) a patient having recorded two HbA1c tests within six months on MBS data, or (iii) completion of a diabetes cycle of care on MBS data. The diabetes cycle of care is an MBS incentive item a GP may claim in the care of a patient with diabetes, conditional on completing a minimum set of management activities within a calendar year. Risk of diabetes was flagged where a patient had (i) a hospitalisation with an ICD-10-AM code for impaired glucose function (E09), or (ii) a single HbA1c test within a six-month period on MBS data (likely indicating testing for diabetes by the GP).

Other clinical cohorts were identified based on the conditions included in the Multipurpose Australian Comorbidity Scoring System. As the MACSS was developed to predict risk of future hospitalisation, these conditions were considered suitable to select cohorts for an analysis of hospitalisation outcomes. The cohorts captured based on the MACSS were cohorts with blood diseases, diseases of the central nervous system, diseases of the circulatory system, diseases of the respiratory system, diseases of the digestive system and diseases of the genitourinary system. Patients entered each of these cohorts if and when they had a hospitalisation with an ICD-10-AM code reflecting the condition, based on the codes contributing to the MACSS (233). The specific conditions contributing to each of these clinical cohorts are listed in Table 7-1.

Table 7-1: Conditions contributing to the capture of clinical cohorts, adapted from Holman et al. (233)

Blood diseases:

Anaemias, coagulopathies

Diseases of the central nervous system or sense organs:

Inflammatory CNS diseases, Parkinson's disease, other extrapyramidal disease, degenerative neurologic or muscular diseases, paraplegia or quadriplegia, infantile cerebral palsy, epilepsy, glaucoma, cataract, blindness and low vision.

Diseases of the respiratory system:

Pneumonia, chronic pulmonary disease, asthma, pleurisy, other respiratory disorders

Diseases of the circulatory system:

Cerebrovascular disease or stroke, hypertension, congestive cardiac failure, myocardial infarction, other ischaemic heart disease, chronic pulmonary circulatory disorders, valvular disease, cardiac dysrhythmias or arrest, peripheral vascular disease, haemorrhoids.

Diseases of the digestive system:

Oesophageal diseases, peptic ulcer, gastritis or duodenitis, cholelithiasis and cholecystitis, chronic liver disease, sequelae of chronic liver disease, abdominal hernia, non-infectious digestive disorders, diverticular disease, peritoneal adhesions, other diseases of intestine, gastrointestinal haemorrhage

Diseases of the genitourinary system:

Chronic renal disease, other kidney, ureter or bladder conditions, urinary tract infections, benign prostatic hypertrophy, breast disorders, pelvic inflammatory disease, cervicitis or vaginitis, genital prolapse, noninflammatory ovarian conditions, uterine disorders, gynaecologic pain, menstrual disorders, menopausal disorders, menstrual disorders, female infertility

7.2.2 Exposures

Exposures used in this analysis were the Modified Regularity Index, explained in manuscript 2, and the continuity of care (COC) index, described in section 3.3.1. For analysis, the modified regularity index was converted into quintiles from least to most regular GP contact. COC was split into five roughly equal groups with categories lowest (COC <0.25), low (0.25–0.49), moderate, (0.50–0.74), high (0.75–0.99) and very high (1). Studies commonly categorise this index similarly, though the specific cut-offs differ (234, 235).

7.2.3 Outcomes

Outcomes of interest included the annual count of unplanned hospitalisations (based on the admission status variable on the HMDC data), and the count of all-cause ED presentations. Although in manuscript 3 the outcome of interest was diabetes-related hospitalisation, there was a substantial change in diabetes coding in Australia in 2011 (236) making consistent assessment of diabetes-related hospitalisations across this period impossible. Furthermore, as multiple conditions were assessed in this analysis, global outcomes were required. Each outcome (unplanned hospitalisations and all-cause ED presentations) was assessed as a count in each calendar year. Where multiple hospitalisation records were part of the same episode of care (where inter-hospital transfers occurred) these were treated as a single outcome.

7.2.4 Covariates

Covariates included both socio-demographics and clinical information in the administrative data. Socio-demographic characteristics were age (categorised as 18-44, 45-54, 55-64, 65-74, 75-84, 85-plus), sex, indigenous status (binary), geographically derived socioeconomic status (based on the socio-economic index for areas – index of relative social disadvantage (SEIFA-IRSD) (237) based on postcode, in quintiles), and remoteness (using the accessibility / remoteness index for Australia (ARIA) (238), based on postcode). Comorbidity was captured based on the number of 17 MACSS conditions (233) for which the patient had been hospitalised in the five prior years. Clinical / health service use covariates were the frequency of GP contacts in each year, the count of specialist contacts in each year, and a binary variable indicating whether the patient had a GP management plan completed within the year. For the cohort with / at risk of diabetes, health status was further captured by the use of binary indicators flagging each of the five potential cohort entry methods each cohort member had recorded as of each year in the study. For the six remaining clinical cohorts, this was instead captured based on a variable indicating the number of years each individual had been in the cohort (that is, the number of years since first recording of the MACSS condition). Finally, in order to understand how associations may have changed over time, a binary variable separated the study period into two eras (2005-2010 and 2011-2015).

7.2.5 Analysis

Summary statistics were produced for each cohort for all covariates, outcomes, and exposures using means and medians or percentages, depending on the variable distribution. As data were a panel the exposures and outcomes were also described in terms of the proportion of the cohort reporting some variation on each of these variables during the study period.

Three different modelling approaches were used to assess the degree to which reported associations were influenced by analytic methods.

- Model 1: exposures and outcomes were measured concurrently and a random-effects model was used. This model is referred to throughout as the unlagged random-effects approach. This model reflects unlagged designs used in many of the studies published on the topic of continuity of care. Using this analysis there are risks of reverse causation and confounding by unobserved variables, as described in section 2.2.2.4.
- Model 2: the risk of reverse causation was removed by lagging the outcomes, where outcomes in one year were regressed on exposures and covariates in the prior year. This model is referred to as the lagged random effects approach.
- Model 3 used a hybrid model which provides separate estimates for within-person effects and between-person effects (165), referred to as the lagged hybrid model approach. In the lagged hybrid model, each exposure entered the model both as a mean (a within-person mean across the study period) and in de-meaned form (the difference between the value in each person-year and the within-person mean value). This produced two regression coefficients for each exposure. The first being the within-person coefficient, reflecting the effect of a change in an individual's regularity / continuity level in a given year (the fixed effect) while the second, the between-person coefficient, reflected the effect of between-person differences in the mean level of each exposure across the study period (165). Within-person coefficients are not confounded by time-invariant characteristics, whether observed or unobserved, hence model 3 was considered the most robust.

These three models were repeated for unplanned hospitalisation and all-cause ED presentation, across all clinical cohorts. Note that all analyses were repeated separately for each clinical cohort – the data for the different clinical cohorts were not pooled. All models included both regularity and continuity and interactions of each exposure with the era variable. As outcomes were counts with over-dispersed distributions, negative binomial regression was used. Associations between exposures and outcomes were reported by era, using effect estimates derived with Stata's `-margins-` command. Marginal effects of each level of regularity / continuity, relative to the least regular / lowest continuity group, were reported by era for each cohort, and are presented as incidence rate ratios (IRRs) throughout. Additionally, the potential for interactions between the regularity and continuity variables were tested. For each outcome, each of the six models (models 1, 2 and 3 for hospitalisation and emergency department outcomes) was repeated, with a regularity X continuity interaction term added. Interactions were assessed on the basis of the IRR and p-value, these are reported separately.

7.3 Results

7.3.1 Cohort descriptions

Clinical cohorts are described in Table 7-2. The smallest cohort was those with blood diseases (n=136,686) while the largest was those with respiratory conditions (n=1,372,356). The mean panel length was approximately five years across all cohorts (range 4.68 (blood) to 5.64 (cardiovascular)). The annual number of GP contacts per year was similar across cohorts, ranging from 7.84 (respiratory) to 10.42 (blood diseases). Mean regularity scores did not differ between cohorts (mean 0.013) while mean COC values ranged from 0.52 (respiratory diseases) to 0.64 (cohort with / at risk of diabetes). All cohorts had a majority of females except for the cohort with / at risk of diabetes and with cardiovascular disease (CVD). A small minority of each cohort were indigenous (range 2.41–5.95%). Health status appeared to differ between cohorts; unplanned hospitalisation occurred in 24.81% of person-years in the cohort with blood diseases, and only 9.84% of person years in the cohort with respiratory conditions. Across all cohorts a majority reported some variation in quintile of regularity through the study period (range from 74.86% in cohort with blood diseases to 82.88% in those with CVD) and this was fairly similar for categories of COC (ranging from 71.30% of those with blood diseases to 78.39% of those with respiratory conditions). Less than half of each cohort reported variation in unplanned hospitalisations (ranging 33.05% in the respiratory disease cohort to 46.57% of those in the blood disease cohort) and more than half of each cohort reported variation in the all-cause ED presentation outcome (ranging from 53.70% of the digestive disease cohort to 61.05% of those in the CVD cohort).

Table 7-2: Demographic characteristics and health service use variables by cohort

Cohort:		Blood disorders		Cardiovascular		CNS		Diabetes		Digestive		Genitourinary		Respiratory	
		Mean	IQR	Mean	IQR	Mean	IQR	Mean	IQR	Mean	IQR	Mean	IQR	Mean	IQR
Years in cohort		4.68	2-7	5.64	3-9	5.14	2-8	5.56	2-9	5.36	2-8	5.41	2-8	5.46	2-8
Frequency ^a		10.42	5-13	9.81	5-12	9.69	5-12	9.88	5-12	8.46	4-10	8.93	4-11	7.84	4-9
Specialist contacts ^a		2.8	0-3	2.48	0-3	2.45	0-3	2.32	0-3	1.91	0-2	2.08	0-3	1.59	0-2
Regularity ^a		0.013	.009-.015	0.013	.009-.015	0.013	.009-.014	0.013	.009-.015	0.013	.009-.014	0.013	.009-.014	0.013	.009-.014
COC ^a		0.58	.33-1	0.61	.33-1	0.59	.33-1	0.64	.375-1	0.54	.29-.87	0.52	.29-.86	0.52	.27-.84
Age		57.27	40-75	59.25	48-72	57.42	44-74	59.06	50-70	48.21	32-63	51.67	37-66	43.9	28-58
		%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq
Sex	Female	63.6	87,063	49.99	201,619	53.86	204,808	47.23	108,080	54.97	421,368	68.86	289,997	56.73	778,543
	Male	36.3	49,623	50.01	201,716	46.14	175,418	52.77	120,768	45.03	345,177	31.14	131,173	43.27	593,813
Indig. status	Non-indig.	94.05	128,551	96.88	390,732	96.82	368,117	90.3	206,640	97.59	748,047	96.47	406,Robins	96.95	1,330,472
	Indig.	5.95	8,135	3.12	12,603	3.18	12,109	5.36	12,259	2.41	18,498	3.53	14,862	3.05	41,884
% with outcome	Unplan. hosp.	24.81	158,650	18.73	426,093	18.22	356,019	17.65	224,677	13.16	540,819	15.63	356,092	9.84	135,081
	ED pres.	36.85	235,671	30.3	689,375	30.79	601,677	28.84	367,206	25.95	1,066,224	28.97	659,894	24.16	331,622
	Hosp.	46.95	64,170	46.57	187,839	42.45	161,403	42.97	98,337	34.81	266,829	39.19	165,053	33.05	453,519
% with variation in outcome	ED pres	58.91	80,525	61.05	246,225	57.76	219,634	56.16	128,517	53.7	411,657	57.01	240,119	54.37	746,117
	Reg.	74.86	102,318	82.88	334,301	79.52	302,366	78.17	178,900	80.68	618,472	80.67	339,764	81.57	1,119,378
	Cont.	71.3	97,459	79.76	321,710	76.04	289,124	74.94	171,505	77.36	592,969	77.38	325,902	78.39	1,075,781
N		136,686		403,335		380,226		228,848		766,545		421,170		1,372,356	

^a indicates value relates to person-years rather than persons

Regularity scores were generally similar between the cohort with / at risk of diabetes-related hospitalisation in the current study and the cohort analysed in manuscript 3. The mean regularity score was 0.0148 in the older data compared to 0.0135 in the current data, while cut-points for eras (providing a comparison of the distribution) suggest that the distributions overall were similar (for example the cut-off for the most regular quintile was 0.0154 in data used in manuscript 3 compared to 0.0157 in the current analysis).

7.3.2 Associations with hospital / ED use

Relationships between exposures and health service use outcomes were similar across cohorts. Results for the cohort with / at risk of diabetes are primarily explained here.

7.3.2.1 Hospitalisation outcomes

In model 1 (lagged random effects) there were substantial negative associations between both exposures and the outcome of unplanned hospitalisation (Figure 7-1). In era 1 a one-quintile increase in regularity was associated with an 8.92% reduction in unplanned hospitalisations (IRR 0.908, 95% CI 0.904–0.912), while a one-level increase in COC was associated with a 6.44% reduction (IRR 0.936, 95%CI 0.931–0.940). Associations in era 2 were slightly smaller (regularity IRR 0.921 (0.917–0.925), COC 0.948 (0.948–0.956)). Different results were observed for model 2, the lagged random effects model (Figure 7-2). In this case regularity was not significantly associated with unplanned hospitalisation in either era. Increased continuity had a small negative association with the outcome in era 1 (IRR 0.975 (0.970–0.980)) which reduced further in era 2 (IRR 0.990 (0.985–0.994)). Model 3, the lagged hybrid model, provides additional information by providing coefficients for both within-person and between-person effects (Figure 7-3). In this model the within-person effects were positive for regularity in both eras (era 1 IRR 1.030 (1.025–1.036), era 2 IRR 1.027 (1.021–1.032)). For COC a small positive effect was observed in era 1 (IRR 1.010 (1.003–1.017)) increasing slightly in era 2 (IRR 1.019 (1.013–1.026)). Regarding the between-effects, in era 1 a one-quintile increase in regularity was associated with a 7.84% reduction in unplanned hospitalisation (IRR 0.922 (0.914–0.929)) though in era 2 this had reduced (IRR 0.951 (0.944–0.958)). Similarly for COC a negative effect in era 1 (IRR 0.925 (0.918–0.932)) reduced substantially by era 2 (IRR 0.947 (0.941–0.953) reduction).

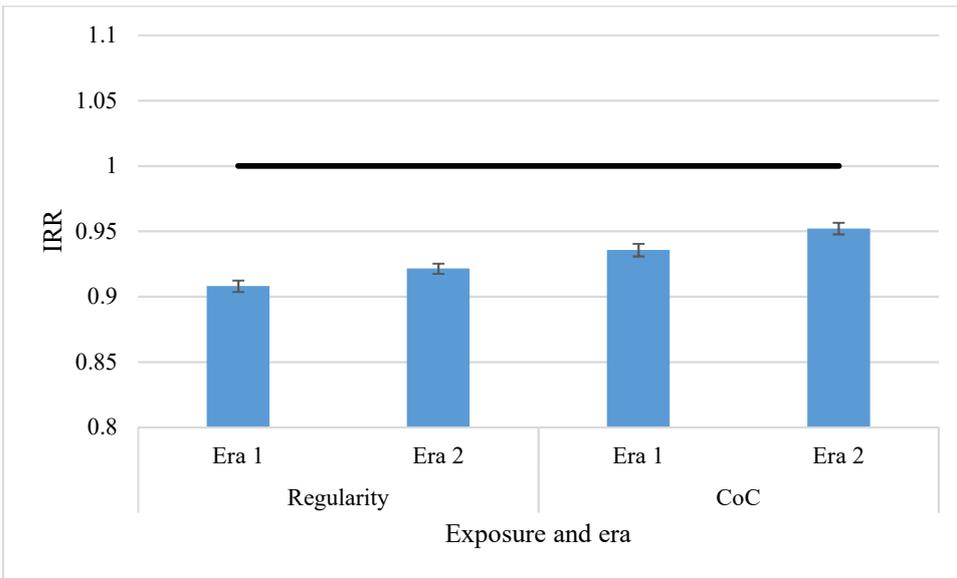


Figure 7-1: Model 1 (unlagged random effects), outcome of unplanned hospitalisation

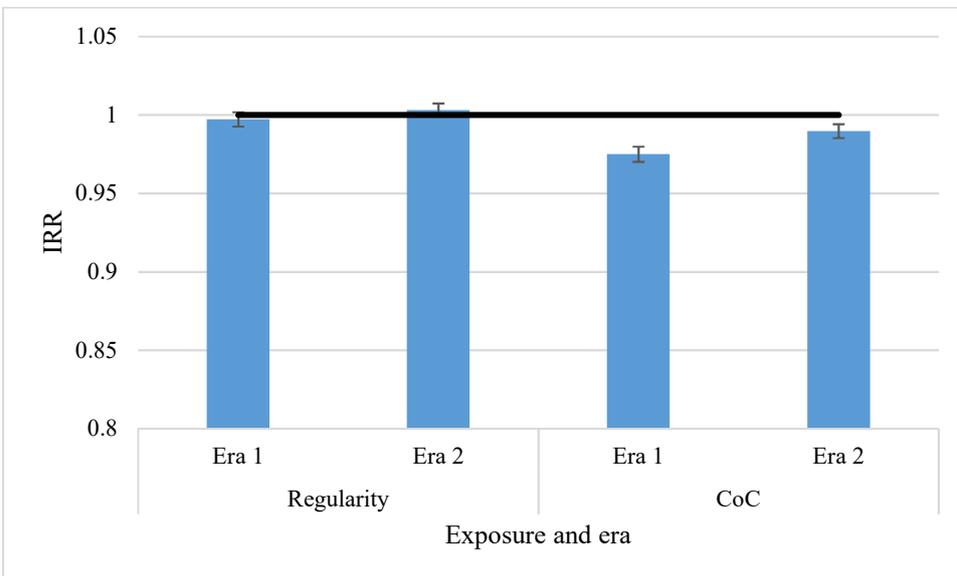


Figure 7-2: Model 2 (lagged random effects), outcome of unplanned hospitalisation

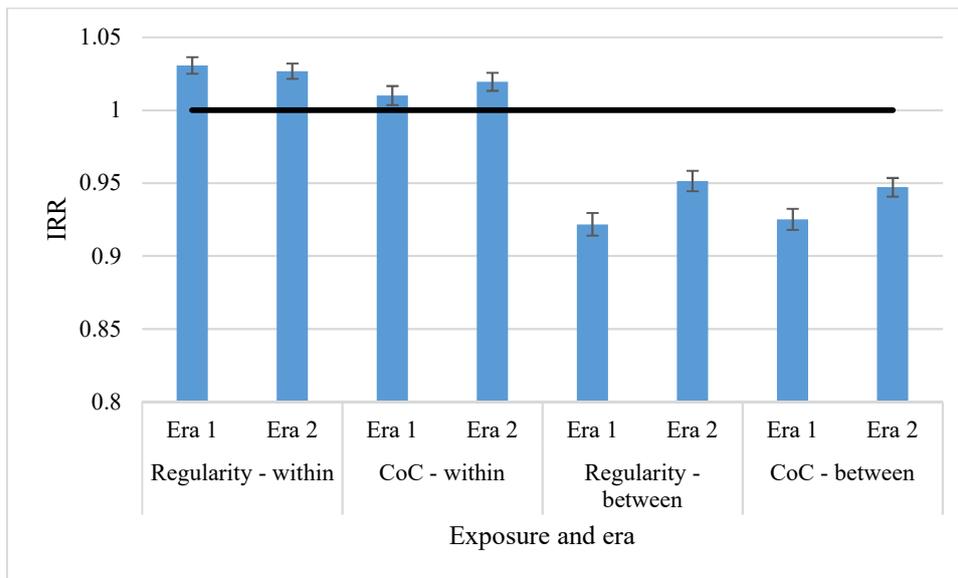


Figure 7-3: Model 3 (lagged hybrid model), outcome of unplanned hospitalisations

7.3.2.2 ED outcomes

Results were generally similar for the outcome of any ED presentation. In model 1 (Figure 7-4) both regularity and continuity were associated with reductions in ED presentations in both eras with a slight reduction from era 1 to era 2 (regularity era 1 IRR 0.922 (0.919–0.925), era 2 IRR 0.931 (0.928–0.934); continuity era 1 IRR 0.921 (0.918 – 0.925), era 2 IRR 0.939 (0.935–0.942)). When outcomes were lagged (model 2, Figure 7-5) a non-significant association for regularity in era 1 changed to a small positive association in era 2 (IRR 1.005 (1.001–1.008)) while for continuity negative associations remained in both eras (era 1 IRR 0.957 (0.953–0.960), era 2 IRR 0.978 (0.976–0.981)). In model 3 (Figure 7-6) the within-person coefficients for regularity were positive in both eras (era 1 IRR 1.029 (1.025–1.033) era 2 IRR 1.026 (1.022–1.030)), and for COC (era 1 IRR 1.006 (1.002–1.011) era 2 IRR 1.016 (1.012–1.021)). Substantial negative between-person coefficients were observed for both exposures, though these declined substantially from era 1 to era 2 (regularity era 1 IRR 0.933 (0.927–0.939), era 2 IRR 0.954 (0.948–0.959); COC era 1 IRR 0.878 (0.873–0.884), era 2 IRR 0.915 (0.910–0.920)).

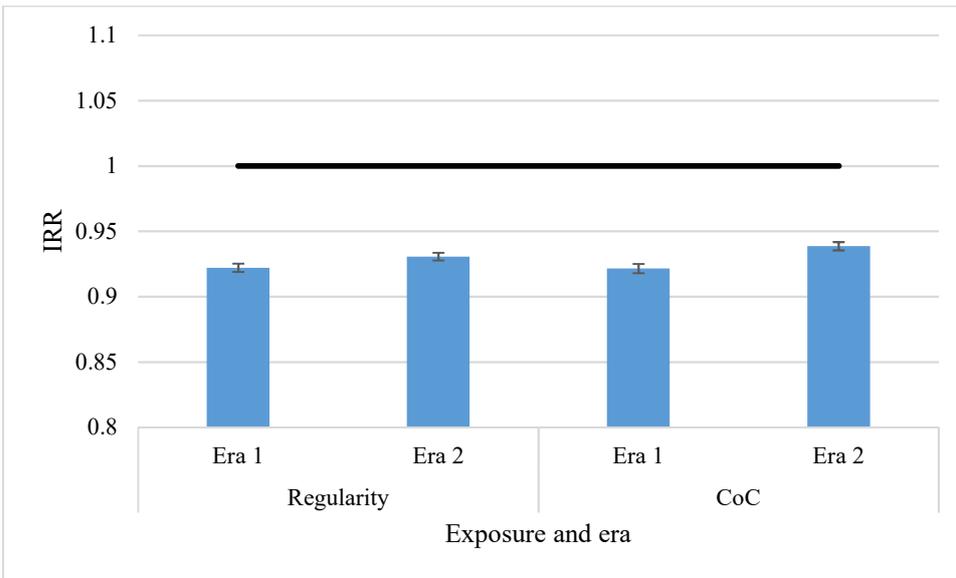


Figure 7-4: Model 1 (unlagged random effects), outcome of all-cause ED presentations

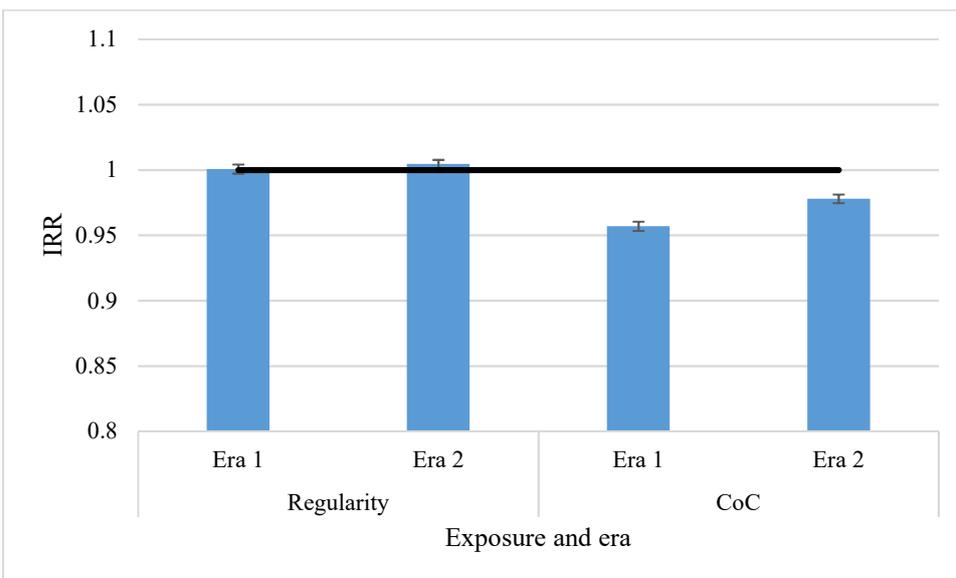


Figure 7-5: Model 2 (lagged random effects), outcome of all-cause ED presentations

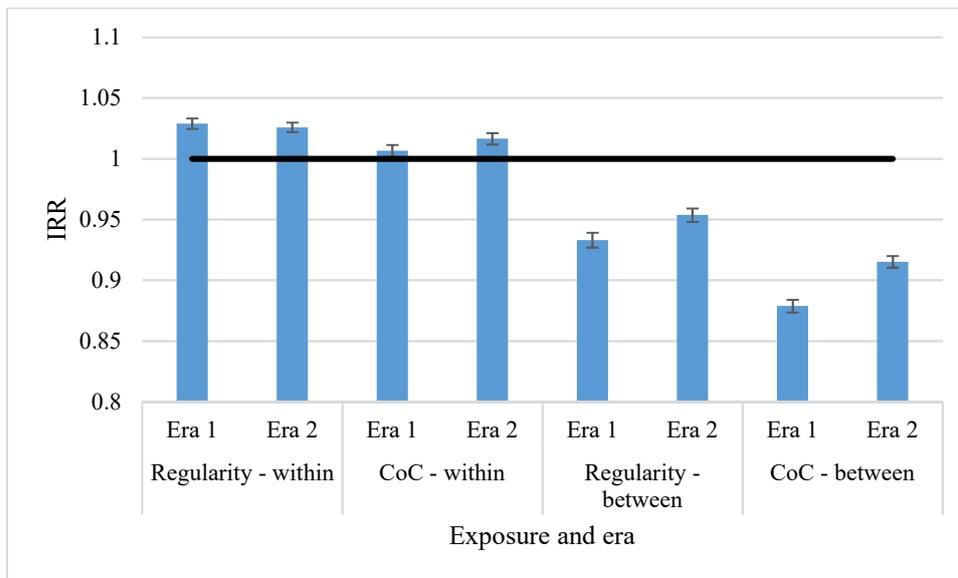


Figure 7-6: Model 3 (lagged hybrid model), outcome of unplanned ED presentations

7.3.2.3 Comparisons between clinical cohorts

Effect estimates for unplanned hospitalisations did not differ dramatically between condition cohorts, as demonstrated in Table 7-3 (for ease of reading non-significant results are shaded, with all non-shaded cells significant; full regression outputs for each model are included in Appendix D. For example, when looking at the results for model 3 (lagged hybrid model), the largest within-effect on the exposure of regularity in era 1 was 1.034 (95% CI 1.029 – 1.039) for the cohort with central nervous system disease, while the smallest was 1.027 (95% CI 1.020 – 1.035) for the cohort with blood diseases. Similarly, for model 1 (unlagged random effects) the largest negative effect for regularity in era 1 was 0.908 (0.906 – 0.910) observed in the cohort with respiratory disease, while the smallest was 0.920 (95% CI 0.917 – 0.923) observed in the cohort with genitourinary disease. There were some cases where these small differences in coefficients resulted in changes in statistical significance. In model 1 associations were significant in all cases. In model 2 regularity reported a significant positive association in era 1 for all cohorts except central nervous system conditions, while in era 2 regularity had a significant positive coefficient for all cohorts except diabetes. In this model COC had significant negative coefficients in era 1 on all cohorts, while in era 2 all cohorts had positive coefficients except diabetes which was negative. In relation to model 3, within-person coefficients were positive in all cases, while between person coefficients were negative in all cases.

Associations with ED outcomes were also similar between cohorts, as demonstrated in Table 7-4. Significant negative associations were observed for all cohorts for both exposures according to model 1. When model 2 was used some differences between cohorts were observed for regularity in era 1 (no significant association for diabetes, cardiovascular and blood diseases, positive associations in all other cases). In model 3 between-person effects were negative in all cases, while within-person effects were positive in all cases except for COC in era 1 where non-significant effects were observed for the cohort with blood diseases.

Table 7-3: IRRs for impact of exposures on unplanned hospitalisation outcomes, by cohort and model used

		Model 1: random effects, unlagged						
Cohort:		Blood	Cardio.	CNS	Diab.	Digest.	Genito.	Resp.
Reg – Random effects	Era 1	0.916	0.912	0.915	0.908	0.912	0.920	0.908
	Era 2	0.933	0.924	0.929	0.921	0.927	0.935	0.922
COC –Random effects	Era 1	0.947	0.955	0.942	0.936	0.958	0.955	0.958
	Era 2	0.968	0.972	0.967	0.952	0.979	0.975	0.979
		Model 2: random effects, lagged						
Cohort:		Blood	Cardio.	CNS	Diab.	Digest.	Genito.	Resp.
Reg –Random effects	Era 1	0.995	1.001	1.005	0.997	1.004	1.004	1.000
	Era 2	1.011	1.007	1.011	1.003	1.012	1.012	1.009
COC –Random effects	Era 1	0.980	0.991	0.984	0.975	0.991	0.989	0.987
	Era 2	1.009	1.010	1.009	0.990	1.009	1.010	1.007
		Model 3: Hybrid model, lagged						
Cohort:		Blood	Cardio.	CNS	Diab.	Digest.	Genito.	Resp.
Reg –within effects	Era 1	1.027	1.030	1.034	1.031	1.033	1.031	1.030
	Era 2	1.025	1.029	1.029	1.027	1.033	1.029	1.028
COC –within effects	Era 1	1.015	1.014	1.016	1.010	1.017	1.016	1.014
	Era 2	1.021	1.020	1.022	1.019	1.019	1.019	1.017
Reg –between effects	Era 1	0.933	0.937	0.947	0.922	0.943	0.948	0.940
	Era 2	0.976	0.955	0.973	0.951	0.968	0.974	0.965
COC –between effects	Era 1	0.940	0.963	0.946	0.925	0.962	0.959	0.956
	Era 2	0.985	0.994	0.988	0.947	0.993	0.993	0.989

* Shaded cells represent non-significant results

Table 7-4: IRRs for impact of exposures on all-cause ED presentations, by cohort and model used

		Model 1: random effects, unlagged						
Cohort:		Blood	Cardio.	CNS	Diab.	Digest.	Genito.	Resp.
Reg –Random effects	Era 1	0.928	0.924	0.930	0.922	0.931	0.937	0.930
	Era 2	0.939	0.930	0.934	0.931	0.938	0.941	0.936
COC –Random effects	Era 1	0.931	0.938	0.927	0.921	0.940	0.934	0.938
	Era 2	0.947	0.951	0.948	0.939	0.954	0.955	0.952
		Model 2: random effects, lagged						
Cohort:		Blood	Cardio.	CNS	Diab.	Digest.	Genito.	Resp.
Reg –Random effects	Era 1	1.001	1.002	1.006	1.001	1.006	1.007	1.003
	Era 2	1.013	1.006	1.009	1.005	1.010	1.006	1.008
COC –Random effects	Era 1	0.960	0.970	0.963	0.957	0.968	0.967	0.965
	Era 2	0.988	0.990	0.989	0.978	0.986	0.991	0.985
		Model 3: hybrid model, lagged						
Cohort:		Blood	Cardio.	CNS	Diab.	Digest.	Genito.	Resp.
Reg –within effects	Era 1	1.026	1.028	1.029	1.029	1.028	1.028	1.024
	Era 2	1.027	1.027	1.027	1.026	1.028	1.022	1.023
COC –within effects	Era 1	1.006	1.009	1.008	1.006	1.009	1.013	1.008
	Era 2	1.015	1.015	1.017	1.016	1.014	1.016	1.013
Reg –between effects	Era 1	0.951	0.945	0.956	0.933	0.956	0.959	0.957
	Era 2	0.976	0.955	0.969	0.954	0.968	0.967	0.971
COC –between effects	Era 1	0.899	0.914	0.900	0.879	0.910	0.902	0.902
	Era 2	0.940	0.947	0.944	0.915	0.942	0.946	0.938

* Shaded cells represent non-significant results

7.3.2.4 Interactions between regularity and continuity

The IRRs and significance for all interaction terms are presented in Table 7-5. There was mixed evidence of interactions between regularity and continuity. For both hospitalisation and ED presentation outcomes, significant interactions were present when model 1 was used (the unlagged random effects model) and the IRRs for these were generally below 1, i.e., indicating that negative associations between regularity and hospital / ED use outcomes were stronger (more negative) at higher levels of CoC, and vice-versa. However, in lagged random effects models, these interactions generally became non-significant, with significant interactions recorded for all cohorts except for those with blood diseases and diabetes for the outcome of unplanned hospitalisation, and only those with genitourinary and respiratory illnesses for the ED presentations outcome; even in cases where significance remained the IRRs reduced in magnitude in comparison to Model 1 for the equivalent outcome. When lagged hybrid models were used, no significant interactions were reported.

Table 7-5: Coefficients and p-values from interactions of Regularity and Continuity exposures. Regressions of unplanned hospitalisation and emergency department presentation in cohorts with prior hospitalisation for seven different conditions.

Cohort	Model:	Outcome - unplanned hospitalisations			Outcome - emergency department presentations		
		1 (unlagged RE)	2 (lagged RE)	3 (lagged hybrid)	1 (unlagged RE)	2 (lagged RE)	3 (lagged hybrid)
Blood	IRR	0.988	1.000	0.997	0.989	1.002	0.999
	P-value	<0.001	0.959	0.330	<0.001	0.089	0.736
Cardiovascular	IRR	0.991	1.002	1.002	0.991	1.000	1.000
	P-value	<0.001	0.021	0.180	<0.001	0.468	0.899
CNS	IRR	0.990	1.002	1.003	0.990	1.000	1.001
	P-value	<0.001	0.035	0.137	<0.001	0.997	0.534
Diabetes	IRR	0.989	1.002	0.999	0.988	1.000	0.999
	P-value	<0.001	0.147	0.604	<0.001	0.997	0.395
Digestive	IRR	0.992	1.003	1.000	0.992	1.001	0.998
	P-value	<0.001	<0.001	0.731	<0.001	0.052	0.068
Genitourinary	IRR	0.993	1.004	1.001	0.991	1.001	0.999
	P-value	<0.001	<0.001	0.569	<0.001	0.038	0.271
Respiratory	IRR	0.991	1.003	1.001	0.991	1.001	-0.001
	P-value	<0.001	<0.001	0.523	<0.001	0.039	0.056

CNS = Central Nervous System, IRR = Incidence Rate Ratio, RE = Random Effects

7.4 Discussion

Large negative associations between exposures and use of tertiary health services were observed in random-effects models in which exposures and health service use outcomes were measured concurrently, though these associations reduced substantially when outcomes were lagged. Furthermore, when hybrid models were used allowing for between-person and within-person (between-years) effects to be estimated separately, it was found that negative associations were present only on the between-person estimates. In other words, people who recorded high average regularity / continuity through the study period had reduced hospital / ED use compared to those with a low average regularity / continuity, though an individual recording a high level of regularity / continuity (relative to their own average) did not lead to reduced hospital / ED use in the following year. Similar patterns were observed across clinical cohorts, for both hospitalisation and ED outcomes, and for both regularity and continuity as exposures.

In manuscript 3, negative associations were reported between regularity of GP contacts and diabetes-related hospitalisations. This manuscript reported associations across a period from 1990 to 2004, split into three eras. In that manuscript, point estimates of these negative associations showed slight declines in the last era relative to the era prior. Similarly, in the current analysis, where negative associations between regularity / continuity and hospital / ED use are reported, these generally decline from era 1 (2005–2010) to era 2 (2010–2014). This may indicate that more substantial negative associations may have existed in the past, which have diminished over time. There have been changes in the Australian health system which could potentially have contributed to such changes. For example, practice sizes have been increasing (195), which may have had implications for the care delivered to patients. Increased use of clinical information systems within practices (239) may have influenced the maintenance of for example informational continuity, modifying the role of interpersonal continuity assessed with the indices used here. Through this period there has been a proliferation in the numbers of evidence-based clinical practice guidelines available for the conditions commonly managed in general practice (240); a general improvement in the management of patients may mean that the potential for benefit from these exposures has diminished.

The differences between models in these analyses are important in understanding the likelihood of associations between exposures being causal. Where exposures and outcomes are measured concurrently there is a risk of reverse causation. The loss of negative association generally observed here once outcomes were lagged suggests that reverse causation bias may play a role in studies of continuity of care, in cases where exposures and outcomes are measured concurrently. Similarly, the differences in the within and between effects in hybrid models are useful in understanding the likelihood of associations being causal. The between effects showed the most substantial negative associations, though these are susceptible to confounding by unobserved characteristics. The within-person effects, for which negative associations were not reported, are not susceptible to any confounding by time-invariant patient factors, whether observed or unobserved (though these may be confounded by unobserved time-varying characteristics) (125). Interactions between regularity and continuity were also assessed, and while significant interactions were observed in models most likely to suffer from reverse causation and unobserved confounding, these interactions reduced in magnitude or disappeared when models were modified to reduce the potential impact of these two issues. This does not provide strong evidence for the presence of interactions between these exposures, a topic that is explored further in Chapter 8 and Chapter 9.

These findings are consistent with those reported by Gill et al. in 2000 (96). This study found that there was a negative association between continuity of care and ED presentations when measured concurrently, but this association reversed when ED outcomes were measured the year following continuity; a positive non-significant association was observed for the outcome of one ED presentation (compared to none) and a significant positive association was observed for the outcome of multiple presentations. Other papers in this area have not explicitly compared analyses with lagged and unlagged outcomes.

Finally, Ride et al. used a similar approach to the hybrid model used here in a study of hospitalisation outcomes among people with serious mental illness, finding a protective effect (125). These researchers similarly made comparisons of within-person effects to estimates from a random effects model, findings that the choice of analysis method did result in substantially different effect estimates, as was the case in the current study. Note that in this study the within-person effects indicated significant negative impacts on some hospitalisation outcomes, in contrast to the findings here. Haggerty et al. suggest that continuity of care in mental illness is usually defined quite differently in the case of mental illness compared to the definitions in primary care in section 2.2.1.1 (84), suggesting that a direct comparison of effect sizes is not informative. However the finding that effect estimates are highly sensitive to analysis techniques supports the findings in the current study.

These findings have implications for future research and policy. In terms of research, this analysis suggests that it is vitally important that researchers assessing continuity of care use designs that minimise risks of reverse causation, whether as a sensitivity analysis or main analysis, rather than solely using unlagged designs which are common in this literature. The choice of analysis dramatically affects the associations observed and as such reliance on a single method without strong justification risks producing biased evidence. Considering studies in this area generally use administrative data, it is likely that researchers are not usually constrained to accessing only a single year of data, and lagging outcomes would generally be possible. Similarly, constructing panel datasets which allow for within-person and between-person estimates to be separately produced should generally be possible.

Similarly, from a policy perspective, these findings have major implications. Policy-makers relying on currently reported associations between continuity and outcomes may implement policies to promote continuity in the hope that this will lead to substantial reductions in hospitalisation. Such reductions may not eventuate if published evidence overstates negative associations between continuity and outcomes, as these analyses suggest. Furthermore if continuity is promoted via policy at the expense of other care characteristics (e.g. rapid access (241)) then downstream outcomes may worsen. Although the specific effect estimates reported here are likely to differ in other settings with different primary care systems, this chapter points towards extensions of the literature that can be replicated in other settings to provide a greater understanding of the relationships between these exposures and outcomes, and hence a stronger evidence base for policy.

The lagging of outcomes and use of a hybrid model have advantages in reducing risk of bias due to reverse causation and unobserved confounding, though may introduce other disadvantages. Most importantly, the lagging of outcomes means that there is up to one year between the measurement of the exposures ending and a potential hospitalisation / ED outcome; patterns of GP contact may continue to change following the end of the exposure period and this is not captured. Gill et al., in explaining the differences in results observed between their analyses with lagged and unlagged outcomes, argued that patients make decisions on whether to seek care at the ED or GP based on their current relationship with the GP, hence considered lagged outcomes less informative than unlagged (96). This may make some sense for ED presentations, being a partially discretionary outcome, though in the current analysis similar changes were observed for hospitalisations which are not discretionary. Given the long-term nature of some of the conditions assessed here, improvements in health in one year would be expected to continue to influence hospitalisation in the following year. The within-person (fixed) effects from the hybrid models may be limited in that these only include those individuals who report some variation in the outcome (242) with those who are never hospitalised being omitted. The long study period used here mitigates this to an extent as with a longer panel more cohort members are likely to record a hospitalisation at some point. Model results are generally similar for hospitalisation outcomes, on which approximately 35–45% of each cohort report variation, and ED outcomes, for which 55%–60% of each cohort report variation, suggesting this may not be a major issue. Finally, while the hybrid model produces within-person effects that are not biased by time-invariant confounders, there is potential for confounding by time-varying variables (125).

Chapter 8 Impacts of regularity / continuity on diabetes monitoring and patient health

8.1 Chapter overview

The previous chapter demonstrated that although negative associations between regularity / continuity and hospitalisation / emergency department outcomes existed, these were highly sensitive to the choice of study design and analysis techniques used. Where the design and analysis were selected to reduce the likelihood of specific biases, and hence produce estimates that were more likely to reflect causative relationships, these negative associations reduced substantially and in many cases disappeared. According to the framework of health service utilisation discussed in section 2.2.1.2, impacts on these downstream outcomes are hypothesised to occur via intermediate processes of care such as the completion of appropriate patient monitoring, adherence to advice and other mediators. Furthermore the framework suggests that outcomes may arise in terms of perceived health and / or evaluated health. This chapter adds to the understanding of how regularity / continuity may influence downstream health service use by assessing associations with processes of care (completion of appropriate monitoring tests) and evaluated health (results on these tests). In addition, this chapter assesses interactions between measures of regularity and continuity in terms of their associations with these process of care and health service use outcomes. This analysis is included to better understand the relationship between these different aspects of primary care contact in influencing the care delivered to patients.

This chapter consists of manuscript 4, which is currently under review. This manuscript is an investigation of the role of regularity and continuity in influencing both processes of care (as measured based on the completion of pathology monitoring tests within recommended timeframes) and an objective measure of patient health (results on these tests within target ranges). This analysis is performed within a cohort of people with type 2 diabetes. This analysis is conducted using the MedicineInsight data collection described in section 3.2.3, where information on the data collection, governance, the profile of the participating GPs and other dataset features was discussed. In addition to providing evidence regarding the role of regularity and continuity in influencing processes of care and patient health, this manuscript provides evidence on the value of these clinical general practice data as a research resource, complementing the more commonly used administrative data collections. This manuscript addresses objective 4a: “Investigate associations between regularity and appropriate use of pathology testing and patient health as indicated by results on pathology tests.” The authors of this manuscript are David Youens, Suzanne Robinson, Jenny Doust, Mark N Harris and Rachael Moorin.

8.2 Manuscript 4: Associations between regular GP contact, diabetes monitoring and glucose control: an observational study using general practice data

BMJ Open Associations between regular GP contact, diabetes monitoring and glucose control: an observational study using general practice data

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ABSTRACT

Objective Continuity and regularity of general practitioner (GP) contacts are associated with reduced hospitalisation in type 2 diabetes (T2DM). We assessed associations of these GP contact patterns with intermediate outcomes reflecting patient monitoring and health.

Design Observational longitudinal cohort study using general practice data 2011–2017.

Setting 193 Australian general practices in Western Australia and New South Wales participating in the MedicinesInsight programme run by NPS MedicineWise. **Participants** 22 791 patients aged 18 and above with T2DM.

Interventions Regularity was assessed based on variation in the number of days between GP visits, with more regular contacts assumed to indicate planned, proactive care. Informational continuity (claims for care planning incentives) and relational continuity (usual provider of care index) were assessed separately.

Outcome measures Process of care indicators were glycosylated haemoglobin (HbA1c) test underuse (8 months without test), estimated glomerular filtration rate (eGFR) underuse (14 months) and HbA1c overuse (two tests within 80 days). The clinical indicator was T2DM control (HbA1c 6.5% (47.5 mmol/mol)–7.5% (58.5 mmol/mol)).

Results The quintile with most regular contact had reduced odds of HbA1c and eGFR underuse (OR 0.74, 95% CI 0.67 to 0.81 and OR 0.78, 95% CI 0.70 to 0.86, respectively), but increased odds of HbA1c overuse (OR 1.20, 95% CI 1.05 to 1.38). Informational continuity was associated with reduced odds of HbA1c underuse (OR 0.53, 95% CI 0.49 to 0.56), reduced eGFR underuse (OR 0.62, 95% CI 0.58 to 0.67) and higher odds of HbA1c overuse (OR 1.48, 95% CI 1.34 to 1.64). Neither had significant associations with HbA1c level. Results for relational continuity differed.

Conclusions This study provides evidence that regularity and continuity influence processes of care in the management of patients with diabetes, though this did not result in the recording of HbA1c within target range. Research should capture these intermediate outcomes to better understand how GP contact patterns may influence health rather than solely assessing associations with hospitalisation outcomes.

Strengths and limitations of this study

- The general practice data used allowed for assessment of both processes of care and clinical outcomes.
- The general practice data used provided for a large cohort and allowed for control of a range of important covariates.
- Information on practices not participating in the MedicinesInsight programme was unavailable, impacting interpretation.
- The data collection used did not capture hospital use, preventing a mediation analysis capturing hospitalisation outcomes.

INTRODUCTION

Continuity of care refers to a relationship between a practitioner and patient extending beyond a single episode of illness, implying some affiliation between patient and provider.¹ Continuity is typically measured by assessing whether a patient has repeated contact with one provider. Our group has assessed this on the basis of the regularity of general practitioner (GP) contact over time, with visits on a regular basis taken to indicate planned, proactive care. Continuity and regularity of GP contact are associated with hospitalisation outcomes among patients with diabetes.^{2–6} Regularity and continuity are assumed to prevent hospitalisation and mortality via intermediate outcomes such as improved monitoring of the patient by the GP,⁷ facilitating detection and responses to deteriorations in condition,⁴ improved medical management and improved patient compliance.^{8,9} Associations reported between these exposures and hospitalisation outcomes may be subject to unobserved confounding, as this research is typically observational.¹⁰ Given the hypothesised mechanisms of action via intermediate outcomes, evidence concerning

associations with these intermediate outcomes is valuable. Intermediate outcomes are categorised here as (1) processes of care, that is, improved patient monitoring or appropriate prescribing and (2) clinical outcomes, that is, objective measures of patient health.¹¹ It has previously been demonstrated that in patients at risk of cardiovascular disease events, regular care and higher continuity were associated with improved statin use, providing some evidence regarding processes of care.¹²

As this work is conducted in Australia, a description of the role of the GP in this setting is warranted. GPs have major responsibility for prescribing and ordering of diagnostic tests; over 60% of encounters result in a prescription and about one-quarter result in diagnostic investigation.¹³ In Australia GPs have a role as gatekeepers, with specialist care requiring a GP referral,¹⁴ and referrals to allied health and hospital also common.¹⁵ GPs operate on a fee-for-service basis with the Federal Government reimbursing GPs for each encounter via Medicare, Australia's universal public insurance programme, though providers may charge additional copayments.¹⁵ Practices are private business, made up of one or more GPs operating as a business unit. A point relevant to continuity is that patients do not formally register with a specific GP or practice, instead people can switch providers at any time.¹⁴ Meanwhile, there is a trend towards larger practice sizes.¹⁵

Much research in this area has relied on the use of administrative (financial) data collections. These provide comprehensive information on services rendered (eg, GP contacts, medication dispensations, hospitalisations) but often lack detailed clinical information.¹⁶ Recently the information captured in general practice clinical information systems has started becoming available to researchers. These provide a potentially rich source of data, containing more detailed clinical information than administrative collections.¹⁷ Importantly for the current work, these include pathology test results. Pathology test results are not generally available in administrative collections and in Australia, administrative data often do not clearly indicate the completion of specific pathology tests as national reimbursement databases often use a single code for multiple tests attracting the same reimbursement.¹⁷

The aim of the current work was to estimate the impact of GP regularity and continuity on (1) diabetes processes of care, as indicated by the completion of pathology tests according to clinical guidelines and (2) clinical outcomes, as indicated by glycosylated haemoglobin (HbA1c) values. This work focusses on type 2 diabetes mellitus (T2DM) due to its high prevalence,¹⁸ the availability of comprehensive management guidelines¹⁹ and the central role of the GP in its management.²⁰ Clinical guidelines are useful in such research as they outline clear regimens for prescribing and pathology testing, and targets on clinical indicators.¹⁹ These guidelines do not intend to provide a prescriptive approach for all patients with a condition, considering the heterogeneous populations clinicians manage, but at the population level researchers can use

the recommendations in guidelines to compare management of conditions across different groups.

Studies have assessed the impact of sex and socioeconomic status on similar outcomes in cohorts with chronic heart disease.^{21, 22} These found that both male gender and lower socioeconomic status were associated with improved care processes (prescribing and completion of monitoring tests), but worse clinical outcomes (based on pathology test results). This highlights the importance of assessing both sets of outcomes to improve the understanding of potential impacts of any explanatory variables on patient management and health.

METHODS

This was an observational longitudinal cohort study consisting of a secondary analysis of longitudinal general practice data. Reporting follows the REporting of studies Conducted using Observational Routinely-collected Data (RECORD) statement.²³

Data

Data were a collection of person-level deidentified general practice clinical information system data, called MedicineInsight, collated by NPS MedicineWise, which is a non-profit organisation aiming to promote the quality use of medicines.²⁴ MedicineInsight was established in 2011 with funding by the Australian Government, with the primary aim of supporting postmarket medication surveillance.²⁴ General practices are recruited to MedicineInsight on a practice opt-in, patient opt-out basis, meaning that when a practice opts in data on all GPs and all patients (except those who explicitly opt-out) will become available. Following recruitment, historical patient data are extracted, deidentified, encrypted and transmitted to the primary care database with ongoing monthly data extracts. Data include patient demographics, diagnoses, prescriptions, pathology results and immunisations, and more.¹⁷ As of October 2018, MedicineInsight had recruited 662 practices across Australia (8.2% of all practices).²⁴ This study used data from all participating practices in Western Australia (N=53) and New South Wales (N=140) from the start of the collection up to late 2017. Compared with the general population visiting general practices in Australia, patients captured in MedicineInsight data are slightly more likely to be female (55.7% vs 52.4%), are similarly likely to be Indigenous (2.6% vs 2.9%), have a similar distribution of age and socioeconomic status, though some states are over-represented compared with others.²⁵ In some cases, multiple physical practices share a Clinical Information System (CIS), and in these cases the multiple practices are considered a single 'site' within the database regardless of the number of physical practices. Approximately 90% of sites are composed of a single practice.²⁴ As part of their participation in the programme, practices receive information on their own care delivery and prescribing, including benchmarking against other providers and

practices, so as to support quality improvement in primary care.²⁶ MedicineInsight data can be used for beneficial research following approval by the Independent Data Governance Committee.²⁷

Design

The data were organised into a longitudinal design to reduce risk of reverse causation. A pre-exposure period ran from 1 January 2011 to 28 February 2015, during which the cohort was identified and baseline patient characteristics assessed; an exposure period from 1 March 2015 to 29 February 2016, during which exposure variables were ascertained; and outcomes assessed during a follow-up period from 1 March 2016 to 30 June 2017. A diagram is provided in online supplemental file 1.

Cohort

A cohort with T2DM was captured based on recorded diagnoses and the reasons for prescription with each prescription record. These fields were text strings and included records generated by clinical information systems (ie, drop down menus) and records entered manually by GPs, hence there was potential for typing errors and a need to manually verify diagnosis data. As there were millions of records a procedure to expedite manual review was used, explained in online supplemental file 2.

Those over 80 were excluded, since HbA1c goals differ for older patients with higher risk of hypoglycaemia.²⁸

Exposures

Regularity of GP contact was based on all contacts with GPs during the exposure period, and refers to the distribution of these contacts over time. Regularity was calculated using a previously described index, based on the variation in the number of days between GP contacts.⁵ In brief, for each GP contact the number of days since the prior contact was counted, and the coefficient of variation in this number of days calculated. An index (R) was calculated by $R=1/(1+(\text{coefficient of variation}(\text{days between visits})))$. This ranges from 0 (least regular) to 1 (most regular). For example, if a patient had four GP contacts within a year, three of which were in January and one in December, they would have a lower regularity score than a patient with four visits in January, March, August and December. This index was split into quintiles based on the distribution within the cohort.

Two exposures assessed continuity of care. The first indicated whether a GP had claimed one of a set of chronic disease management (CDM) financial incentives reimbursed via Medicare during the exposure period including preparation or review of a GP management plan, co-ordination of team care arrangements or contribution to a multidisciplinary care plan.²⁹ Claiming these items in relation to a patient is taken to indicate informational continuity (ie, information on past events and circumstances is available so appropriate care can be provided,¹ following Ride *et al*³⁰

The Usual Provider of Care (UPC) index was also used. This captures the proportion of all GP visits made to the usual provider during the exposure period³⁰ (ie, the provider the patient visited most often). For example, if a patient visits provider A three times during the exposure period and provider B once, their UPC score will be 0.75. This is a measure of interpersonal continuity (an ongoing relationship between the patient and provider)¹ UPC was categorised as low (0–0.39), intermediate (0.4–0.59), high (0.6–0.99) and perfect (UPC=1). Though this is usually categorised, cut-off values differ^{6,7} with no gold standard. This index is included as visit-based measures are the most commonly used continuity measures. In the current data patient identifiers are practice-specific, meaning that a patient visiting two separate practices will appear as two separate patients, while visits to practices not participating in MedicineInsight are not captured. If a patient visits multiple practices, of which only one participates in MedicineInsight, they may record a high UPC despite having lower continuity in reality. This is referred to as 'practice-specific UPC'.

The cohort was restricted to patients with at least three GP contacts as the regularity score cannot be calculated with fewer than three contacts.

Outcomes

Outcomes were processes of care and clinical indicators developed using pathology testing records. These records were electronically coded in contrast to the free-text diagnosis fields described earlier. We assessed indicators concerning management of HbA1c, as one of the most important markers of diabetes control, and the estimated glomerular filtration rate (eGFR), as a marker of the development of one of the most important diabetes complications.

Processes of care relate to pathology testing within timeframes recommended by guidelines.¹⁹ These recommend HbA1c testing every 6 months, with a maximum frequency of every 3 months. Guidelines also recommend testing the eGFR every twelve months (along with other tests not assessed here). Three process of care outcomes were defined. The first two were underuse of HbA1c, defined as any 8-month period during follow-up without an HbA1c test; and underuse of eGFR, defined as any 14-month period during the follow-up without a test. Underuse represents potentially inappropriate care as changes in health and opportunities to adjust treatment may be missed. The third was overuse of HbA1c, defined as two tests within 80 days. Overuse may be problematic as HbA1c reflects glycaemic control over 3 months (the half-life of red blood cells)³¹ hence tests within this window are not informative. More frequent use represents wasted resources³² and may impact clinical decision making. For example, where medications are changed following a test indicating poor glycaemic control, a follow-up test within 3 months may incorrectly suggest that the treatment has not worked as the effects of the medication change will not yet be fully evident, potentially leading

to further unnecessary medication changes and risk of hypoglycaemia.⁵²

The clinical indicator was an HbA1c result within treatment targets. Participants were flagged as being outside or within target range (6.5% (47.5 mmol/mol)–7.5% (58.5 mmol/mol)) on the first test during the follow-up.¹⁹ The cohort here differed, as those without an HbA1c test during follow-up were excluded. Treatment targets may be modified for some patients based on clinical judgement. Patient-specific treatment targets are not available in the data, however, and at the cohort level an overall indicator was considered appropriate as adjustments to targets for some patients are unlikely to systematically bias analyses. A variable indicating an HbA1c result within target on any test during the follow-up was not considered as this would depend on both clinical outcomes and processes of care (number of tests).

Covariates

Patient characteristics included sex, age, rurality (Accessibility and Remoteness Index of Australia (ARIA)),⁵³ state of residence, Indigenous and smoking status. Baseline HbA1c was based on the final test in the pre-exposure period. A measure of comorbidity was calculated based on the RxRisk comorbidity index.⁵⁴ The RxRisk index identifies up to 46 conditions, based on an individual having prescriptions for medications pathognomonic for these conditions. The index provides an integer ranging from 0 to 46 indicating the number of RxRisk conditions present, based on 5 years of prescription data prior to the exposure period. The frequency of GP contacts in the exposure period was also captured, that is, the count of visits made by the patient to the general practice captured in the CIS. Categories for all covariates are displayed in table 1. Missing values were treated as a separate category so as to prevent data loss in regression models.

Practice-level characteristics included the Socio-Economic Index for Areas-Index of Relative Social Disadvantage decile of the practice⁵⁵ and practice rurality (ARIA). Practice size was based on the number of GPs working at each practice.

Statistical analysis

Descriptive statistics were generated for sociodemographics, health service use variables, outcomes and practice characteristics.

Data were multilevel, with patients nested within practices. Patients may see multiple GPs at one practice hence patients were not nested within providers. Patients may also visit multiple practices, but in the data patient IDs were practice-specific, hence patients could not be tracked across practices. Random intercept logistic regression models were used, common in analysing general practice data.^{56 57} The same analysis was applied to all outcomes. Intraclass correlation coefficients (ICCs) were calculated to determine the proportion of variation in outcomes determined by the practice level by fitting

Table 1 Characteristics of cohort and practices contributing data

Variable		N	%
Sociodemographics			
Sex	Male	12 349	54.18
	Female	10 437	45.79
	Not stated¶	<5	–
Age	20–29	167	0.73
	30–39	826	3.62
	40–49	2301	10.10
	50–59	4951	21.72
	60–69	7792	34.19
	70–79	6754	29.63
Rurality	Major cities	14 391	63.14
	Inner regional	5797	25.44
	Outer regional	2216	9.72
	Remote	256	1.12
	Very remote	50	0.22
	Missing	81	0.36
State	New South Wales	15 847	69.53
	Western Australia	6944	30.47
Indigenous status	Aboriginal/TSI	865	3.80
	Neither	18 781	82.41
	Not stated	3145	13.80
Smoking	Smoker	2826	12.40
	Ex-smoker	8230	36.11
	Non-smoker	10 652	46.74
	Not stated	1083	4.75
Health service use (exposure period)*			
Frequency	0–4	8276	36.31
	5–9	8161	35.81
	10–14	3559	15.62
	15+	2795	12.26
Practice-specific UPC	0–0.39	6657	29.21
	0.4–0.59	5231	22.95
	0.6–0.99	3507	15.39
		7396	32.45
CDM† item	No	8125	35.65
	Yes	14 666	64.35
Rx-risk comorbidity conditions‡	0	874	3.83
	1–2	3852	16.90
	3–4	5577	24.47
	5–6	5339	23.43
	7+	7149	31.37
Outcome variables (outcome period)§			
HbA1c overuse	No	19 525	85.67
	Yes	3266	14.33
HbA1c underuse	No	9129	40.06
	Yes	13 662	59.97

Continued

Table 1 Continued			
Variable		N	%
eGFR underuse	No	16 719	73.36
	Yes	6072	26.64
HbA1c within target on first test in follow-up	No	12 708	55.76
	Yes	6667	24.87
	No test	4416	19.38
Total		22 791	100
Practice characteristics			
State	New South Wales	140	72.54
	Western Australia	53	27.46
SEIFA decile	1 (most disadvantage)	9	4.66
	2	18	9.38
	3	22	11.46
	4	24	12.50
	5	14	7.29
	6	34	17.71
	7	§	4.17
	8	13	6.74
	9	26	13.54
	10 (least disadvantage)	26	13.54
Missing	<5	–	
Practice rurality	Major cities	125	64.77
	Inner regional	39	20.21
	Outer regional	23	11.92
	Remote/very remote	*	3.11
No of GPs	1	68	35.23
	2–9	63	32.64
	10–19	45	23.32
	20+	17	8.81
No of patients	<750	38	19.69
	750–999	20	10.36
	1000–1499	54	27.98
	1500–1999	29	15.03
	2000+	52	26.94
Total		193	100

*March 2015–February 2016.

†Reimbursement to GP for certain care coordination activities.

‡Over 5-year period to end of exposure.

§March 2016–June 2017.

¶Where cell is <5, other values on variable altered to protect confidentiality.

CDM, Chronic Disease Management; eGFR, estimated glomerular filtration rate; GP, general practitioner; HbA1c, glycosylated haemoglobin; SEIFA, Socio-Economic Index for Areas; TSI, Torres Strait Islander; UPC, Usual Provider of Care.

an empty model (no explanatory variables) using the `xtmelogit` command in Stata V.14.³⁵

Models included all patient-level exposures and covariates described under those sub-headings. For the

assessment of HbA1c overuse and underuse, two separate logistic regression models were used rather than an ordered logistic regression characterising underuse/overuse/appropriate use. This was because drivers of overuse and underuse may have differed, and because there was no clear ordering of these three levels, that is, neither underuse or overuse could be considered closer to appropriate use.

Effect modification

Effect modification was assessed in relation to the number of providers and patient comorbidity variables, as these practice and patient characteristics may influence patterns of GP contact and/or the outcomes examined. Each of the four models in the main analysis (ie, one model per outcome) was repeated twice, once including interactions with the number of providers (for all three exposure variables), and once with the exposures interacted with patient comorbidity. Each of these eight unrestricted models was compared with the equivalent restricted model (ie, the main analysis for each outcome) using likelihood ratio tests using Stata's `lrtest` command. Where the likelihood ratio test was significant, the full output of the unrestricted model was reported and interpreted.

Sensitivity analysis: all diabetes

Many of the diagnosis records mentioned diabetes without stating the type, meaning that there were likely some patients with type 2 diabetes excluded from the study cohort (as only those with a clear indication of type 2 diabetes were included). As a sensitivity analysis, we identified the cohort of all patients with diabetes (type 1, type 2 and where type was unspecified), as the outcomes assessed here are also relevant to type 1 diabetes.^{39,40} All analyses were repeated for this cohort to understand if this uncertainty over diabetes type may have influenced results.

Patient and public involvement

Patients were not involved in the design or conduct of this research. NPS MedicineWise maintain a web page for consumers with information on why and how their data may be used along with details of approved studies, and provide information to participating practices to display in waiting areas.

RESULTS

Cohort characteristics

Table 1 displays descriptive statistics of the 22 791 individuals and 193 practices included. A flow chart detailing cohort selection is included as online supplemental file 1. Most were male (54.2%), lived in major cities (63.1%), were non-Indigenous (82.4%) and were non-smokers or ex-smokers (82.9%), while the largest age group was 60–69 (34.2%). Almost all had medications for at least one comorbidity (96.2%). Fourteen per cent had

Table 2 Univariate relationships between three exposures and each outcome

Exposure		Process of care outcomes			Clinical outcome
		HbA1c underuse	HbA1c overuse	eGFR underuse	HbA1c within target on first test in f/up
Regularity	Least	65.77	12.33	31.66	29.73
	2	59.35	14.44	25.95	31.17
	3	57.31	14.90	24.77	31.88
	4	56.60	15.38	23.94	30.09
	Most	56.70	14.61	26.89	31.28
Significance		$\chi^2(4)=84.8, p<0.001$	$\chi^2(4)=20.5, p<0.001$	$\chi^2(4)=85.2, p<0.001$	$\chi^2(4)=5.4, p=0.245$
Practice-specific UPC index	0–0.39	56.21	17.65	24.83	31.51
	0.4–0.59	56.67	15.85	26.34	30.69
	0.6–0.99	63.05	12.69	29.54	30.76
	1	62.74	11.05	27.11	30.35
Significance		$\chi^2(3)=80.2, p<0.001$	$\chi^2(3)=142.3, p<0.001$	$\chi^2(3)=27.3, p<0.001$	$\chi^2(3)=1.9, p=0.598$
CDM*	No	71.54	9.83	34.54	29.75
	Yes	53.52	16.82	22.27	31.36
Significance		$\chi^2(1)=707.6, p<0.001$	$\chi^2(1)=207.9, p<0.001$	$\chi^2(1)=402.5, p<0.001$	$\chi^2(1)=4.9, p=0.027$

For process of care outcomes n=22 791, for the clinical outcome n=18 381. Displaying % of each group with outcome.

*Reimbursement to GP for certain care coordination activities.

CDM, chronic disease management; eGFR, estimated glomerular filtration rate; GP, general practitioner; HbA1c, glycosylated haemoglobin; UPC, Usual Provider of Care.

records indicating HbA1c overuse during the follow-up, 60.0% underuse and 26.7% had records indicating eGFR underuse. One-quarter (24.9%) had an HbA1c result within target on the first test during follow-up while 19.4% had no HbA1c test; of those with at least one test during follow-up the result on the first test was within target for 30.8%. Most practices (64.8%) were in major cities, 35.2% were solo practices and 8.8% had over 20 GPs. Both the regularity and UPC measures showed significant, positive correlations between the exposure and follow-up periods, indicating these measures were stable over time (online supplemental file 3).

Univariate analyses are presented in table 2. Informational continuity was associated with an increased likelihood of recording an HbA1c result within target (31.4% among those with a CDM record compared with 29.8% among those without, $p=0.027$), though relational continuity and regularity were not. All exposures were associated with each process of care measure. Underuse of HbA1c and eGFR were each most likely among the least regular quintile and those without a CDM item, while HbA1c overuse showed the reverse. UPC results differed, HbA1c and eGFR underuse were most likely among the high relational continuity group, while HbA1c overuse was most likely among the low relational continuity group. There were weak correlations between each pair

of exposure variables during the exposure period (online supplemental file 3).

Model outcomes

ICCs for each outcome are presented in table 3. The practice level explained 11.7% of the variation in HbA1c underuse, 15.5% of HbA1c overuse, 21.5% of eGFR underuse and 1.6% of the HbA1c within target range outcome.

Model outputs, displaying ORs for exposures of interest only, are presented in figure 1 with full outputs in online supplemental file 4. Higher regularity (adjusted for practice-specific UPC, CDM and other covariates) was associated with reduced odds of HbA1c underuse (OR for most regular group 0.74, 95% CI 0.67 to 0.81) and

Table 3 Intraclass correlation coefficients (ICCs)

Outcome variable	ICC
HbA1c underuse	0.117
HbA1c overuse	0.155
eGFR underuse	0.215
HbA1c within target	0.016

eGFR, estimated glomerular filtration rate; HbA1c, glycosylated haemoglobin.

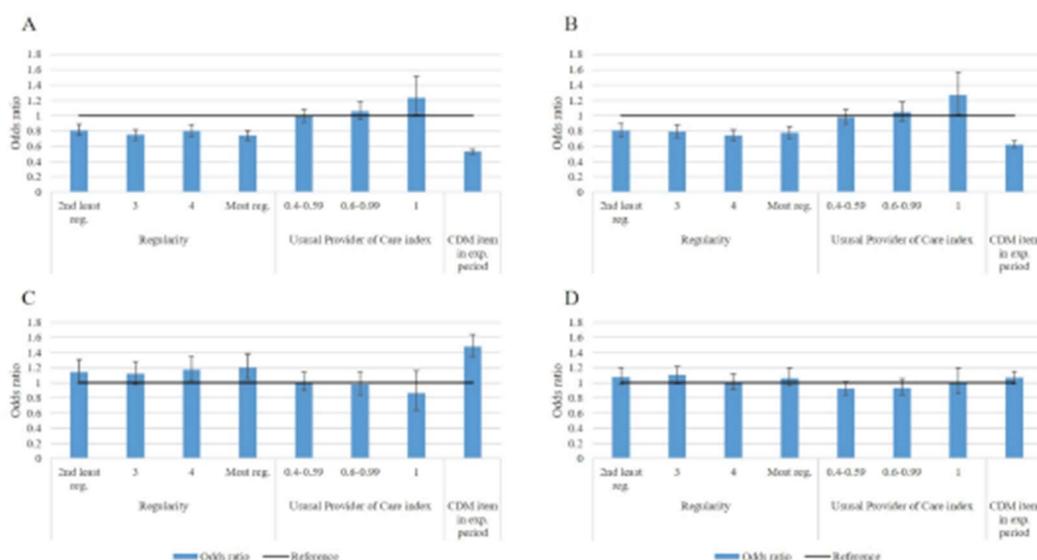


Figure 1 Outputs of regression models, ORs for exposures of main interest only. Outcomes represented are: (A) HbA1c underuse, (B) eGFR underuse, (C) HbA1c overuse and (D) recording a HbA1c value within target range on first measure during follow-up. Bars represent ORs while black lines represent reference values, that is, the least regular, lowest continuity and no chronic disease management (CDM) item groups. eGFR, estimated glomerular filtration rate; HbA1c, glycosylated haemoglobin.

eGFR underuse (OR for most regular group 0.78, 95% CI 0.70 to 0.86). A dose–response relationship was not observed. Higher regularity was also associated with higher odds of HbA1c overuse (OR for most regular group 1.20, 95% CI 1.05 to 1.38). For the outcome of HbA1c result within target, ORs for regularity were positive (ie, increased odds of a result within targets) but non-significant. Similar patterns were seen for informational continuity, which was associated (adjusted for regularity, practice-specific UPC and other covariates) with reduced odds of HbA1c underuse (OR 0.53, 95% CI 0.49 to 0.56), reduced eGFR underuse (OR 0.62, 95% CI 0.58 to 0.67) and higher odds of HbA1c overuse (OR 1.48, 95% CI 1.34 to 1.64). This exposure also had a non-significant positive association with recording HbA1c within target (OR 1.07, 95% CI 0.99 to 1.15). Results differed for the practice-specific UPC index. The perfect UPC group (adjusted for regularity, CDM and other covariates) was more likely to report HbA1c underuse (OR 1.24, 95% CI 1.01 to 1.52) and eGFR underuse (OR 1.27 95% CI 1.02 to 1.57) though no other significant associations were observed.

Of the covariates, age reported significant associations with all outcomes as did comorbidity, socioeconomic status was associated with the three process of care indicators, and indigenous status was associated with all outcomes apart from HbA1c overuse. Results for these and other covariates are available in online supplemental file 4.

Effect modification

Outputs of likelihood ratio tests are provided in online supplemental file 3 along with full outputs of unrestricted models in cases where the likelihood ratio test was significant. The only interaction with a significant likelihood ratio test was the model of eGFR underuse with practice size as the effect modifier (χ^2 (21)=36.55, $p=0.019$). In this model the only significant interaction term was the interaction of having a CDM item with the largest practice size (20+ providers). The OR for this interaction was 0.71 ($p=0.001$) indicating that the negative association between having a CDM completed and eGFR underuse (ie, a beneficial association) was greater where the practice size was larger.

Sensitivity analysis

Outcomes of sensitivity analysis are reported in online supplemental file 5. The cohort of all people with diabetes (irrespective of type) was 34% larger than the T2DM cohort ($n=30\ 453$). Cohort characteristics were similar, with relative sizes of groups differing by 1%–2%.

In terms of model outcomes, the ORs for regularity did not change substantially on any outcome, with the largest being a change of 0.04 for one level of regularity in relation to HbA1c overuse, and significance mostly unchanged (the exception being one additional level of regularity being significant in relation to HbA1c overuse). ORs for the CDM items also matched the main analysis, with the exception of the HbA1c within target outcome for which the positive association became significant

(likely due to the larger cohort size). Regarding practice-specific UPC, ORs for HbA1c overuse outcomes remained non-significant in all cases. Associations with HbA1c and eGFR underuse were non-significant at all levels in contrast to the T2DM cohort for which perfect UPC had a positive association with these outcomes. The moderate UPC group had a negative association with the likelihood of recording HbA1c within target range though the high and perfect practice-specific UPC groups had no such associations; whereas in the T2DM cohort no level of UPC was associated with this outcome.

DISCUSSION

Regularity of GP contact was associated with processes of care, as was informational continuity. Interpersonal continuity measured via practice-specific UPC was generally not associated with these outcomes, with the exception of perfect UPC (all visits to the same GP) being associated with underuse of HbA1c and eGFR. The clinical outcome, HbA1c within target, was not significantly associated with any exposure in the main analysis.

The practice level accounted for a smaller proportion of the variation in HbA1c results than it did for processes of care. This makes sense as the GP/practice has a direct role in test ordering while blood glucose is determined by factors over which the GP has a more indirect influence (diet,⁴¹ lifestyle,⁴² medication adherence,⁴³ genetics,⁴⁴ etc). This may also partially explain the lack of significant association most exposures had with HbA1c level. Similarly, GPs may decide to adopt different treatment targets for some patients. Although associations with this outcome were non-significant, ORs did consistently point in the same direction as for process of care measures, and non-significant associations may reflect a modest effect size and insufficient power for this outcome rather than clear evidence of a null effect. The fact that the CDM item exposure was associated with this outcome in the sensitivity analysis supports this.

Continuity of care was assessed using two measures with contrasting results. Informational continuity reported results in line with regularity, while relational continuity differed; perfect UPC was associated with an increased likelihood of monitoring tests being missed. The limitation of the UPC here is that patient identifiers were practice specific and not all practices participate in MedicineInsight, hence some of those with high or perfect UPC may also have visited non-participating GPs and in reality had lower continuity than observed here. Meanwhile the baseline group is made up of people with all (recorded) visits to the same practice even if different providers were seen, hence interpretation of this index differs compared with most studies. The NPS are undertaking work to allow for observation of patients across practices,²⁴ which would allow UPC and other indices to be calculated more accurately. In 2017 53% of patients in Australia visited only one practice, 30% visited two, with the remainder visiting three or more.⁴⁵ Studies of

patient preferences have assessed whether patients value informational or relational continuity more highly, with conflicting results.^{46,47} There was some evidence that the impact of CDM activities may be modified by practice size, with the benefits in terms of eGFR testing greater for larger practices, suggesting that shared care plans may become more important in settings where interpersonal continuity is more difficult to achieve. In practice relational continuity implies the presence of informational continuity, so there is never a 'trade-off' between these. Trade-offs may exist between relational continuity and access (eg, policies which promote rapid GP access may reduce the chance of seeing the same GP)⁴⁸ and in this context evidence regarding the value of relational continuity in isolation from informational continuity may be meaningful.

Although this is the first work to assess associations between regular GP contacts and diabetes control, some papers have assessed the effects of continuity on comparable outcomes, with inconsistent results. One large-scale study set in Israel found that continuity (UPC) had no effect on diabetes monitoring, but was associated with lower HbA1c.⁴⁹ In this study, patients could be observed visiting different practices, interpretation of UPC differed from the current work. A study from the USA using a similar continuity measure was set at a single practice, so was comparable in the measurement of relational continuity. This study reported similar findings to the work from Israel, that is, continuity had no effect on monitoring tests but led to improvements in HbA1c.⁵⁰ However, another single-site study from the USA found that having a personal physician did not influence the odds of a healthy HbA1c result.⁵¹ Comparisons across settings are challenging due to differences in payment mechanisms which may influence pathology ordering, potential financial barriers faced by patients influencing visit patterns, and other contextual differences.

This study found contrasting results for HbA1c underuse and overuse outcomes. Increased regularity and informational continuity were each associated with a reduced likelihood of underuse but an increased likelihood of overuse, making interpretation challenging. Effect sizes were larger in relation to the underuse outcomes (based on absolute coefficient values), so the beneficial effects for one outcome may outweigh the negative effects on the other. Of course, this assumes that HbA1c underuse and overuse are equally problematic, which may not be the case. Nonetheless, for the eGFR test, where overuse is not an issue in the same way, beneficial associations were observed. We did not develop an overall indicator of appropriate/inappropriate testing. As the drivers of overuse and underuse appear to differ, we considered that any attempt to produce a single measure would likely obfuscate this information and provide less meaningful results. These results indicate that patterns of primary care contact may be influential in terms of the quality of care received by patients. Previous studies have suggested associations between continuity/regularity of

care and hospitalisation outcomes.^{2,4,6} The current work adds to this literature by presenting some evidence for pathways via which such associations may occur, though further research may be required to understand the discrepancy in findings between process of care outcomes and the clinical indicator assessed. At the practice level, these findings reinforce the need for practices to maintain continuity with patients to support the delivery of quality care.

Strengths and limitations

This work is strong in several respects. The availability of pathology test ordering and results supported the assessment of multiple intermediate outcomes. The MedicineInsight data provided a large study cohort and important covariates at the patient and practice levels. The longitudinal design prevents reverse causation bias.

There are also limitations to this analysis. First, the lack of visit data on visits to practices not participating in MedicineInsight is a limitation, as discussed previously, which impacts the interpretation of UPC. As the data were not generated for research purposes, it is inevitable that some potentially useful information (eg, patient health behaviours and attitudes) were mostly unavailable (except smoking status). This work aims to better understand causal pathways influencing hospitalisation outcomes. Being a general practice collection, MedicineInsight does not include information on hospitalisations, hence it was not possible to investigate the role of these intermediate outcomes as mediators.

Results reported here may differ outside of the Australian context. Different registration systems, financial barriers, payment systems and diagnostic test ordering approaches must be considered when considering relationships elsewhere. Although findings of the sensitivity analysis capturing all people with diabetes were generally similar to the main analysis of T2DM, there were some minor differences in results. This may suggest that findings here may not be generalisable to cohorts with type 1 diabetes.

Missing data can be an issue in any study making secondary use of routinely collected data. We have managed this issue by using the fields least likely to suffer from missing data for our exposures and outcomes of main interest. Our exposures, being patterns of GP contact, only rely on a record being created for each GP visit, while the pathology data used for outcomes are transmitted electronically from pathology labs to practice CIS's and results stored in the correct fields. Missing information on covariates was managed by recoding these records as a separate category to prevent data loss.

Finally, in interpreting the outcome of HbA1c results, patients with no HbA1c tests during follow-up were necessarily omitted, which could bias findings. If lower regularity is associated with both a reduced likelihood of HbA1c testing being performed (which these results suggest), and poorer HbA1c control, the omission of

those patients with no tests during follow-up would bias results towards a null or negative effect.

CONCLUSION

Previous works have demonstrated associations between regularity/continuity of GP contact and hospitalisation outcomes, with authors hypothesising that any beneficial effects result from improved patient monitoring and treatment. This analysis demonstrated that among patients with T2DM, more regular GP contact was associated with a reduced likelihood of monitoring tests being missed, but this is balanced against an increased likelihood of overtesting, which may represent inefficient use of resources and potentially suboptimal patient care. Overall regular GP contacts were associated with small, non-significant associations with the likelihood of recording HbA1c results within a healthy range. Similar results were observed in relation to informational continuity. It is plausible that associations with hospital and emergency department outcomes occur via these intermediate outcomes.

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Patient consent for publication Not applicable.

Ethics approval Approvals were granted by the Curtin University Human Research Ethics Committee, HRE2017-0579, and the MedicineInsight independent external Data Governance Committee on 22 August 2017, reference 012-2017.

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Data availability statement Data may be obtained from a third party and are not publicly available.

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8.3 Interactions between regularity and continuity

8.3.1 Introduction

In this section, interactions between regularity and continuity measures are assessed in terms of their associations with the processes of care and evaluated health outcomes included in Manuscript 4. While interaction analyses reported in Chapter 7 did not find evidence for interactions between these exposures, the current chapter assesses a different cohort, investigates different outcomes (processes of care and evaluated health outcomes, rather than use of tertiary health services in Chapter 7) and uses different statistical analyses. Assessment of interactions in additional cohorts and contexts will provide a stronger understanding as to the generalisability the results reported in Chapter 7.

8.3.2 Methods

Methods used here reflected the methods described within manuscript 4 in terms of the cohorts selected, exposure variables of interest, outcomes, covariates and modelling approach. In order to assess interactions between regularity and continuity measures, the four models described in Manuscript 4 were modified to include an interaction between regularity (quintiles) and practice-specific UPC (four levels), and an interaction between regularity and completion of the CDM item (binary indicator). The presence of potential interactions was assessed based on the p-values of the 12 coefficients resulting from the regularity x UPC interaction, and the four levels of the regularity x CDM interaction, for the models assessing each of the four outcomes. Likelihood ratio tests were additionally performed in which the unrestricted model for each outcome (i.e. including the interaction terms) was compared to the restricted model (without interactions, i.e. models reported in manuscript 4); the p-value of the likelihood ratio test is reported as a global test of the significance of all interaction terms for each model.

8.3.3 Results

Analyses suggested little evidence of interactions between regularity and practice-specific UPC or CDM items. For the outcome of HbA1c underuse (Table 8-1) none of the 16 interaction terms were significant nor was the likelihood ratio test ($\text{Chi}^2(16)=9.89$, $p=0.872$); results were similar for the outcome of eGFR underuse (Table 8-2) (likelihood ratio test $\text{Chi}^2(16)=15.20$, $p=0.510$). For the outcome of HbA1c overuse, there was a significant interaction term for one level of the regularity x practice-specific UPC interaction and one level of the regularity x CDM item interaction (Table 8-3), however the likelihood ratio test remained non-significant ($\text{Chi}^2(16)=23.43$, $p=0.103$). For the one evaluated health outcome of recording an HbA1c within target range (Table 8-4), there were no significant interaction terms and a non-significant likelihood ratio test ($\text{Chi}^2(16)=18.62$, $p=0.289$).

Table 8-1: Model for outcome of HbA1c underuse, including interactions between regularity and measures of continuity, presenting coefficients for exposures of interest only

Variable	Level		OR	SE	Lower CI	Upper CI
Regularity quintile main effect	Least regular	2	0.81	0.09	0.65	1.01
		3	0.72	0.08	0.58	0.89
		4	0.74	0.08	0.60	0.92
			0.63	0.07	0.51	0.78
	Most regular		Reference			
Usual Provider of Care Index main effect	0 - 0.39 0.40 - 0.59 0.60 - 0.99	1	1.30	0.17	1.01	1.67
			0.98	0.09	0.82	1.17
			1.04	0.12	0.84	1.29
			Reference			
CDM item main effect			0.48	0.04	0.41	0.55
Regularity x UPC interaction	2nd reg. quintile x 0.40 - 0.59		0.96	0.12	0.75	1.23
			0.93	0.14	0.70	1.25
	2nd reg. quintile x 0.60 - 0.99		0.87	0.10	0.68	1.10
			1.06	0.14	0.83	1.37
	3rd reg. quintile x 0.40 - 0.59		0.99	0.15	0.74	1.33
			0.99	0.12	0.78	1.25

	4th reg. quintile x 0.40 - 0.59	0.96	0.12	0.75	1.24
	4th reg. quintile x 0.60 - 0.99	1.10	0.16	0.83	1.47
	4th reg. quintile x 1	0.92	0.11	0.73	1.17
	Most reg. quintile x 0.40 - 0.59	1.09	0.14	0.85	1.41
	Most reg. quintile x 0.60 - 0.99	1.06	0.15	0.80	1.41
	Most reg. quintile x 1	1.01	0.12	0.80	1.28
Regularity x CDM interaction	2nd reg. quintile x CDM completed	1.11	0.11	0.91	1.35
	3rd reg. quintile x CDM completed	1.05	0.11	0.86	1.29
	4th reg. quintile x CDM completed	1.15	0.12	0.94	1.40
	Most reg. quintile x CDM completed	1.21	0.12	1.00	1.47

Table 8-2: Model for outcome of eGFR underuse, including interactions between regularity and measures of continuity, presenting coefficients for exposures of interest only

Variable	Level	OR	SE	Lower CI	Upper CI
Regularity quintile main effect	Least regular	Reference			
	2	0.89	0.10	0.71	1.11
	3	0.85	0.10	0.68	1.08
	4	0.65	0.08	0.52	0.83
	Most regular	0.73	0.08	0.58	0.92
Usual Provider of Care Index main effect	0 - 0.39	Reference			
	0.40 - 0.59	0.95	0.10	0.78	1.17
	0.60 - 0.99	1.01	0.12	0.80	1.26
	1	1.26	0.17	0.96	1.65
CDM item main effect		0.63	0.05	0.55	0.73
Regularity x UPC interaction	2nd reg. quintile x 0.40 - 0.59	0.88	0.13	0.67	1.17
	2nd reg. quintile x 0.60 - 0.99	0.89	0.14	0.64	1.22
	2nd reg. quintile x 1	0.96	0.13	0.74	1.25
	3rd reg. quintile x 0.40 - 0.59	1.07	0.15	0.80	1.42
	3rd reg. quintile x 0.60 - 0.99	1.06	0.17	0.77	1.45
	3rd reg. quintile x 1	0.97	0.13	0.74	1.26
	4th reg. quintile x 0.40 - 0.59	1.02	0.15	0.76	1.36
	4th reg. quintile x 0.60 - 0.99	1.13	0.18	0.82	1.55
	4th reg. quintile x 1	1.00	0.14	0.76	1.30
	Most reg. quintile x 0.40 - 0.59	1.21	0.18	0.91	1.62

	Most reg. quintile x 0.60 - 0.99	1.13	0.18	0.83	1.54
	Most reg. quintile x 1	1.09	0.15	0.84	1.43
Regularity x CDM interaction	2nd reg. quintile x CDM completed	0.96	0.10	0.78	1.18
	3rd reg. quintile x CDM completed	0.86	0.09	0.70	1.06
	4th reg. quintile x CDM completed	1.18	0.13	0.95	1.45
	Most reg. quintile x CDM completed	0.95	0.10	0.78	1.17

Table 8-3: Model for outcome of HbA1c overuse, including interactions between regularity and measures of continuity, presenting coefficients for exposures of interest only

Variable	Level	OR	SE	Lower CI	Upper CI	
	Least regular	Reference				
		2	1.34	0.22	0.97	1.85
		3	1.09	0.19	0.78	1.52
		4	1.27	0.21	0.92	1.75
Regularity quintile main effect	Most regular		1.53	0.25	1.11	2.10
	0 - 0.39	Reference				
	0.40 - 0.59		0.90	0.12	0.69	1.17
Usual Provider of Care Index main effect	0.60 - 0.99		0.85	0.15	0.60	1.19
		1	0.89	0.17	0.62	1.29
CDM item main effect			1.79	0.21	1.43	2.24
	2nd reg. quintile x 0.40 - 0.59		1.09	0.20	0.76	1.55
	2nd reg. quintile x 0.60 - 0.99		0.97	0.22	0.62	1.52
	2nd reg. quintile x 1		0.94	0.16	0.67	1.32
	3rd reg. quintile x 0.40 - 0.59		1.10	0.20	0.76	1.58
	3rd reg. quintile x 0.60 - 0.99		1.69	0.37	1.09	2.61
	3rd reg. quintile x 1		1.13	0.19	0.81	1.58
	4th reg. quintile x 0.40 - 0.59		1.26	0.23	0.88	1.79
	4th reg. quintile x 0.60 - 0.99		1.28	0.28	0.83	1.97
	4th reg. quintile x 1		0.88	0.15	0.63	1.24
	Most reg. quintile x 0.40 - 0.59		1.18	0.22	0.82	1.69
	Most reg. quintile x 0.60 - 0.99		0.96	0.21	0.62	1.49
Regularity x UPC interaction	Most reg. quintile x 1		0.94	0.16	0.67	1.32
	2nd reg. quintile x CDM completed		0.81	0.12	0.59	1.09
Regularity x CDM interaction	3rd reg. quintile x CDM completed		0.87	0.14	0.64	1.18

4th reg. quintile x CDM completed	0.84	0.13	0.63	1.14
Most reg. quintile x CDM completed	0.70	0.10	0.52	0.93

Table 8-4: Model for outcome of HbA1c within target, including interactions between regularity and measures of continuity, presenting coefficients for exposures of interest only

Variable	Level	OR	SE	Lower CI	Upper CI	
	Least regular	Reference				
		2	1.14	0.14	0.89	1.46
		3	1.09	0.14	0.85	1.40
		4	0.94	0.12	0.73	1.20
Regularity quintile main effect	Most regular		0.85	0.11	0.66	1.09
	0 - 0.39	Reference				
	0.40 - 0.59		0.90	0.10	0.73	1.11
	0.60 - 0.99		0.91	0.11	0.72	1.17
Usual Provider of Care Index main effect		1	0.96	0.12	0.75	1.22
CDM item main effect			1.03	0.08	0.87	1.21
	2nd reg. quintile x 0.40 - 0.59		0.86	0.13	0.65	1.15
	2nd reg. quintile x 0.60 - 0.99		0.89	0.15	0.64	1.24
	2nd reg. quintile x 1		0.95	0.13	0.73	1.25
	3rd reg. quintile x 0.40 - 0.59		0.95	0.14	0.72	1.27
	3rd reg. quintile x 0.60 - 0.99		1.07	0.18	0.77	1.49
	3rd reg. quintile x 1		0.90	0.12	0.69	1.18
	4th reg. quintile x 0.40 - 0.59		1.18	0.17	0.88	1.58
	4th reg. quintile x 0.60 - 0.99		1.14	0.19	0.82	1.59
	4th reg. quintile x 1		1.18	0.16	0.91	1.55
	Most reg. quintile x 0.40 - 0.59		1.19	0.18	0.89	1.60
	Most reg. quintile x 0.60 - 0.99		1.05	0.17	0.76	1.45
Regularity x UPC interaction	Most reg. quintile x 1		1.23	0.17	0.94	1.62
	2nd reg. quintile x CDM completed		1.03	0.12	0.82	1.29
	3rd reg. quintile x CDM completed		1.06	0.12	0.84	1.33
	4th reg. quintile x CDM completed		0.95	0.11	0.76	1.18
Regularity x CDM interaction	Most reg. quintile x CDM completed		1.19	0.13	0.95	1.49

8.3.4 Conclusions

These results suggest that effects of the regularity and continuity measures adopted here are additive rather than multiplicative, i.e., any potential benefit of regularity is similar regardless of the level of continuity between the patient and their providers, and vice-versa. This is consistent with the minimal evidence for interactions between these exposures reported in Chapter 7. This is relevant to the planning of policy, in that it provides some insight into the possible impact of policies which may have differing effects on the regularity and continuity experienced by patients. The assessment of interactions here is limited to a single cohort of patients with diabetes and assesses only a specific set of process and outcome indicators. Interactions are further assessed in a different cohort with a different outcome in section 9.3. Section 9.3 additionally includes a fuller comparison of measures of regularity and continuity in terms of their relationships with other patient characteristics, facilitated by the use of the self-reported 45 and Up Study data used in that chapter.

8.4 Sensitivity analysis – alternative continuity measure

8.4.1 Introduction

As discussed in section 2.2.2.6, there are several different potential measures of continuity which are calculated differently, with different conceptual underpinnings and advantages and disadvantages. The main analysis in Manuscript 4 made use of the Usual Provider of Care (UPC) index, a density measure. In this section a sensitivity analysis is performed in which continuity is measured using the Continuity of Care (COC) index, a dispersion measure.

8.4.2 Methods

Methods used here reflect those reported in Manuscript 4, section **Error! Reference source not found.** For analyses here, the practice-specific UPC is replaced by a practice-specific COC, calculated according to the equation in section 3.3.1. For each of the four outcomes assessed in Manuscript 4, odds ratios are reported for the exposures of interest only, for both the models using UPC (i.e. replicating the results reported in Manuscript 4) and for models using COC, to allow the impact of the choice of continuity index to be assessed for all exposures and outcomes.

8.4.3 Results

Table 8-5 to Table 8-8 demonstrate changes in odds ratios and significance resulting from changes in the continuity index used. For the exposures of regularity and completion of a CDM item, there is no change in any odds ratio or associated significance level when the UPC index is replaced with the COC index. Of greater interest is the difference in odds ratios for the COC index itself compared to the UPC index. The largest observed difference between the two indexes is a change in OR from 0.92 to 0.99 for the second lowest level of continuity (reference category lowest continuity) in the model assessing the recording of a healthy HbA1c on the first test during follow-up (Table 8-8). However in this case ORs are non-significant in both cases. In general, ORs are within 0.02 units of each other across most models, and there are no examples of the choice of index changing an OR from significant – non-significant or vice-versa.

Table 8-5: Odds ratios from models assessing HbA1c underuse among patients with type 2 diabetes mellitus, models using the UPC and COC indices, n=22,752.

UPC as continuity measure			COC as continuity measure		
	OR	P-value		OR	P-value
Regularity			Regularity		
Least regular	Reference		Least regular	Reference	
2	0.81	<0.005	2	0.81	<0.005
3	0.75	<0.005	3	0.75	<0.005
4	0.80	<0.005	4	0.80	<0.005
Most regular	0.74	<0.005	Most regular	0.74	<0.005
UPC index			COC index		
0-0.39	Reference		0-0.39	Reference	
0.40-0.59	1.00	0.909	0.40-0.59	1.02	0.737
0.60-0.99	1.06	0.285	0.60-0.99	1.04	0.483
1	1.24	0.036	1	1.23	0.043
CDM item in exp. period	0.53	<0.005	CDM item in exp. period	0.53	<0.005

OR = odds ratio, UPC= usual provider of care, COC = continuity of care, CDM = chronic disease management.

Outcome of HbA1c underuse was an eight-month period with no HbA1c test during follow-up.

Table 8-6: Odds ratios from models assessing eGFR underuse among patients with type 2 diabetes mellitus, models using the UPC and COC indices, n=22, 752.

UPC as continuity measure			COC as continuity measure		
	OR	P-value		OR	P-value
Regularity			Regularity		
Least regular	Reference		Least regular	Reference	
2	0.81	<0.005	2	0.81	<0.005
3	0.79	<0.005	3	0.79	<0.005
4	0.74	<0.005	4	0.74	<0.005
Most regular	0.78	<0.005	Most regular	0.78	<0.005
UPC index			COC index		
0-0.39	Reference		0-0.39	Reference	
0.40-0.59	0.98	0.721	0.40-0.59	1.00	0.954
0.60-0.99	1.05	0.445	0.60-0.99	1.04	0.509
1	1.27	0.032	1	1.27	0.030
CDM item in exp. period	0.62	<0.005	CDM item in exp. period	0.62	<0.005

OR = odds ratio, UPC= usual provider of care, COC = continuity of care, CDM = chronic disease management.

Outcome of eGFR underuse was a 14-month period with no eGFR test during follow-up.

Table 8-7: Odds ratios from models assessing HbA1c overuse among patients with type 2 diabetes mellitus, models using the UPC and COC indices, n=22, 752.

UPC as continuity measure	COC as continuity measure
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	OR	P-value		OR	P-value
Regularity			Regularity		
Least regular	Reference		Least regular	Reference	
2	1.14	0.050	2	1.14	0.051
3	1.12	0.098	3	1.12	0.098
4	1.18	0.015	4	1.18	0.016
Most regular	1.20	0.009	Most regular	1.20	0.010
UPC index			COC index		
0-0.39	Reference		0-0.39	Reference	
0.40-0.59	1.01	0.836	0.40-0.59	0.96	0.542
0.60-0.99	0.98	0.782	0.60-0.99	1.00	0.958
1	0.87	0.337	1	0.87	0.356
CDM item in exp. period	1.48	<0.005	CDM item in exp. period	1.48	<0.005

OR = odds ratio, UPC= usual provider of care, COC = continuity of care, CDM = chronic disease management.

Outcome of HbA1c overuse was the recording of two HbA1c tests within 80 days during follow-up

Table 8-8: Odds ratios from models assessing the recording of a healthy evel on the first test during follow-up among patients with type 2 diabetes mellitus, models using the UPC and COC indices, n=18,348.

UPC as continuity measure			COC as continuity measure		
	OR	P-value		OR	P-value
Regularity			Regularity		
Least regular	Reference		Least regular	Reference	
2	1.08	0.135	2	1.08	0.140
3	1.10	0.080	3	1.10	0.079
4	1.01	0.880	4	1.01	0.871
Most regular	1.06	0.253	Most regular	1.07	0.247
UPC index			COC index		
0-0.39	Reference		0-0.39	Reference	
0.40-0.59	0.92	0.091	0.40-0.59	0.99	0.895
0.60-0.99	0.93	0.237	0.60-0.99	0.96	0.500
1	1.01	0.922	1	1.05	0.591
CDM item in exp. period	1.07	0.079	CDM item in exp. period	1.07	0.079

OR = odds ratio, UPC= usual provider of care, COC = continuity of care, CDM = chronic disease management.

8.4.4 Discussion

The choice of continuity index did not make any notable difference to the odds ratios or significance of any of the exposures of interest. This indicates that the overall relationships recorded in Manuscript 4 are robust to the choice of measure used, despite the conceptual differences in these measures discussed in section 2.2.2.6. This sensitivity analysis has been applied to a single cohort in a study using a single modelling approach. To further assess the potential impact of the choice of continuity measure, a similar sensitivity analysis is included in Chapter 9.

8.5 Chapter summary

This chapter demonstrates that although regularity and continuity of care are associated with processes of care, as indicated by the completion of recommended pathology tests amongst patients with T2DM, this change in processes reflects both positive (reduced undertesting) and negative (increased overtesting) associations. Furthermore, there is limited evidence for these exposures having significant associations with evaluated patient health as indicated by HbA1c levels. The previous chapter demonstrated that negative associations with hospital / ED use outcomes were highly sensitive to the study design and analysis used; when the design and analysis were used which minimised the risk of bias, negative associations with use of tertiary health services disappeared. The current study builds on these findings by explicitly assessing intermediate factors expected to contribute to hospital / ED use outcomes, as an alternative approach to understand possible causal pathways. Additionally, this chapter tested for interactions between regularity and continuity in their associations with these processes of care and measures of evaluated health, finding little evidence for interactions. This is consistent with interaction analyses in Chapter 7, which found little evidence for interactions with tertiary health service use outcomes across multiple conditions. Correlations and interactions between these measures are presented with another analysis in section 9.3. This study presents a significant contribution to the literature by demonstrating that, although regularity / continuity are associated with improved processes of care, the evidence for translation into improvements on measures of evaluated health is more limited. Where the evidence for positive effects on these intermediate outcomes is limited, the interpretation of recorded associations with downstream tertiary health service use outcomes is challenged, and the suitability of these exposures as intervention targets must be questioned. A secondary contribution of this study is a demonstration of the value of alternative data collections to the commonly used administrative data in forming a stronger understanding of the relationships of interest.

Chapter 9 Impacts of regularity / continuity on statin medication adherence and cardiovascular hospitalisation

9.1 Chapter overview

Chapter 7 demonstrated that among different clinical cohorts, associations between regularity / continuity and hospital / emergency department outcomes were sensitive to study design and analysis methods. Chapter 8 then demonstrated that among patients with type 2 diabetes mellitus, regularity and continuity were associated with changes in care processes in terms of pathology testing, though this did not translate into changes in outcomes on glycosylated haemoglobin tests. This chapter extends on these analyses by examining another care processes, appropriate medication use, and further examining impacts of this care process on hospital / ED use. This analysis is performed in relation to use of statins among a cohort at risk of cardiovascular disease events, using the New South Wales 45 and Up data.

Manuscript 5 assesses the impacts of regularity and continuity on adherence to statin medication among a cohort of existing statin users, and on statin initiation among non-users. This manuscript finds that both regularity and continuity of care are each significantly associated with adherence among existing users and with initiation among non-users, suggesting that this is a plausible pathway by which downstream outcomes may be impacted. This manuscript addresses objective 4b: “Investigate associations between regularity and the appropriate use of preventive medications.” Note that where supplementary material is referred to within manuscript 5, this is included in Appendix F.

The full citation for this manuscript is:

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A subsequent analysis extends on this by performing mediation analyses, in which cardiovascular hospital / ED use are outcomes and statin use variables are mediating variables. These analyses are performed to provide for a fuller examination of the causal pathways that are assumed to exist with reference to the framework of health service use described in section 2.2.1.2. This section addresses objective 4c: “Assess appropriate medication use as a mediator of relationships between regularity and hospital / ED outcomes.” These analyses find that although regularity and continuity are associated with improved statin use, and with reductions in cardiovascular hospitalisations and ED presentations, only a small, mediated effect is present.

An additional analysis assesses the relationships between measures of regularity and continuity, both in terms of their correlations with each other, and interactions in their associations with statin use. This analysis addresses objective 2b: “Compare regularity to commonly used measures of continuity by investigating interactions between exposures in influencing outcomes.” This analysis finds that although there are small correlations between regularity and continuity, there is little evidence of interactions in their effects on statin use.

The findings in this chapter present several major contributions to the literature. The finding that regularity and continuity are associated with improvements in statin use suggests plausible pathways via which effects on hospitalisation outcomes may occur, though the findings of the mediation analysis suggest that any effect on hospitalisation via this mediator (an association shown to follow a hypothesised causal pathway) is modest. As with the findings in Chapter 7 and Chapter 8, this suggests that potential causal association between regularity / continuity and hospital / ED use outcomes may be more modest than reported in much of the literature on continuity of care. This makes a significant contribution to future researchers in the area of continuity of care, by demonstrating a method by which causal pathways can be better understood, using the administrative data typically available. This also contributes from a policy perspective. The analysis finds that although negative associations between regularity / continuity and hospital / ED outcomes exist, the proportion of this association which is via the mediator and hence more likely to reflect a causal relationship is small. This indicates that the potential benefit of policies targeting regularity or continuity may have only modest impacts on outcomes.

The findings relating to interactions between regularity and continuity are also relevant from a policy perspective. As measures of regularity and continuity both reflect patterns of general practitioner contact it is likely that any policy targeting one of these exposures will have potential to additionally impact the other. An improved understanding of how patterns of GP contact are likely to influence outcomes, across multiple dimensions, will allow for the potential impacts of primary care policy to be better understood in the future.

9.2 Manuscript 5: Regularity and continuity of GP contacts and use of statins amongst people at risk of cardiovascular events

Regularity and Continuity of GP Contacts and Use of Statins Amongst People at Risk of Cardiovascular Events



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BACKGROUND: Regularity and continuity of general practitioner (GP) contacts are associated with reduced hospitalisation. Opportunities for improved medication management are cited as a potential cause.

OBJECTIVE: Determine associations between continuity and regularity of primary care and statin use amongst individuals at risk of cardiovascular disease (CVD) outcomes.

DESIGN: Observational cohort study using self-report and administrative data from 267,153 participants of the Sax Institute's 45 and Up Study conducted in New South Wales, Australia, from 2006 to 2009. Medicare Benefits Schedule (MBS) and Pharmaceutical Benefits Scheme (PBS) data, from Services Australia, were linked to survey, hospital and death data by the NSW Centre for Health Record Linkage.

PARTICIPANTS: The 45 and Up Study participants at risk of CVD outcomes based on self-report and administrative data, divided into existing users and potential users based on dispensing records through the exposure period.

MAIN MEASURES: The Continuity of Care index (COC), measuring whether patients see the same GP, and an index assessing whether GP visits are on a regular basis, measured from July 2011 to June 2012. Amongst potential users, statin initiation from July 2012 to June 2013 was assessed using logistic regression; amongst existing users, adherence was assessed from July 2012 to June 2015 using Cox regression (non-adherence being 30 days without statins).

KEY RESULTS: Amongst 29,420 potential users, the most regular quintile had 1.22 times the odds of initiating statin (95%CI 1.11–1.34), while the high continuity group had an odds ratio of 1.12 (95%CI 1.02–1.24). Amongst 30,408 existing users, the most regular quintile had 0.82 the hazard of non-adherence (95%CI 0.78–0.87); the high continuity group had a hazard ratio of 0.89 (95%CI 0.84–0.94).

CONCLUSIONS: Regularity and continuity of care impact on medication management. It is possible that this mediates impacts on hospitalisation. Where there is a risk of unobserved confounding, potential causal pathways should be investigated.

KEY WORDS: statins; adherence; general practice; continuity of care.

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INTRODUCTION

Within primary care, continuity of care can be defined as a relationship between a practitioner and patient extending beyond specific episodes of illness or disease, implying a sense of affiliation.¹ Definitions describe continuity as including multiple dimensions, for example the 1975 definition by Hennen² which outlined chronological, geographical, interdisciplinary and interpersonal continuity. Continuity of care has been demonstrated to be associated with reduced hospitalisations,^{3–8} emergency department use,^{6, 7, 9} mortality³ and healthcare costs.^{3, 4, 6, 8} Although there are many indices for measuring continuity of care,^{10, 11} most measure whether a patient consistently visits the same general practitioner (GP) or switches between providers. In recognition of the broader definitions of the concept, our research group has assessed continuity by measuring the regularity of GP contact, as distinct from the frequency of contact. In this context, frequency refers simply to the number of GP contacts a patient may have through a measurement period, while regularity refers to the spread of these visits over time. Regular GP contact may reflect a planned and proactive approach to care, while irregular contact (a period without any GP contact followed by repeated visits in a short timeframe) may reflect more reactive care. Regular GP contact has been demonstrated to be associated with improved outcomes, including reduced hospital use in certain chronic conditions.^{12, 13}

Researchers assessing these relationships generally describe potential causal mechanisms via which GP contact may affect hospitalisation. These include an improved knowledge of the patient's health by the GP, an improved ability to detect and respond to problems and an improved patient-provider communication.^{3, 5, 7, 14} Many also suggest that where continuity of care exists, patient adherence with treatment may improve,^{3–7, 15–21} resulting from increased trust in the doctor.^{2, 5–7, 9, 22} In comparison to the volume of research assessing

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downstream outcomes of hospitalisation and mortality, there is little research assessing intermediate outcomes such as the medical management of conditions. Understanding the effects of GP contact on these outcomes is an important step to determining potential causal pathways, and hence suitability of these exposures as intervention targets.

In assessing medical management, statins present a suitable area of study, on account of their impact on hospitalisation,^{23–26} evidence that many people at high risk of cardiovascular events do not initiate statins through primary care,^{27, 28} and evidence indicating that adherence is often poor amongst those using statins.^{29–31} Improved statin use therefore presents a pathway via which regularity/continuity of GP contact may influence hospitalisation. One previous study has assessed associations between continuity of care³² (i.e. repeat visits to the same provider) and statin adherence amongst existing statin users, finding higher continuity to be associated with improved adherence. Gaps remain in the literature concerning the impact of continuity of care on the initiation of new statin therapy amongst those at risk. Additionally, the effect of regularity of GP contact on statin use has not been investigated; hence, there is potential for an improved understanding of the patterns of GP contact on statin outcomes.

The objective of this project was to determine associations between regularity/continuity of GP contact and statin initiation and adherence, amongst a cohort of patients at high risk of cardiovascular disease (CVD) or who had a prior history of CVD over a 3-year period of follow-up.

METHODS

Data

This study used the Sax Institute's 45 and Up Study,³³ based in the population of the state of New South Wales (NSW), Australia. Prospective participants were randomly sampled from the Services Australia (formerly the Australian Government Department of Human Services) enrolment database, which provides near-complete population coverage. People 80+ years of age and residents of rural and remote areas were oversampled. A total of 267,153 participants joined the study by completing a baseline questionnaire (between January 2006 and December 2009) and giving signed consent for follow-up and linkage of their information to routine health databases. About 18% of invitees participated and participants included about 11% of the NSW population aged 45 years and over.

This study used the Study baseline questionnaire (<https://www.saxinstitute.org.au/our-work/45-up-study/>) linked to (i) the NSW Admitted Patient Data Collection (APDC), covering all public and private hospital discharges (2005–2017); (ii) the Pharmaceutical Benefits Scheme (PBS) capturing dispensed subsidised prescription medicines (2005–2017); (iii) the Medicare Benefits Schedule (MBS) covering all claims for medical and

diagnostic services through Medicare, Australia's universal health insurance scheme (2005–2017); and (iv) the NSW Register of Births Deaths and Marriages (RBDM) (2006–2017). Linkage of APDC and RBDM to the survey data was conducted by the NSW Centre for Health Record Linkage (<http://www.cherel.org.au>). MBS and PBS data were supplied by Services Australia and linked by the Sax Institute using a unique identifier provided by Services Australia. Quality assurance of the data linkage method showed false-positive and false-negative rates of <0.5 and <0.1%, respectively.³⁴ CHEReL performs linkage using probabilistic matching complemented by a clerical review of uncertain matches, with reviews of random samples for quality assurance.

Approvals were provided by the Curtin University Human Research Ethics Committee and the NSW Population and Health Services Research Ethics Committee. The 45 and Up Study was approved by the University of NSW Human Research Ethics Committee.

Cohort

Our study included individuals aged 55–75 at risk of CVD as of July 2011. It was selected following Liu et al.³⁵ with modifications.

The cohort consisted of two groups: those at high risk of CVD (primary prevention group) and those with a history of CVD. Those at high risk of CVD were selected using self-reported age, sex, diabetes status, smoking status, hypertension and high cholesterol, based on a threshold equivalent to a risk of CVD over 5 years of >15% (details in Appendix 1). Those with a history of CVD were captured from (i) hospitalisation with a diagnosis of ischaemic heart disease (IHD), transient ischaemic attack (TIA), ischaemic stroke, atrial fibrillation or other CVD, or a procedure pathognomic of IHD; (ii) MBS items pathognomic of IHD or ischaemic stroke; (iii) PBS records for drugs pathognomic of IHD; or (iv) self-reported heart attack/angina/stroke or self-reported operation for heart disease or TIA (codes in Appendix 1).

The cohort was further divided into two sub-cohorts analysed separately: those taking statins during the exposure period, for whom adherence was assessed, and those who had no history of statin use, for whom the outcome was statin initiation. These are called 'existing users' and 'potential users', respectively.

Exclusions were as follows: apparent linkage errors, potential users who died during follow-up, anyone who died prior to the end of the exposure period, those with fewer than three GP contacts during the exposure period as regularity and continuity could not be calculated and those who received statin medication during the pre-exposure period but not the exposure period as categorisation of their usage is unclear. A flow chart is included in Appendix 2.

Table 1 Demographic Characteristics of 45 and Up Participants at High Risk for Cardiovascular Events According to Statin Usage during July 2011–June 2012 Exposure Period

Variable		Potential users		Existing users		Statistical significance ^f
		n	%	n	%	
Age	55–60	7,974	27.1	5,648	18.57	Chi ² (3) = 814, p<0.001
	60–65	8,128	27.63	7,898	25.97	
	65–70	7,537	25.62	9,185	30.21	
	70–75	5,781	19.65	7,677	25.25	
Gender	Male	21,597	73.41	19,263	63.35	Chi ² (1) = 699, p<0.001
	Female	7,823	26.59	11,145	36.65	
Overall health rating ^a	Excellent	3,058	10.39	1,939	6.38	Chi ² (5) = 817, p<0.001
	Very good	10,676	36.29	9,238	30.38	
	Good	10,717	36.43	12,177	40.05	
	Fair	3,643	12.38	5,194	17.08	
Quality of life rating ^a	Poor	549	1.87	935	3.07	Chi ² (5) = 336, p<0.001
	Excellent	5,887	20.01	4,829	15.88	
	Very good	10,768	36.6	10,378	34.13	
	Good	8,537	29.02	9,785	32.18	
Smoking status ^a	Fair	2,518	8.56	3,298	10.85	Chi ² (3) = 299, p<0.001
	Poor	420	1.43	603	1.98	
	Never smoker	10,206	34.69	12,495	41.09	
	Current smoker (at baseline survey)	2,614	8.89	2,298	7.56	
CVD status	Ex-smoker (at baseline survey)	16,548	56.25	15,492	50.95	Chi ² (1) = 2500, p<0.001
	High CVD risk	20,611	70.06	15,171	49.89	
Dispensing in follow-up year	History of CVD	8,809	29.94	15,237	50.11	N/A
	No	21,854	74.28	N/A		
Prescriber ^b	Yes	7,566	25.72			N/A
	GP	N/A		24,913	81.93	
Dosage ^{b, c}	Other			4,681	15.39	N/A
	Low	N/A		918	3.02	
	Moderate			16,692	54.89	
Outcome	High			11,984	39.41	N/A
	Failure (non-adherence recorded)	N/A		16,360	53.80	
	No failure (remained adherent)			13,146	43.23	
	Censored by death			902	2.97	
Variable		Median	IQR	Median	IQR	Statistical significance^g
Frequency		7	5–11	9	6–14	Z = - 38.31, p<0.001
Comorbidity measures	RxRisk (5 years) ^d	3	1–6	6	4–8	Z = - 84.93, p<0.001
	MACSS (5 years) ^e	3	0–5	3	1–6	Z = - 27.66, p<0.001
Total		29,420		30,408		

^aCells do not sum to total due to missing responses

^bReports characteristics of first statin dispensation within exposure year

^cGraded following Chou et al. 2016³⁵

^dNumber of 46 RxRisk conditions based on prior 5 years of medication dispensing records⁴³

^eNumber of Multipurpose Australian Comorbidity Scoring System (MACSS) conditions recorded in prior 5 years of hospitalisation records⁴⁴

^fBased on chi-square tests

^gBased on Wilcoxon rank-sum tests

Design

Figure 1 presents information assessed in the pre-exposure (July 2006–June 2011), exposure (July 2011–June 2012) and follow-up (July 2012–June 2015) periods.

Exposure Variables

Exposures were regularity and continuity of GP contact. GP contact was captured based on MBS claims for ‘attendances by General Practitioners.’³⁶ Regularity refers to the distribution of GP contacts over time, as distinct from the frequency (number) of contacts, with regularly spaced visits assumed to indicate planned, proactive care. This was captured using our Modified Regularity Index³⁷, based on the variation in the number of days between GP contacts. For each GP visit, the number of days since the prior visit is counted, and the coefficient of variation in this number of days calculated. An index (*R*) is calculated using the formula $R=1/1+(\text{coefficient of variation (days between visits)})$. This ranges from 0 to 1 (1

being most regular) and is grouped into quintiles based on the score’s distribution within each cohort.

Continuity measures assess whether a patient is consistently seeing the same GP, or switching between providers. Continuity was measured using the Continuity of Care (COC) index³⁸ which assesses the dispersion of visits across providers:

$$COC = \frac{\sum_{j=1}^M n_j^2 - N}{N(N-1)}$$

where *N* is the total number of GP visits, *n_j* the number of visits to GP *j*; *j*, a given GP; and *M*, the number of GPs. This formula results in a score ranging from 0 to 1. For analysis, patients are often categorised to aid interpretation though there are no universally accepted cut-offs for categorisation,^{3, 7} in this study, patients were allocated to four groups: low (index range 0–0.49), moderate (0.5–0.74), high (0.75–0.99) and perfect (1) continuity.

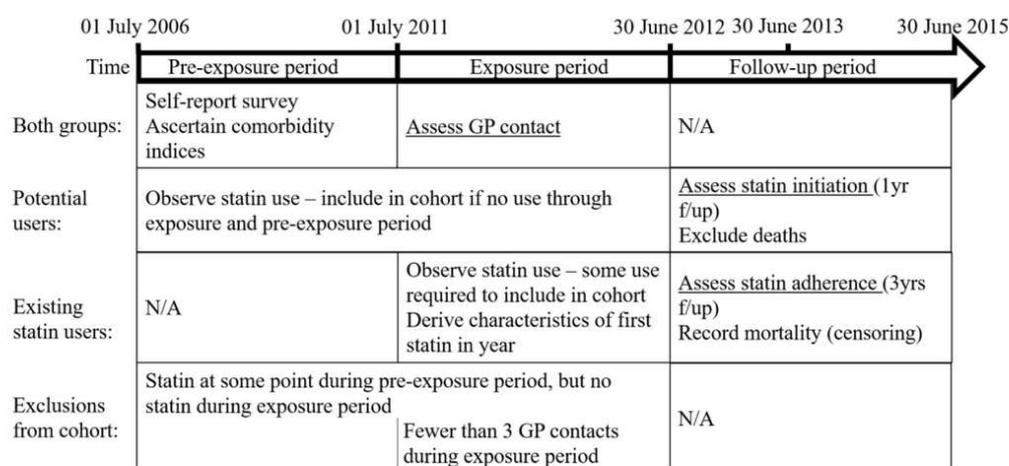


Figure 1 Study time period and main measurements. Measurement of exposure and outcome variables underlined.

The frequency (count) of GP contacts within the exposure year was also calculated.

Outcomes

Two outcomes were defined. The first was statin initiation, i.e. any statin dispensed during the follow-up period, assessed amongst potential users.

The second was time to non-adherence amongst existing users, typically defined as occurring where patient records indicate a given number of days without statins in supply.³⁹⁻⁴¹ Patients were non-adherent if they spent 30 consecutive days without statin supply during follow-up, which in Australia reflects one dispensing being missed. The ‘failure’ date was the first day of this 30-day period. Days in hospital were removed, as the hospital pharmacy would supply patients at these times. Where a packet was dispensed, early overlapping days were carried forward.⁴² Other common measures of adherence, for example the Medication Possession Ratio, do not support the use of time-to-event analyses which was the preferred method for the current study.

Study Period

As displayed in Figure 1, exposures were measured through the 2011/2012 financial year. The statin initiation outcome was measured through the 2012/2013 financial year, i.e. for the 12 months to 30 June 2013. Time to non-adherence was measured from the start of the 2012/2013 financial year through to the end of the 2014/2015 financial year, i.e. for 36 months, and censored by death or study end.

The administrative data covered 5 years prior to the exposure period to measure comorbidity indicators and capture statin dispensing prior to exposure, ensuring potential users were correctly identified.

Covariates

The 45 and Up Study data includes self-report information on a range of factors including socio-demographics, health conditions and family history, limitations, self-rated health and quality of life and behaviours such as smoking and exercise.³³ Comorbidity was assessed based on PBS data using the RxRisk indicator⁴³ and additionally assessed via inpatient diagnoses using the Multipurpose Australian Comorbidity Scoring System (MACSS),⁴⁴ through the pre-exposure period. For existing users, information on the first statin dispensed during the exposure period was derived including the dose (low, medium or high⁴⁵) and prescriber (GP or other). A variable stating whether an individual belonged to the group at high risk or the group with a history of CVD was used as a covariate. Socioeconomic status and service accessibility were based on postcode using the Socioeconomic Index for Areas (SEIFA) Index of Relative Socio-economic Disadvantage⁴⁶ and the Accessibility/Remoteness Index of Australia (ARIA),⁴⁷ respectively. Missing data on categorical variables were given values to prevent data loss.

Analysis

Multivariable logistic regression assessed statin initiation amongst potential users. Multivariable Cox regression assessed time to non-adherence amongst existing users.

In each case, outcomes were regressed on regularity, continuity, frequency and covariates selected via forward stepwise selection. Covariates were selected based on their impact on associations between GP contact and statin outcomes. Models were run in which outcomes were regressed on regularity, continuity and frequency and then compared to models where each individual candidate covariate was included. Covariates were ranked based on how they affected coefficients for the regularity variable, from the largest to smallest change. Covariates were then added iteratively and kept if they improved

model fit according to Bayes Information Criterion (BIC) and discarded; otherwise, the model was final when no further additions improved BIC.

Proportionality of hazards was tested using a Cox model including interactions between all independent variables and time; significant interactions indicated non-proportionality.⁴⁸ As large sample sizes can make inconsequential violations significant, proportionality was also assessed by examining graphs of the scaled Schoenfeld residuals, with a zero slope indicating proportionality.⁴⁸ Where proportionality was violated, problematic variables were included as stratifying variables rather than covariates.⁴⁸ Model fit was assessed by examining the Cox-Snell residuals.

Two sensitivity analyses were performed. Firstly, the model assessing statin initiation was repeated with a 2-year follow-up, rather than 1 year. Secondly, adherence was assessed with 'failure' defined by 60 rather than 30 days without statin supply.

Stata version 15 was used⁴⁹ with a significance level of $\alpha=0.05$ for all analyses.

RESULTS

Cohort Description

The cohort of potential users (without statin dispensed during or prior to the exposure period) included 29,420 individuals and there were 30,408 existing users (with medication dispensed during the exposure period).

Cohort characteristics are described in Table 1. In line with the higher risk of CVD in males, the cohort had a majority of men: potential users 73.4% and existing users 63.4%. Existing users were slightly older, with the largest group being those aged 65–70 (30.2%) compared to 60–65 (27.6%) for potential users. Amongst existing users, 40.1% described their health as 'good,' while amongst potential users there was an even split between those reporting good (36.4%) and very good (36.3%) health. The majority were ex-smokers (56.3% of potential users and 51.0% of existing users). Amongst potential users, 70.1% were at high risk of CVD (i.e. where statins, if used, would represent primary prevention) while the cohort of existing users was equally split between those at high risk (49.9%) and those with a history of previous CVD (50.1%). In terms of outcomes, 25.7% of potential users initiated statins during follow-up, while 53.8% of existing users recorded a failure during follow-up, with the remainder censored by death (3.0%) or study end (43.2%).

Table 2 compares cohort members to those excluded due to either <3 GP contacts ($n=8325$) or other reasons (mainly lower CVD risk, $n=198,094$). Those with <3 contacts were more often male, had better self-rated health and lived in areas of lower disadvantage. In this group, potential statin users were less likely to initiate than cohort members (9.0% vs 25.7%) and existing users were more often non-adherent (58.5% vs 41.1%). Those excluded for other reasons, compared to cohort

members, were more likely female, younger, self-reported better health and smoked less.

Initiation amongst Potential Statin Users

Amongst statin potential users, higher continuity and regularity were associated with increased odds of statin dispensing during follow-up (Table 3). After adjustment, the most regular quintile had 1.22 times the odds of commencing on a statin medication compared with least regular (95% CI 1.11–1.34). High provider continuity was associated with 1.12 times the odds of statin initiation compared to low continuity (95% CI 1.02–1.24), though the perfect continuity group reported a non-significant odds ratio of 1.07 (95% CI 0.99–1.15). Several influential covariates were included resulting from the step-wise selection. These included the RxRisk index, the presence of several specific comorbidities and one demographic (language spoken at home).

Adherence amongst Existing Statin Users

Figure 2 displays the cumulative hazard of non-adherence. A brief increase in hazard appears after 460 days, coinciding with a documentary critical of statins airing on television in Australia, and known to have influenced usage.⁵⁰

Violations of proportionality were observed for one level of regularity, age, prescriber, language spoken at home and one level of socio-economic status (results not shown). Therefore, in the final model, these covariates were included as stratifying variables rather than predictors. Regularity was retained as a predictor as coefficients were required for exposure variables. The plot of scaled Schoenfeld residuals displayed zero slopes for each level of regularity (see Appendix 3), suggesting that violations of proportionality were not practically meaningful. Cox-Snell residuals indicated that the model fit was good (Appendix 3).

Higher regularity/continuity was associated with a reduced hazard of non-adherence amongst existing users as displayed in Table 4. The most regular quintile had a hazard ratio of 0.82 (95% CI 0.78–0.87) compared to the least regular (i.e. a 16% reduction in likelihood of non-adherence). The perfect continuity group had a hazard ratio of 0.90 (95% CI 0.86–0.94) compared to the low continuity group. As with the model of statin initiation, the RxRisk index was included as a covariate along with certain comorbidities and demographics, though the specific conditions and demographics differed between models.

Sensitivity analyses suggested that findings were robust. When a 60-day period without supply was used to define non-adherence (rather than 30 days), a slight increase in the hazard rates for regularity and continuity was observed (Appendix 3). When statin initiation was assessed with a 2-year rather than 1-year follow-up, coefficients on the regularity variable decreased by about 20–30%, while coefficients on the continuity variable changed by 20–50% (Appendix 3).

Table 2 Characteristics of Cohort Members (Including Existing and Potential Statin Users) in Comparison to Those Excluded from Study Due to Having Fewer than Three GP Contacts, and in Comparison to All Other 45 and Up Study members

Variable	Category	In cohort ^d		Excluded for all other reasons		Excluded due to <3 visits		Total	
		N	%	N	%	N	%	N	%
Age	Male	40,860	68.3	75,416	38.1	7086	86.1	123,362	46.4
	Female	18,968	31.7	122,678	61.9	1149	14.0	142,795	53.7
Sex	55–60	13,622	22.8	107,092	54.1	3411	41.4	124,125	46.6
	60–65	16,026	26.8	21,575	10.9	2550	31.0	40,151	15.1
	65–70	16,722	28.0	15,119	7.6	1554	18.9	33,395	12.6
	70–75	13,458	22.5	54,308	27.4	720	8.7	68,486	25.7
Self-rated health ^a	Excellent	4997	8.6	32,544	17.1	1317	16.4	38,858	15.1
	Very good	19,914	34.3	71,637	37.6	3301	41.0	94,852	36.9
	Good	22,894	39.4	61,241	32.1	2591	32.2	86,726	33.8
	Fair	8837	15.2	21,143	11.1	746	9.3	30,726	12.0
Self-rated quality of life ^a	Poor	1484	2.6	4024	2.1	94	1.2	5602	2.2
	Excellent	10,716	18.8	46,962	25.1	2178	27.5	59,856	23.8
	Very good	21,146	37.1	69,699	37.3	3145	39.8	93,990	37.3
	Good	18,322	32.1	51,075	27.3	1959	24.8	71,356	28.3
Smoking status	Fair	5816	10.2	16,151	8.6	513	6.5	22,480	8.9
	Poor	1023	1.8	3135	1.7	115	1.5	4273	1.7
	Never smoked	22,701	38.1	127,034	64.5	2291	27.9	152,026	57.4
	Current smoker	4912	8.2	13,058	6.6	1012	12.3	18,982	7.2
Language spoken at home	Past smoker	32,040	53.7	56,771	28.8	4918	59.8	93,729	35.4
	English	54,511	91.1	178,684	90.2	7587	92.1	240,782	90.5
	Other	5316	8.9	19,408	9.8	648	7.9	25,372	9.5
	SEIFA ^a	Highest disadvantage	13,736	23.6	39,216	20.3	1505	18.9	54,457
ARIA ^a	High disadvantage	13,352	22.9	40,811	21.2	1670	20.9	55,833	21.6
	Moderate	11,088	19.0	36,881	19.1	1527	19.2	49,496	19.1
	Less disadvantage	9494	16.3	33,509	17.4	1424	17.9	44,427	17.2
	Least disadvantage	10,611	18.2	42,432	22.0	1848	23.2	54,891	21.2
RxRisk categories (5 years) ^b	Very remote	47	0.1	236	0.1	33	0.4	316	0.1
	Remote	513	0.9	1634	0.9	67	0.8	2214	0.9
	Moderate	6517	11.1	19,685	10.1	1093	13.6	27,295	10.5
	Accessible	22,099	37.6	67,285	34.6	3230	40.1	92,614	35.5
MACSS conditions (5 years) ^c	Highly accessible	29,588	50.4	105,567	54.3	3628	45.1	138,783	53.1
	0	9387	15.7	61,261	30.9	3117	37.9	73,765	27.7
	1–2	11,815	19.8	59,925	30.3	3014	36.6	74,754	28.1
	3–5	18,900	31.6	43,778	22.1	1723	20.9	64,401	24.2
Total	6+	19,726	33.0	33,130	16.7	381	4.6	53,237	20.0
	0	18,518	31.0	77,314	39.0	3860	46.9	99,692	37.5
	1–2	12,682	21.2	48,916	24.7	1995	24.2	63,593	23.9
	3–5	19,942	33.3	47,976	24.2	1950	23.7	69,868	26.3
Total	6+	8686	14.5	23,888	12.1	430	5.2	33,004	12.4
		59,828	22.5	198,094	75.4	8235	3.1	266,157	100

^aDoes not sum to total due to missing responses

^bNumber of 46 RxRisk conditions in previous 5 years of medication dispensing data

^cCount of Multipurpose Australian Comorbidity Scoring System (MACSS) conditions recorded in previous 5 years of hospital admissions data

^dCohort members differed significantly from the two excluded groups on all variables listed based on chi-square testing

DISCUSSION

Higher continuity and regularity of GP contact were associated with a higher likelihood of statin initiation amongst people at risk of CVD outcomes, and with improved adherence after initiation. This highlights the importance of ongoing relationships between GPs and at-risk patients. Policies which interfere with such relationships therefore have implications for the quality of preventive care received. In recent years, policies such as compulsory patient co-payments for GP visits have been proposed in Australia with discussion on the potential impact of such policies on preventive care.⁵¹ Meanwhile, a trend towards larger practice sizes⁵² and the impacts of this for provider continuity⁵³ has implications for the patient-provider relationship.

Much work assesses relationships between GP contact and hospitalisation outcomes, and researchers have hypothesised that associations observed between these results from improved medical management. While the current observational

work cannot establish causation, it does suggest that medication management is a plausible mechanism by which continuity/regularity may influence hospitalisation. As previous studies involve health service use as both exposure (continuity) and outcome (hospitalisation) variables, the risk of confounding by unobserved patient factors is high and work to better understand the plausibility of causation is worthwhile. While an association between statin adherence and continuity has previously been reported,³² this study additionally demonstrates an association with the initiation of statins amongst those at high risk of cardiovascular disease. Given that previous primary care studies have reported that only a minority of patients at high risk of cardiovascular disease are initiated on statins,^{27, 28} evidence to improve the understanding of factors contributing to initiation, in addition to understanding adherence amongst existing users, is valuable. This work also provides evidence regarding the impact of patterns of GP contact beyond the commonly used provider continuity

Table 3 Results of Logistic Regression Reporting Associations between Continuity of Primary Care from July 2011 to June 2012 and Odds of Statin Initiation in the Following Year, amongst Cohort of Potential Users

Variable		OR (95% CI)	Std. Err.	z	p>Z
Regularity	Least regular	Reference			
	2	1.108 (1.009–1.217)	0.053	2.16	0.031
	3	1.118 (1.019–1.227)	0.053	2.36	0.018
	4	1.153 (1.051–1.265)	0.055	3.01	0.003
	Most regular	1.221 (1.111–1.341)	0.059	4.16	<0.001
COC index	<0.5	Reference			
	0.5–0.74	1.069 (0.991–1.152)	0.041	1.72	0.086
	0.75–0.99	1.123 (1.019–1.239)	0.056	2.34	0.020
	1	1.066 (0.992–1.147)	0.040	1.73	0.083
Frequency	3–5	Reference			
	6–9	1.202 (1.111–1.300)	0.048	4.58	<0.001
	10–14	1.317 (1.205–1.440)	0.060	6.08	<0.001
	15–19	1.164 (1.040–1.302)	0.067	2.65	0.008
	20+	1.080 (0.960–1.215)	0.065	1.28	0.201
RxRisk ^a	0	Reference			
	1–2	0.810 (0.735–0.892)	0.040	-4.27	<0.001
	3–5	1.615 (1.483–1.760)	0.071	10.99	<0.001
	6+	3.304 (3.008–3.360)	0.158	24.92	<0.001
	High risk of CVD	Reference			
CVD status	History of CVD	2.184 (2.003–2.381)	0.096	17.71	<0.001
	Heart disease ^b	1.164 (1.058–1.280)	0.056	3.13	0.002
Diabetes ^b	Yes	2.730 (2.524–2.953)	0.109	25.12	<0.001
High blood pressure ^b	Yes	1.324 (1.248–1.404)	0.040	9.31	<0.001
Language other than English ^b	Yes	1.131 (1.023–1.250)	0.058	2.41	0.016
Stroke ^b	Yes	0.717 (0.621–0.827)	0.052	-4.57	<0.001
Non-melanoma skin cancer ^b	Yes	0.858 (0.805–0.914)	0.028	-4.73	<0.001
Depression ^b	No	Reference			
	Yes	0.792 (0.727–0.863)	0.035	-5.31	<0.001
	Missing ^b	0.987 (0.905–1.076)	0.043	-0.31	0.760
Constant		0.098 (0.087–0.111)	0.056	-38.32	<0.001

^aNumber of 46 RxRisk conditions based on prior 5 years of medication dispensing records ⁴³

^bBased on self-report

^cQuestion not included in the first version of the survey

measures, by additionally assessing the regularity of contacts. This provides a more comprehensive understanding of patterns of GP contact on statin use and potential downstream outcomes.

To some extent, a relationship between GP contact and statin adherence is self-evident, as a GP visit must occur to receive a prescription. However, statin prescriptions are generally provided with five monthly ‘repeats’ in Australia. A single prescription therefore can provide for a 6-month supply, meaning that adherence can be achieved with only two GP visits per year. As this analysis is restricted to people with ≥ 3 GP contacts, all cohort members have the potential to remain compliant; furthermore, analyses are adjusted for the number of GP contacts.

In Australia, GPs perform most prescribing, in particular for common medications such as statins, though in some cases, specialists may have a larger role in prescribing and condition management. Australia’s universal public insurance system, Medicare, reimburses GPs on a fee-for-service basis (though GPs may charge additional out-of-pocket fees)⁵⁴ and medications are subsidised via the PBS,⁵⁵ with small co-payments required. Patients in Australia are free to choose their GP and may switch at any time. In countries with different registration systems, different prescribing practices or where different financial barriers exist, the associations reported here may differ.

Strengths

A strength of this study is the comprehensiveness of the data available. The combination of self-reported and administrative collections provides information on a range of patient demographics, behaviours, health status and use of health services, reducing the likelihood of omitted variable bias.

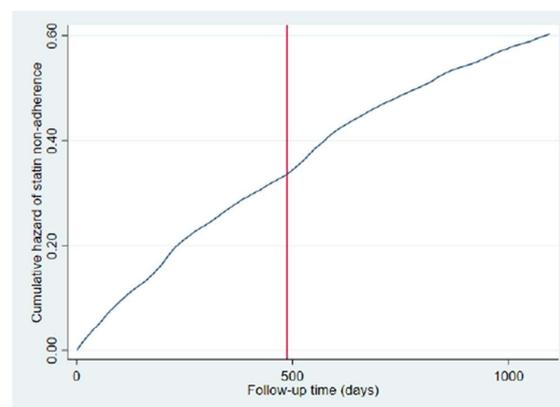


Figure 2 Line chart representing the cumulative proportion of cohort members failing to adhere to statin therapy according to dispensing records, over time. Day 0 indicates the first day of follow-up, the vertical line indicates the date of a documentary critical of statins airing in Australia.

Table 4 Results of Cox Regression Reporting Association between Primary Care Continuity from July 2011 to June 2012 and Statin Non-adherence through the Following 3 Years, amongst Cohort Members Using Statins during the Exposure Period

Variable*		Haz. ratio (95% CI)	Std. Err.	z	p>Z
Regularity	Least regular	Reference			
	2	0.932 (0.884–0.982)	0.025	– 2.64	0.008
	3	0.891 (0.845–0.940)	0.024	– 4.25	<0.001
	4	0.850 (0.805–0.897)	0.023	– 5.92	<0.001
COC index	Most regular	Reference			
	<0.5	0.824 (0.780–0.871)	0.023	– 6.87	<0.001
	0.5–0.74	0.934 (0.892–0.977)	0.021	– 2.98	0.003
	0.75–0.99	0.888 (0.838–0.941)	0.026	– 3.99	<0.001
Frequency	1	0.901 (0.863–0.942)	0.020	– 4.64	<0.001
	3–5	Reference			
	6–9	0.931 (0.887–0.977)	0.023	– 2.91	0.004
	10–14	0.903 (0.854–0.953)	0.025	– 3.67	<0.001
	15–19	0.898 (0.840–0.960)	0.031	– 3.14	0.002
RxRisk ^a	20+	0.825 (0.768–0.886)	0.030	– 5.27	<0.001
	0	Reference			
	1–2	1.433 (1.337–1.537)	0.051	10.16	<0.001
	3–5	1.101 (1.037–1.169)	0.033	3.16	0.002
Current work status ^b	6+	0.915 (0.862–0.972)	0.028	– 2.90	0.004
	Other	Reference			
	Fully retired	0.825 (0.792–0.859)	0.017	– 9.36	<0.001
Highest qualification ^b	Missing	0.000	0.000	0.00	1.000
	No school certificate or other qualification	Reference			
	School or intermediate certificate	0.989 (0.933–1.049)	0.030	– 0.36	0.715
	Higher school or leaving certificate	1.107 (1.030–1.190)	0.041	2.75	0.006
	Trade or apprenticeship	1.080 (1.012–1.152)	0.036	2.32	0.021
	Certificate or diploma	1.130 (1.062–1.201)	0.035	3.89	<0.001
	University degree or higher	1.326 (1.247–1.411)	0.042	8.98	<0.001
High blood pressure ^b	Missing	1.154 (1.006–1.323)	0.081	2.05	0.040
	No	Reference			
CVD status	Yes	0.855 (0.825–0.886)	0.015	– 8.67	<0.001
	High risk of CVD	Reference			
Heart disease ^b	History of CVD	1.008 (0.963–1.055)	0.024	0.34	0.737
	No	Reference			
	Yes	0.853 (0.811–0.897)	0.022	– 6.16	<0.001

*Stratifying variables include age, language other than English at home, prescriber, and SEIFA

^aNumber of 46 RxRisk conditions based on prior 5 years of medication dispensing records

^bBased on self-report

Limitations

We did not have access to a practice identifier. It is unclear if patients with low continuity visited different GPs at the same practice (i.e. where patient records would still be available), or visited different practices, and how continuity of practice may differ from the continuity of GP. Unobserved patient characteristics are also a potential issue. Although the survey captured information on a range of characteristics, there are likely factors which are difficult for a survey to fully capture such as participants’ personal characteristics, family dynamics which may influence the use of services, and so on.

Reasons for statin cessation were unknown. Statin therapy may be stopped for clinical reasons such as adverse events, in which case people may have been incorrectly categorised as non-adherent. Symptoms of intolerance may occur in approximately 20% of statin users, but may usually be resolved with dose reduction or switching.⁵⁶ Where these approaches are used, patients would remain adherent in these analyses, so this is unlikely to impact findings.

The participation rate of the 45 and Up Study was approximately 18%.³³ As a result, the study population may not be representative of the broader community. However, a previous validation study has suggested that even with this low response rate, exposure-outcome estimates derived in this cohort

may remain generalizable, based on comparisons to relationships derived from a comparable cohort with a higher response rate.⁵⁷

This study ended in 2015, and it is possible that the relationships observed have changed since. However, analysing a later period would increase the risk of misclassification bias due to participants’ status on baseline survey variables changing; hence, the time period used was considered suitable to balance currency of findings against the risk of bias.

Finally, this analysis is restricted to those with at least 3 visits per year. The analysis suggested that those with fewer than 3 visits per year differed from the study cohort both on baseline characteristics and on statin use outcomes; findings here are not meaningful in relation to this excluded group.

CONCLUSION

Regularity and continuity of care are associated with improved medication management, which offers a plausible pathway for continuity/regularity of care to influence hospitalisation. Future research could explore mechanisms of action by investigating other measures of patient health, such as biomedical markers captured in pathology tests. Future research could

also assess the impact of comorbid conditions on relationships observed.

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Conflict of interest: The authors declare that they do not have a conflict of interest.

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9.3 Sensitivity analysis – alternative measures of continuity

9.3.1 Introduction

In Chapter 8, a sensitivity analysis was performed in which the analysis of the impact of regularity and continuity on diabetes processes of care was compared between models where the UPC and COC indices were used. This sensitivity analysis suggested that the choice of continuity measure did not alter findings. To further explore the potential impact of the choice of continuity measure on relationships of interest, a similar sensitivity analysis is reported here relating to the analysis of statin initiation / non-adherence.

9.3.2 Methods

Methods reflect those reported in Manuscript 5. While Manuscript 5 made use of the COC index to measure continuity, the sensitivity analysis here uses the UPC index. Analyses reported in manuscript 5 are reproduced here alongside analyses where the UPC index is instead used, to allow a comparison of effect estimates from the two measures. Results include the odds ratios, hazard ratios and significance values from models assessing the initiation of statins among potential users, and non-adherence to statins among existing users. Results are reported for regularity and continuity variables only as the exposures of interest.

9.3.3 Results

Results are presented in Table 9-1 and Table 9-2. Tables indicate minimal changes in results when different continuity measures are used. In the model of statin initiation (Table 9-1), ORs for the second-lowest level of continuity (baseline lowest) is slightly smaller in the model with the UPC index, however significance does not change between the two models, while other levels of continuity and all levels of regularity show almost no change between models. For the model of statin non-adherence among existing statin users (Table 9-2), there is a change in the second lowest level of continuity, with the HR moving closer to 1 and becoming non-significant, while other levels of continuity and all levels of regularity show minimal change regardless of the continuity measure used.

Table 9-1: Odds of statin initiation among cohort of potential statin users, according to level of regularity / continuity. Left panel from models in which the COC index is used, right panel from model in which the UPC index is used.

	OR	P value		OR	P value
Regularity			Regularity		
Least regular	Reference		Least regular	Reference	
2	1.11	0.031	2	1.08	0.032
3	1.12	0.018	3	1.12	0.019
4	1.15	0.003	4	1.15	0.003
Most regular	1.22	<0.001	Most regular	1.22	<0.001
COC index			UPC index		
Lowest continuity	Reference		Lowest continuity	Reference	
2	1.07	0.086	2	0.99	0.828
3	1.12	0.02	3	1.12	0.006
Highest continuity	1.07	0.083	Highest continuity	1.06	0.142

OR= Odds ratio, COC = continuity of care, UPC = usual provider of care.

Table 9-2: Odds of statin non-adherence among cohort of existing statin users, according to level of regularity / continuity. Left panel from models in which the COC index is used, right panel from model in which the UPC index is used.

	HR	P value		HR	P value
Regularity			Regularity		
Least regular	Reference		Least regular	Reference	
2	0.93	0.008	2	0.93	0.008
3	0.89	<0.001	3	0.89	<0.001
4	0.85	<0.001	4	0.85	<0.001
Most regular	0.82	<0.001	Most regular	0.82	<0.001
COC index			UPC index		
Lowest continuity	Reference		Lowest continuity	Reference	
2	0.93	0.003	2	0.97	0.406
3	0.89	<0.001	3	0.89	0.001
Highest continuity	0.90	<0.001	Highest continuity	0.89	<0.001

OR= Odds ratio, COC = continuity of care, UPC = usual provider of care.

9.3.4 Discussion

Sensitivity analysis suggested that the choice of continuity index had minimal impact on the results reported. Across three levels of continuity and four levels of regularity, in two separate cohorts with separate outcomes, there was only a single coefficient for which the significance changed as a result of the continuity measure used. This is in line with results from Chapter 8. In that case, the choice of continuity measure did not make a difference to effect estimates in the assessment of diabetes processes of care. This may suggest that associations between continuity and process of care outcomes are generally robust to the choice of continuity measure used, despite the conceptual differences between these measures.

9.4 Analysis 2: Interactions between regularity and continuity of care

9.4.1 Introduction

An important consideration that was not discussed in the manuscript due to word count constraints is the possibility of interactions between regularity and continuity in influencing these outcomes. It is plausible that the effects of the two exposures are either multiplicative (regular contacts are more beneficial only where these are to the same provider, that is where continuity is achieved, but otherwise less effective) or substitutive (regular contacts may be beneficial for patients who do not report continuity of care but offer little additional benefit to those patients where continuity is already achieved). The presence of possible interactions is relevant from a policy / practice point of view. For example, if a multiplicative relationship exists, this would be informative regarding the likely impact of policies to promote regular care, against a context of increasing practice sizes (243) and decreasing provided continuity (244).

Although most papers that report studies of continuity of care do not generally report testing for interactions, a few have reported interactions between continuity and other features of care in influencing patient outcomes. These papers include an American study (245) which assessed the value of continuity of primary care and high-functioning teams (high-functioning status being based on various practice characteristics capturing team-based care) and found no evidence for interactions between the two exposures, with the authors concluding that a team being high-functioning could not compensate for poor continuity. Another paper assessed interactions of continuity with patient age and number of primary care physician visits (129) finding positive interactions for both (continuity was more beneficial among older patients and those having high numbers of physician visits). A third reported an interaction between continuity of care and high specialty care use (246), finding that although continuity was associated with the study outcome of care coordination (as opposed to the downstream outcomes typically assessed), this association was not evident among high specialty-care users, possibly due to the primary providers facing greater difficulty in coordinating care among these patients. Although research assessing interactions of continuity with other features of care is rare, the available evidence suggests that interactions do in fact occur with other aspects of the organisation of care and hence support the assessment of interactions in the current work. As both exposures in this work assess patterns of care with the GP, it seems plausible that interactions will occur, and additionally seems likely that a policy aimed at one exposure may have implications for the other, making evidence regarding potential interactions important.

9.4.2 Methods

While most methods are explained in manuscript 5, a brief overview of the most important points is provided here, along with an explanation of the methods applicable to the analysis of interactions.

9.4.2.1 Data

Data used in these analyses are from the 45 and Up Study, administered by the Sax Institute. These data are explained in detail in section 3.2.2.

9.4.2.2 Cohort

The cohort selection is explained in manuscript 5. The cohort consists of individuals with high absolute cardiovascular disease risk, being those people with at least a 15% likelihood of experiencing a cardiovascular event within the following five years. This cohort includes people with existing CVD, among whom statin use would represent secondary prevention, and people at risk of developing CVD, among whom statin use would represent primary prevention. The cohort is further divided into those who have never used statins (potential users) and those taking statins through the exposure period (existing users).

9.4.2.3 Exposures

The exposures, regularity and continuity, are described in manuscript 5. Regularity is assessed based on the Modified Regularity index, converted into quintiles from least to most regular. Continuity is measured using the Continuity of Care index, with categories of low (0–0.49), moderate (0.5–0.74), high (0.75–0.99) and perfect (1) continuity.

9.4.2.4 Measures of statin use

Among the cohort of potential users, statin use was assessed as initiation of statin therapy, which was flagged based on the dispensing of a statin medication at any point during one year of follow-up, assessed via logistic regression. Among existing users, statin use was assessed in terms of adherence. Non-adherence was flagged where dispensing records indicated a period of 30 days without statins in supply, assessed through a three-year follow-up via cox regression.

9.4.2.5 Analysis

9.4.2.5.1 Associations between regularity and continuity

If both regularity and continuity capture information regarding planned or managed care between the patient and GP as hypothesised, a positive association between them would be expected. Initially, regularity and continuity were crosstabulated (in their categorical forms as described under Exposures) to examine their association, with chi-square testing to assess significance.

A correlation coefficient was also considered useful to better understand relationships between the variables. A very low correlation coefficient would suggest no relationship between the variables, while a very high value would suggest that limited information is captured by including both variables in models, that is they are in fact measuring the same thing. As a correlation coefficient requires continuous, normally distributed variables, the distributions of regularity and continuity were assessed. For ease of reading, the assessment and transformation of the distributions is described here, including the results of tests used for development of methods. Meanwhile, the results section displays the results of final analysis only. This approach is common in economics literature though less common in public health.

Both exposures had non-normal distributions. Among existing statin users, regularity had an extreme right skew (see Figure 9-1) with a skewness of 39.20 and kurtosis of 2,104.13.

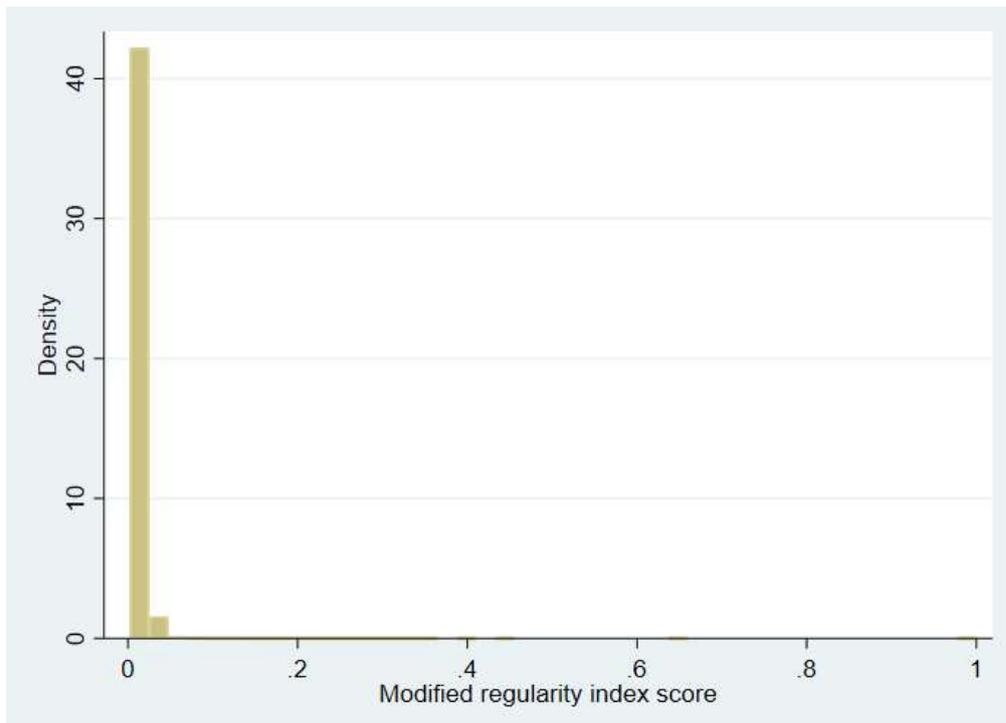


Figure 9-1: Histogram of regularity score values, cohort of existing statin users

After log-transformation the distribution (see Figure 9-2) remained non-normal (skewness=1.46 and kurtosis=11.47 in comparison to the values of 0 and 3 respectively which are defining features of a normal distribution (247)), though was substantially closer to normality. Other transformations tested on this data did not result in a distribution any closer to normality. The distribution of the continuity variable was also non-normal (see Figure 9-3); in this case there is a mass of values at exactly 1 with 28.6% of the cohort having all visits to the same provider, i.e. perfect continuity. Given this distribution, any transformation of this variable will have the same mass at the upper limit, and this variable cannot be transformed into a continuous variable to suit the estimation of a correlation coefficient. These distributions were similar for potential statin users (see Appendix F).

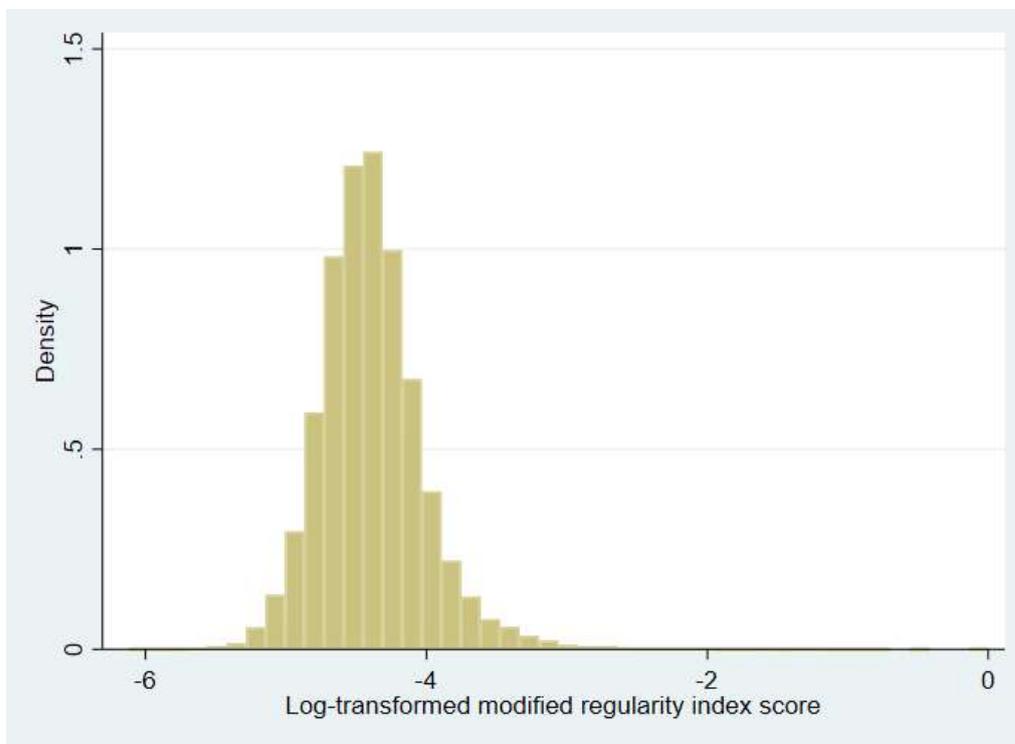


Figure 9-2: Histogram of regularity score values following log-transformation, cohort of existing statin users

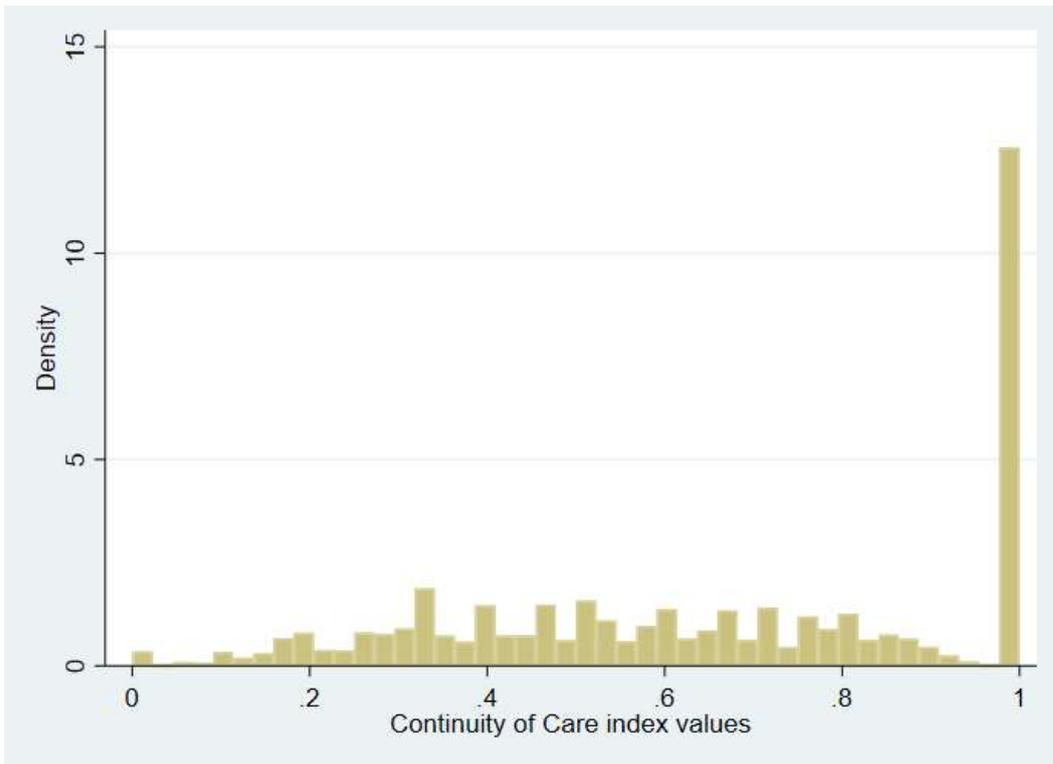


Figure 9-3: Histogram of continuity score values, cohort of existing statin users

On account of these distributions, an R^2 value was calculated by regressing regularity on continuity using linear regression. The log-transformed regularity score was regressed on the categorised continuity score as the distribution of the continuity score did not support log-transformation. Model results are presented with coefficients back-transformed (248). Residuals were assessed for normality using and heteroscedasticity using Cameron & Trivedi's information matrix test (249), kernel density plots and plots of residuals versus fitted values.

9.4.2.5.2 Relationships of regularity and continuity with other patient characteristics

Secondly, the relationships that each of regularity and continuity have with various demographic and health status variables was assessed. In the context of the Andersen model of health service use, if both of these measures are enabling characteristics reflecting the organisation of care, they would likely have similar relationships with predisposing demographic, social and belief factors, and the feedback loops in the Andersen framework would also suggest that they may be similarly influenced by past health status. Indicators of patient health status were self-reported health, and comorbidity as calculated using the RxRisk and Multipurpose Australian Comorbidity Scoring System indexes. Predisposing factors were age and sex. Smoking status and alcohol intake were assessed as health behaviours. Relationships were assessed by crosstabulating each of regularity and continuity (in their categorical forms) with each patient characteristic. Chi-square tests indicated the significance of relationships between each exposure and each patient characteristic. Results are presented using histograms of the percentage of each category of each patient characteristic in each quintile of regularity / category of continuity, to allow for a visual comparison of the relationship the two exposures have with each patient characteristic.

9.4.2.5.3 Interactions in effects on statin use

Finally, the models presented in manuscript 5 were repeated with interactions of regularity and continuity included. This provides information regarding possible interactions (effect moderation) between regularity and continuity in influencing statin use. As the models in the manuscript included both regularity and continuity as categorical variables, interactions were added using factor variable notation. As these interactions involved estimation of 12 additional parameters (five levels of regularity by four levels of COC, minus reference categories), Wald tests were performed to test the joint significance of interactions using Stata's `-testparm-` command. Where the Wald test indicated a significant interaction, predictive margins were produced to display estimated statin use outcomes for each regularity / continuity level interaction to understand potential effect modification. Two models were run, following manuscript 5. The first was a logistic regression in which the outcome was initiation of statin therapy, among a cohort of potential users. The second was a time-to-event model in which the outcome was statin non-adherence, among a cohort of existing statin users. Covariates were those described in manuscript 5.

9.4.3 Results

9.4.3.1 Associations between regularity and continuity

Table 9-3 demonstrates that among the cohort of existing users there was generally a positive association between regularity and continuity, with those in the perfect continuity group almost twice as likely to be in the highest regularity category than the lowest (28.0% compared to 15.3%).

Table 9-3: Crosstab of regularity and continuity categories among existing statin users

		Continuity level				Total
		Low	Moderate	High	Perfect	
Regularity level	Lowest	2,414 (24.43)	1,532 (20.26)	807 (18.83)	1,329 (15.31)	6,082
	2	2,268 (22.96)	1,515 (20.03)	833 (19.44)	1,467 (16.90)	6,083
	3	2,000 (20.24)	1,552 (20.52)	890 (20.77)	1,636 (18.85)	6,078
	4	1,792 (18.14)	1,556 (20.57)	915 (21.35)	1,816 (20.92)	6,079
	Highest	1,406 (14.23)	1,408 (18.62)	840 (19.60)	2,432 (28.02)	6,086
Total		9,880	7,563	4,285	8,680	30,408

Table 9-4 demonstrates that that the association between regularity and continuity was similar among potential statin users.

Table 9-4: Crosstab of regularity and continuity categories among potential statin users

		Continuity level				Total
		Low	Moderate	High	Perfect	
Regularity level	Lowest	2,520 (22.96)	1,273 (19.04)	537 (18.04)	1,504 (17.13)	6,082
	2	2,490 (22.68)	1,337 (20.00)	565 (18.98)	1,502 (17.11)	6,083
	3	2,290 (20.86)	1,356 (20.28)	654 (21.97)	1,602 (18.24)	6,078
	4	2,036 (18.55)	1,412 (21.12)	640 (21.50)	1,799 (20.49)	6,079
	Highest	1,641 (14.95)	1,307 (19.55)	581 (19.52)	2,374 (27.04)	6,086
Total		9,880	7,563	4,285	8,680	30,408

Results of the regressing regularity on continuity for existing users are displayed in Table 9-5. Consistent with the crosstabulations above, positive coefficients are observed with larger coefficients for increasing levels of continuity. The regression returned an estimated R^2 value of 2.7%. This suggests that although there is a positive relationship between regularity and continuity, the continuity variable only explains a small fraction of the variation in regularity.

Table 9-5: Output of regression of log-transformed regularity values on levels of continuity of care among cohort of 30,408 existing statin users

Continuity	Coefficient	SE	P	95% CI
Low continuity	Reference			
Moderate continuity	0.051	0.006	<0.001	0.039–0.063
High continuity	0.058	0.007	<0.001	0.043–0.073
Perfect continuity	0.175	0.006	<0.001	0.162–0.188
Constant	-0.988	0.004	<0.001	-0.988 to -0.988

The information matrix test indicated that residuals were non-normal and heteroscedasticity ($p < 0.001$ for tests of heteroscedasticity, skewness and kurtosis). The density plot of residuals against the normal distribution (Figure 9-4) suggests only slight kurtosis and a minor skew, suggesting that highly significant test results may reflect the large sample size.

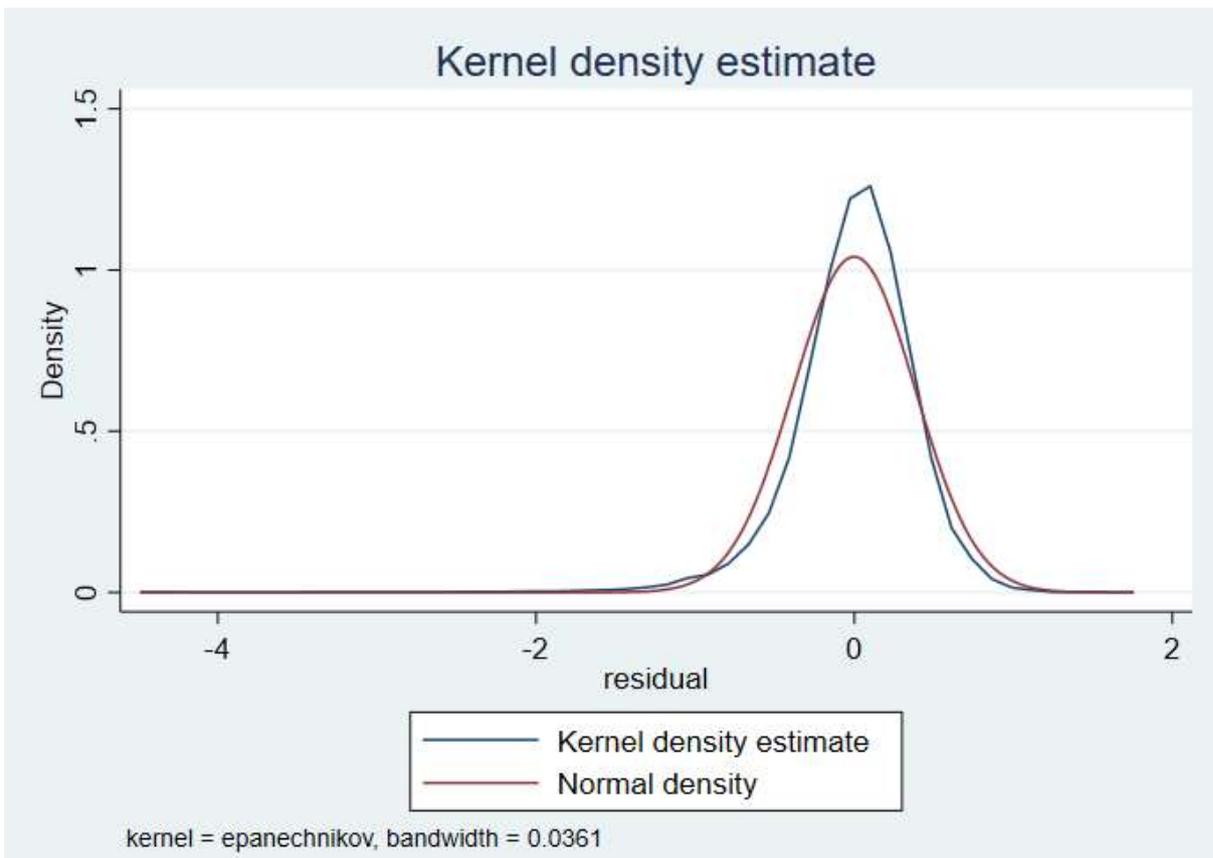


Figure 9-4: Distribution of residuals against normal distribution, cohort of existing statin users

Similarly, the plot of residuals against fitted values (Figure 9-5) does not suggest substantial heteroscedasticity.

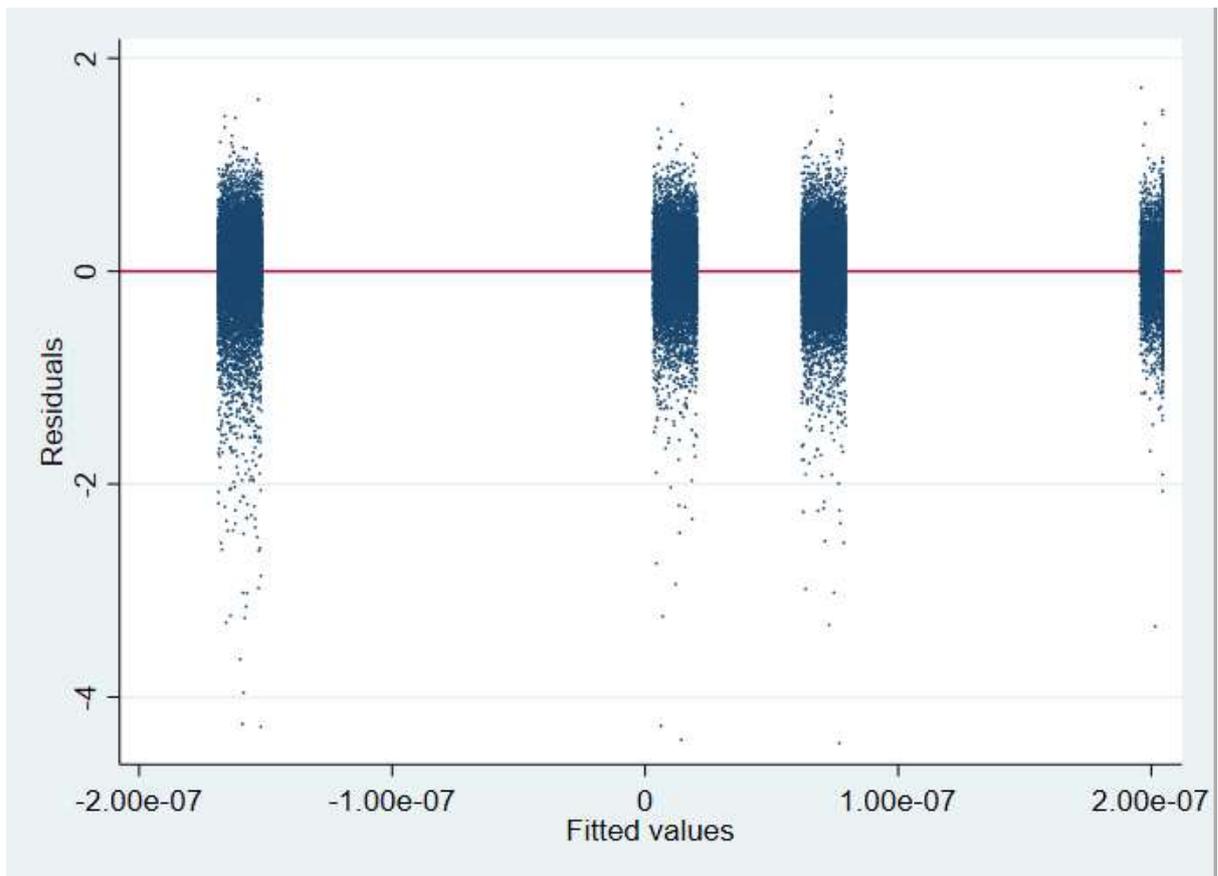


Figure 9-5: Plot of residuals against fitted values, cohort of existing statin users. Fitted values present as four bands as the regression had a single predictor with four levels, a horizontal jitter has been introduced to provider more clarity on individual data

Regression results were similar among potential users (Table 9-6), among this cohort the R² value was 1.9%.

Table 9-6: Output of regression of log-transformed regularity values on levels of continuity of care among a cohort of 29,420 potential statin users

Continuity	Coefficient	SE	P	95% CI
Low continuity	Reference			
Moderate continuity	0.046	0.006	<0.001	0.034–0.059
High continuity	0.053	0.008	<0.001	0.036–0.070
Perfect continuity	0.147	0.006	<0.001	0.133–0.160
Constant	-0.989	0.004	<0.001	-0.988 to -0.989

Diagnostic tests produced similar findings to those described for existing users. Non-normality and heteroscedasticity were present in the residuals ($p < 0.001$ for tests of skewness, kurtosis and heteroscedasticity). As was the case with existing statin users, the density plot of residuals and plot of fitted versus residual values suggested that concerns of non-normality and heteroscedasticity were minor (Appendix F).

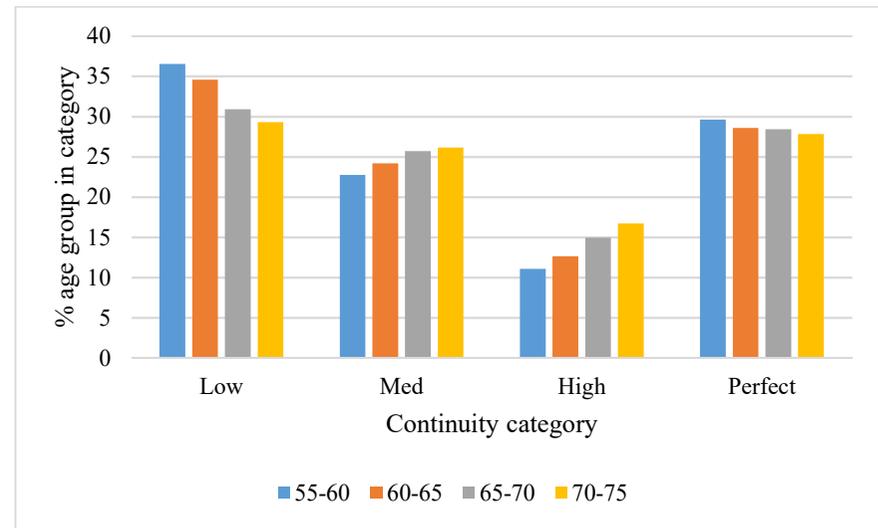
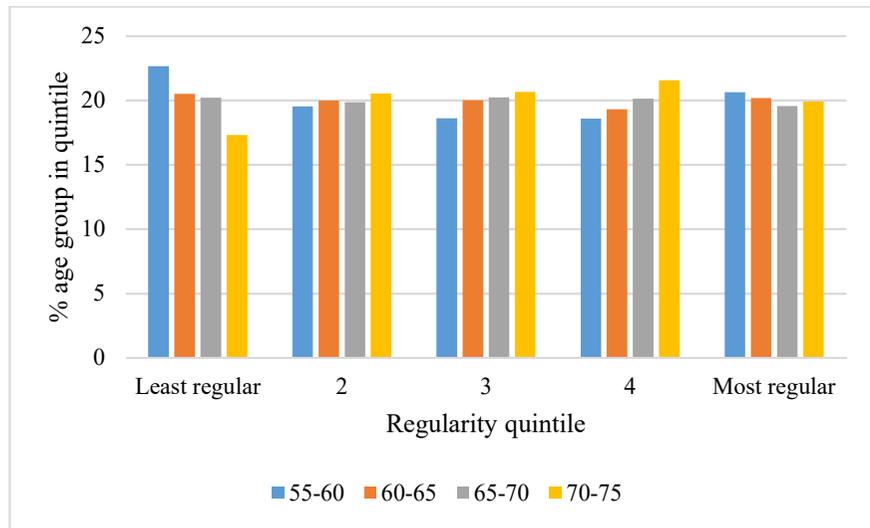
9.4.3.2 Relationships of regularity and continuity with other patient characteristics

Results are presented separately for existing and potential statin users.

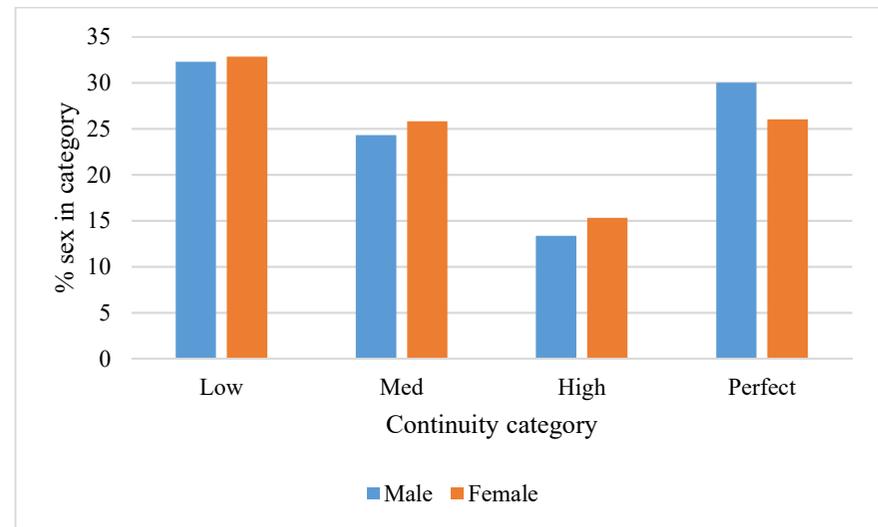
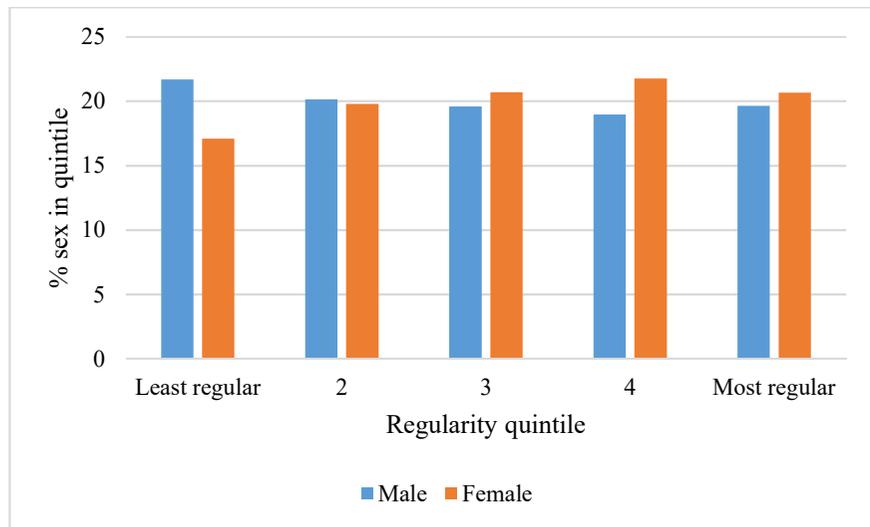
9.4.3.2.1 Existing statin users

For both regularity and continuity, associations with all patient characteristics tested were statistically significant with the exception of smoking status by continuity in the cohort of existing users ($p = 0.056$; $p < 0.001$ for all other relationships plotted in Figure 9-6 and Figure 9-7). Among existing statin users (Figure 9-6), older age was associated with higher regularity and high continuity (except perfect continuity). Regularity was higher among women than men, as was continuity, barring the highest level. Poorer self-rated health was associated with higher regularity and continuity, again barring the highest continuity level. In terms of comorbidity, the likelihood of multiple comorbid conditions increased with increasing continuity (except the highest level) according to both RxRisk and MACSS. For both comorbidity variables the likelihood of having multiple comorbidities increased with increasing regularity though this trend reversed in the most regular group. These were the only variables where this reversal in trend was observed at the highest level of regularity, in contrast to continuity for which this reversal was observed for most variables. Rates of smoking did not follow any obvious trend for continuity, though the least regular group were more likely to be smokers. Alcohol intake was higher among those with low regularity and low continuity (barring the highest level).

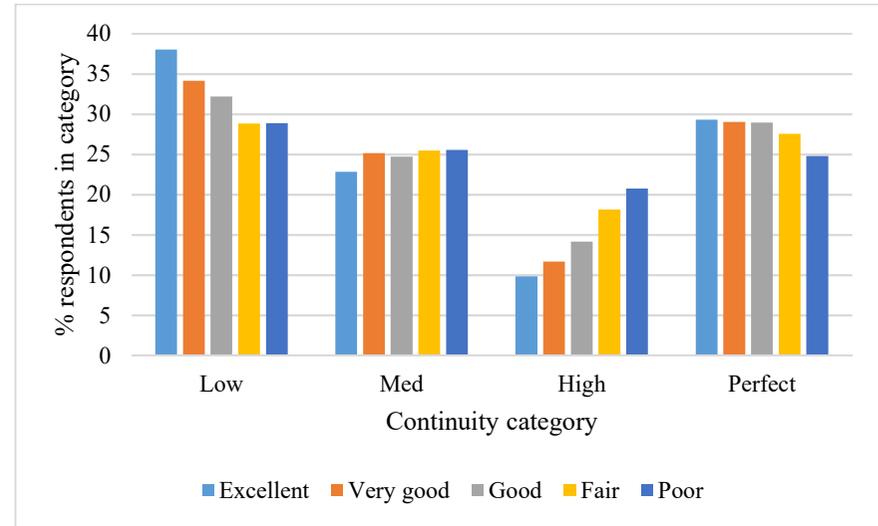
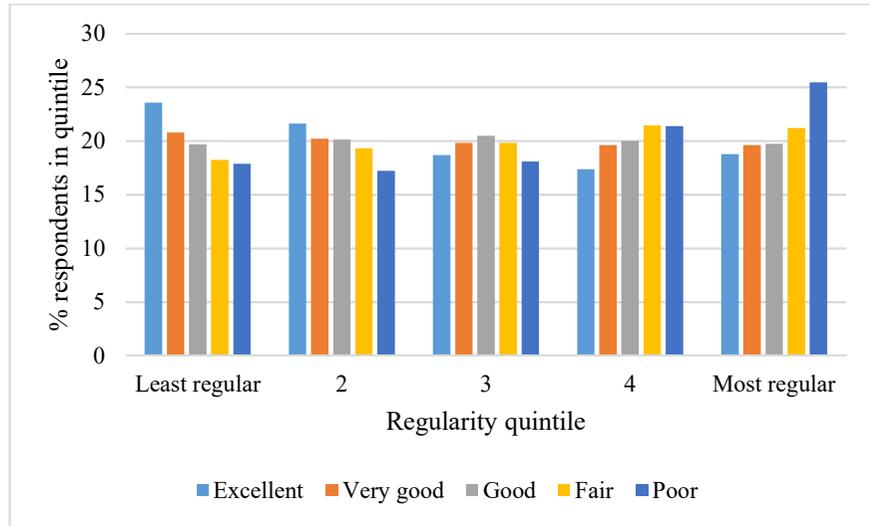
Age group



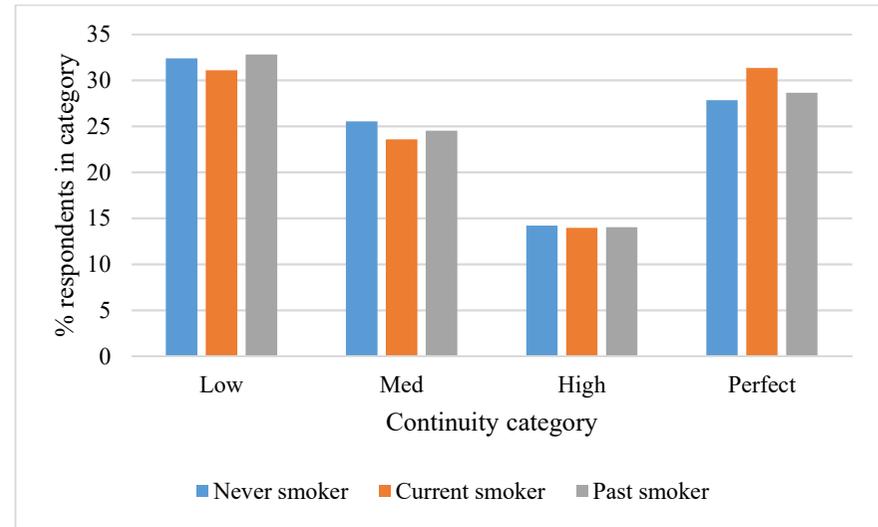
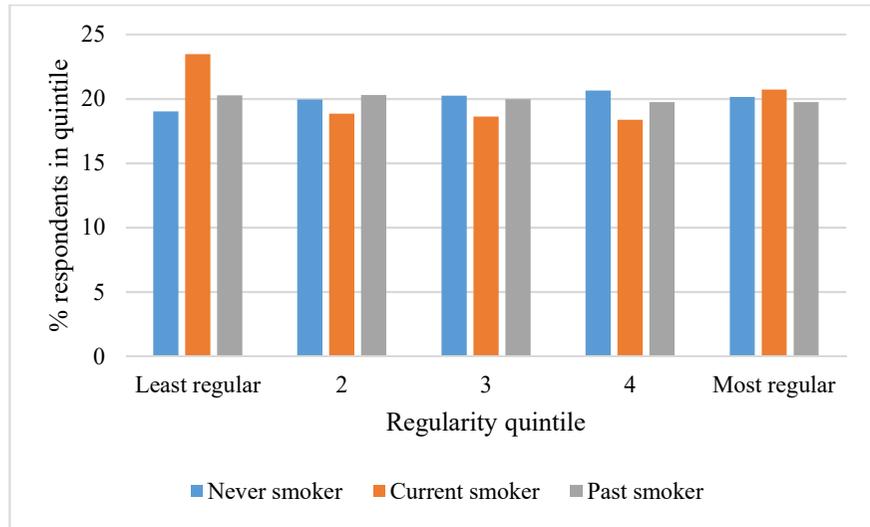
Sex



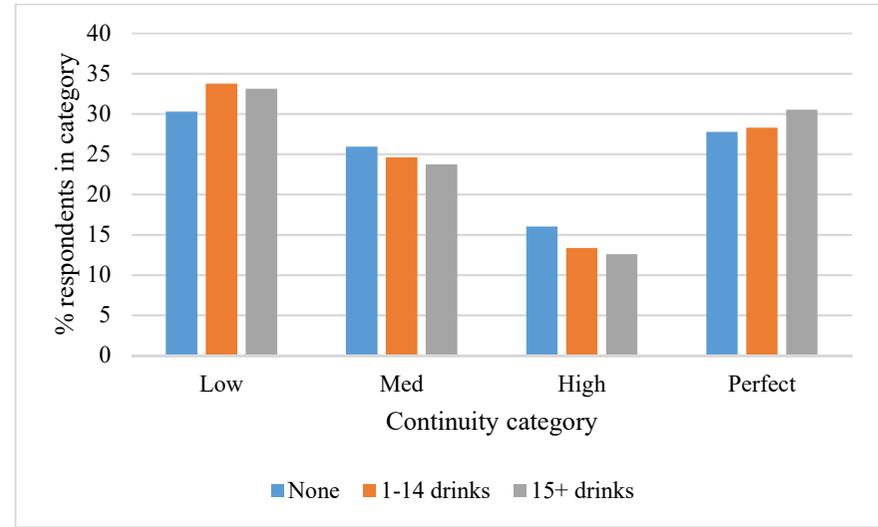
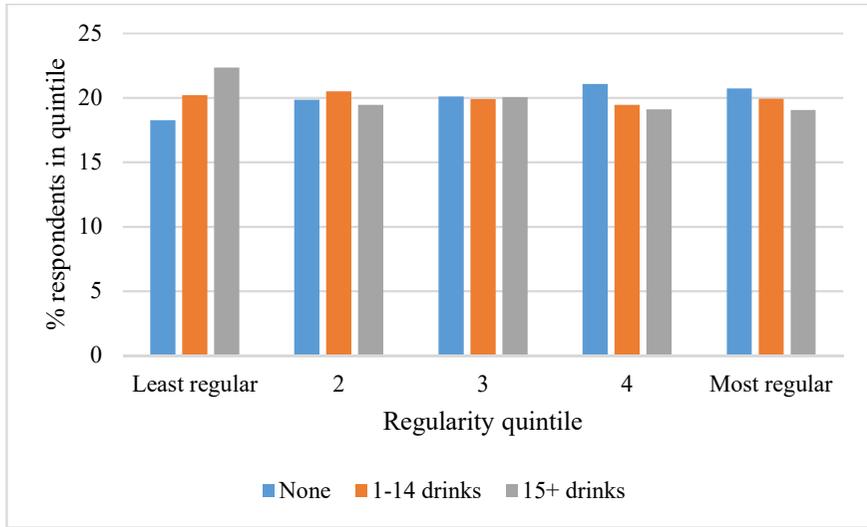
Self-reported health



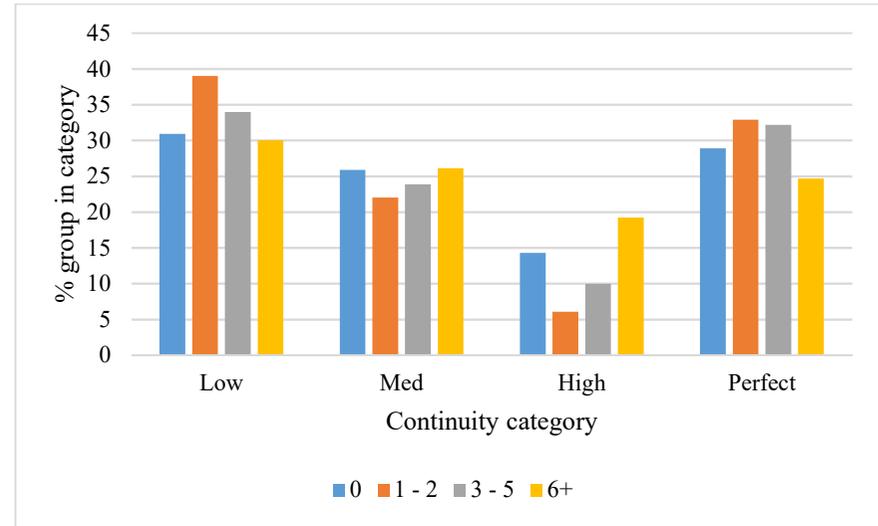
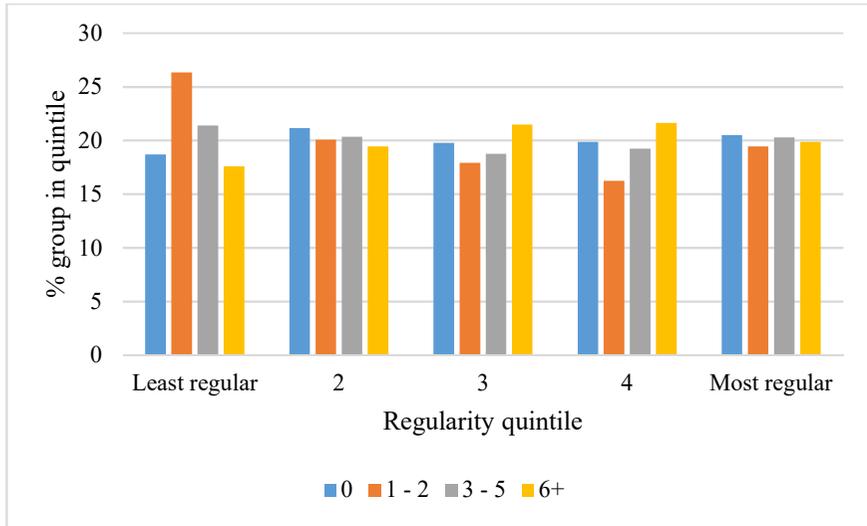
Smoking status



Alcohol intake



RxRisk – comorbidity count



MACSS – comorbidity count

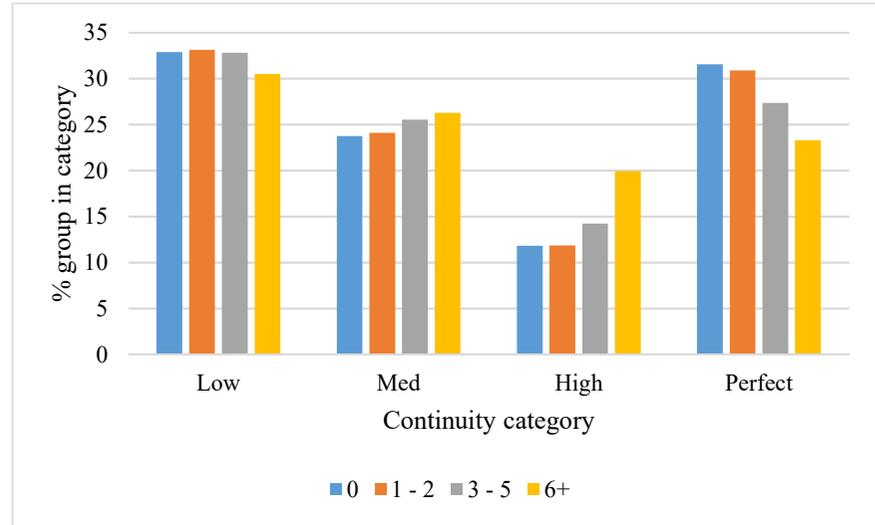
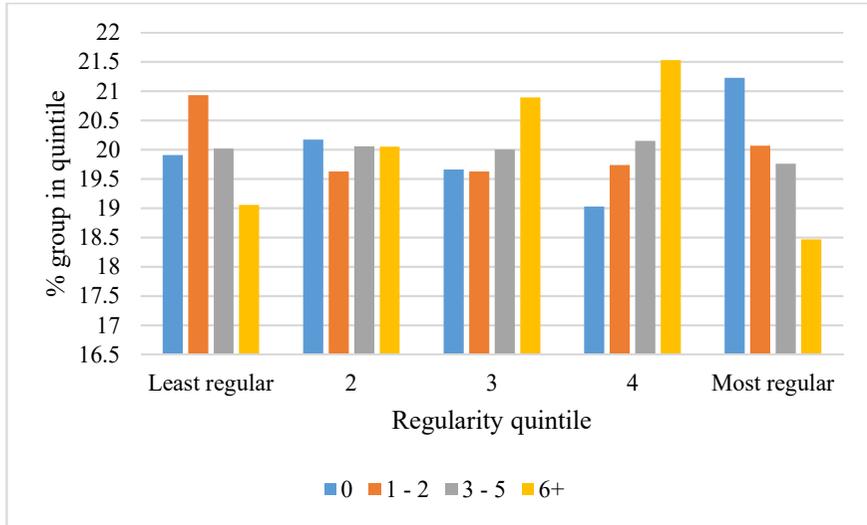
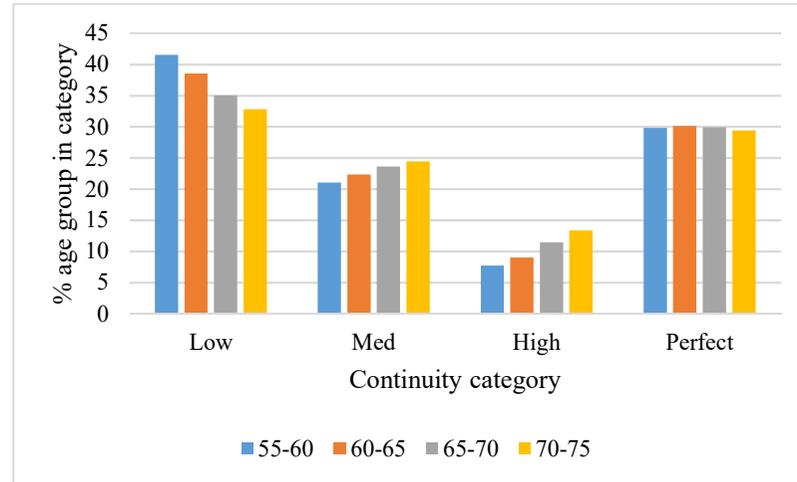
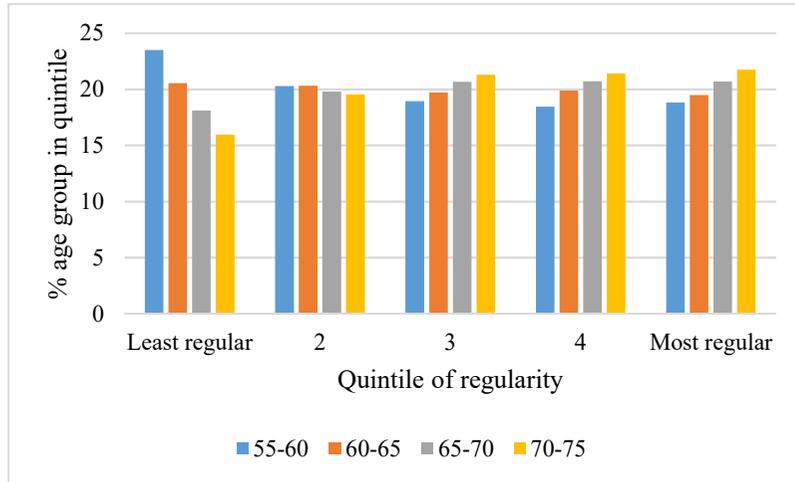


Figure 9-6: Relationships of regularity and continuity with various patient characteristics, cohort of existing statin users

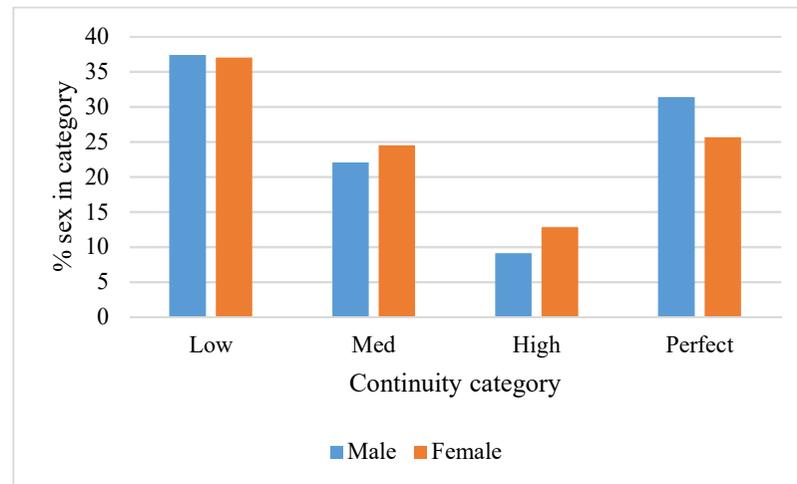
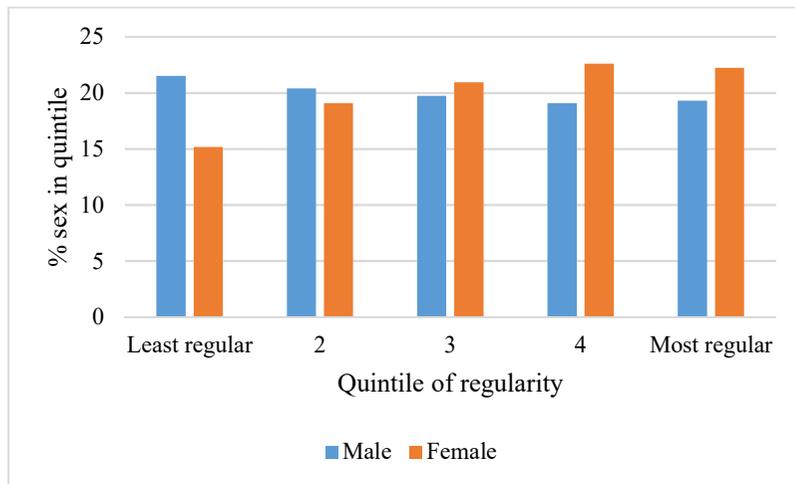
9.4.3.2.2 Potential statin users

Among potential statin users (those not using statins during the exposure period) associations with all patient characteristics tested were statistically significant for both exposures ($p < 0.001$ in all cases). Older age was associated with more regular care and higher continuity (except the perfect continuity group) (Figure 9-7). Women had higher regularity and continuity, again except for the perfect continuity group. Higher regularity was associated with both poorer self-rated health, as was continuity (barring the highest level). Regularity was generally higher among those with more comorbidities according to both RxRisk and MACSS. The same was observed for continuity, again barring the highest level. Alcohol intake was lower among those with high regularity and the same was true for continuity. The low regularity group were more likely to be current smokers, though for continuity, relationships with smoking status were unclear.

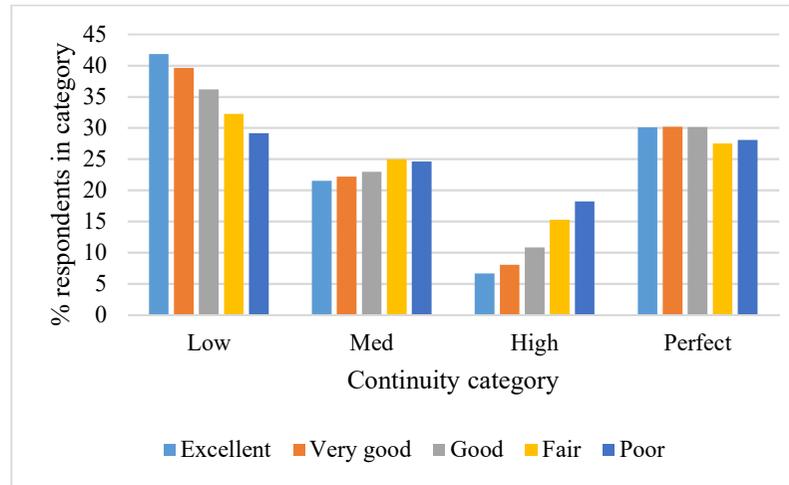
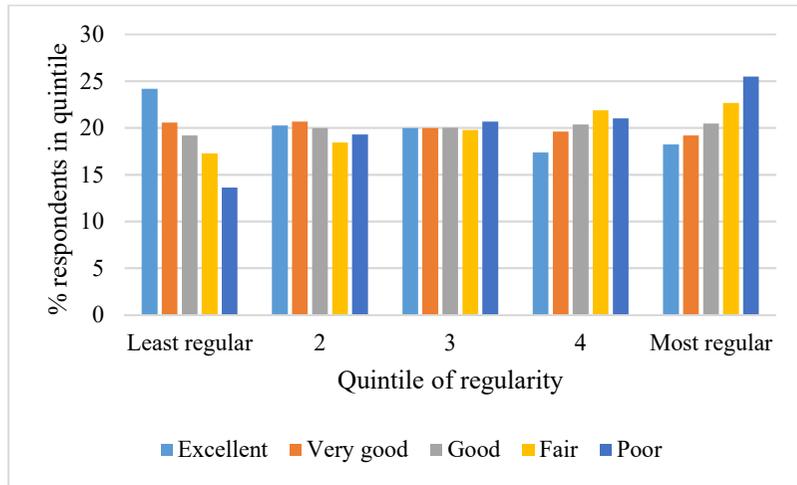
Age group



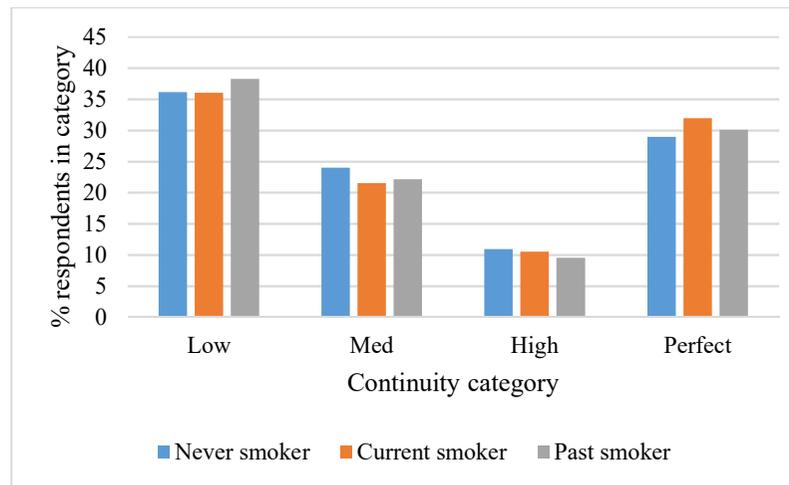
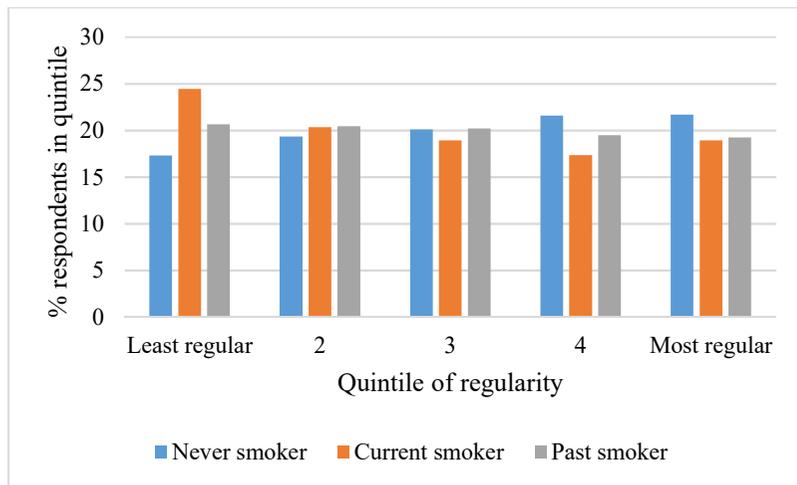
Sex



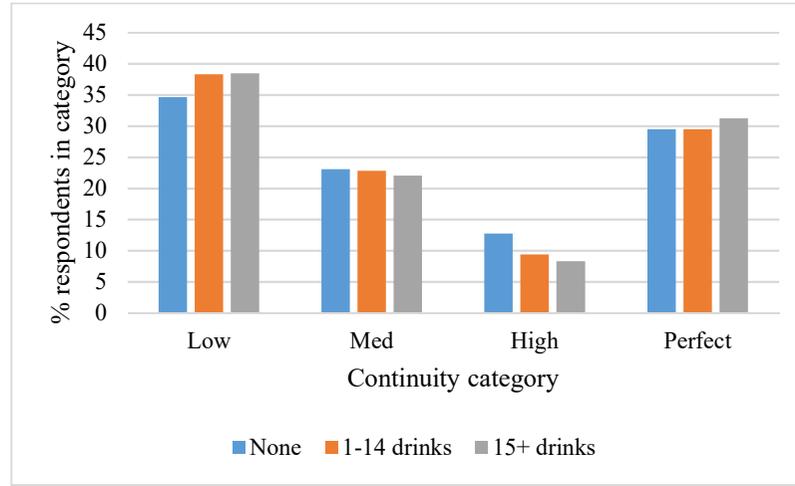
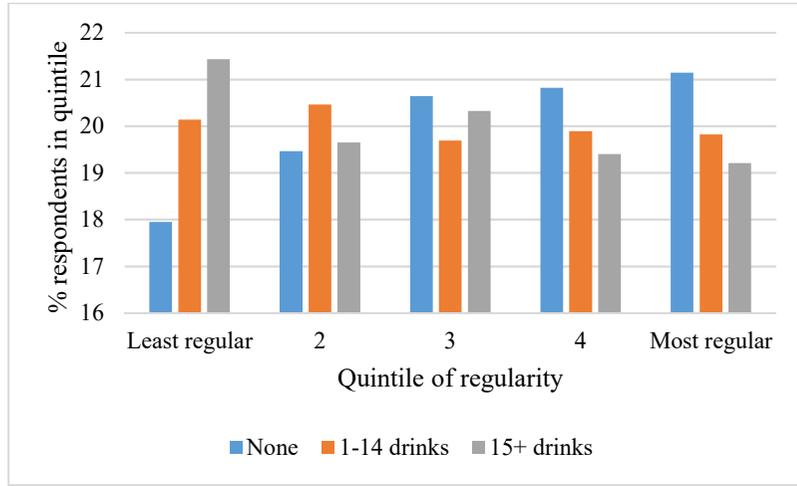
Self-reported health



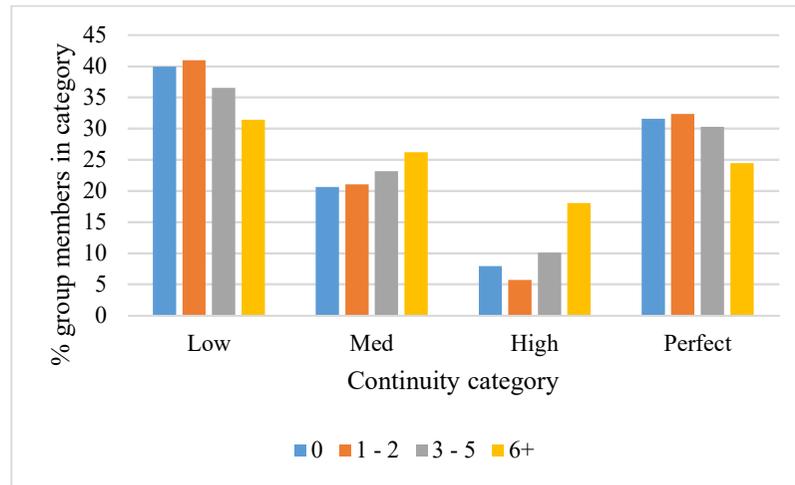
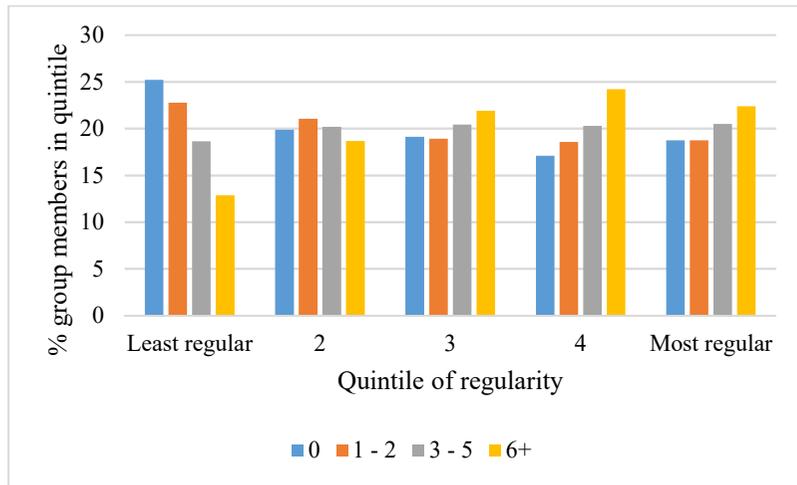
Smoking status



Alcohol intake



RxRisk – comorbidity count



MACSS – comorbidity count

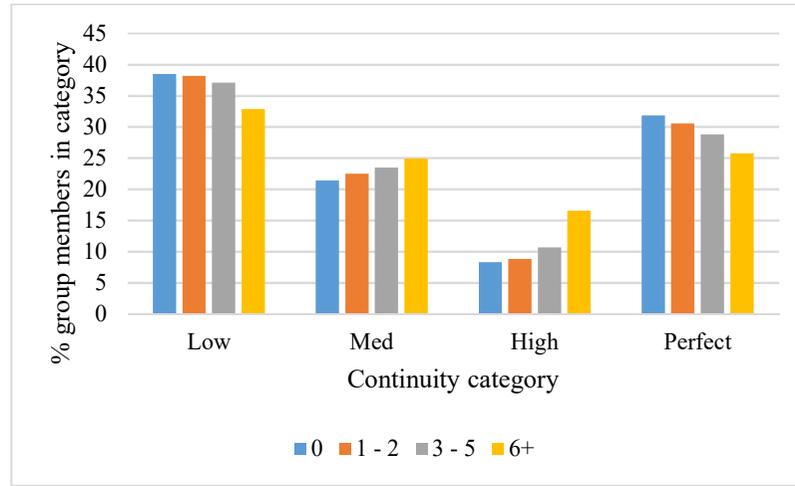
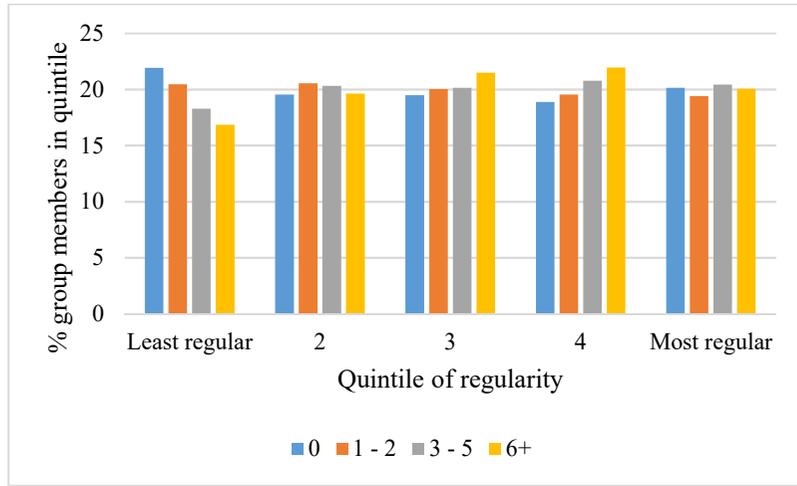


Figure 9-7: Regularity and continuity, relationship with various patient characteristics, cohort of potential statin users

9.4.3.3 Interactions between continuity and regularity in effects on statin use

Results are presented separately for existing and potential statin users.

9.4.3.3.1 Existing statin users

Table 9-7 displays results from the model of time to statin non-adherence among existing users, including an interaction between regularity and continuity. The joint test of significance suggested the interaction was not significant (Wald test $\text{Chi}^2(12)=6.51$, $p=0.888$), nor was any individual interaction parameter significant. In this model the main effects for continuity were marginally non-significant although point estimates remained similar to those reported in manuscript 5; the inclusion of the interaction term resulted in a substantial increase in the number of parameters estimated and hence larger standard errors.

Table 9-7: Results of model including interaction, cohort of existing users

		Haz ratio (95% CI)	SE	z	p
Regularity	Least regular	Reference			
	2	0.93 (0.86–1.01)	0.04	-1.62	0.105
	3	0.89 (0.82–0.97)	0.04	-2.59	0.010
	4	0.82 (0.75–0.90)	0.04	-4.20	<0.001
	Most regular	0.87 (0.79–0.96)	0.04	-2.82	0.005
Continuity	<0.5	Reference			
	0.5–0.75	0.93 (0.85–1.02)	0.04	-1.47	0.141
	0.75–0.99	0.89 (0.79–1.00)	0.06	-1.89	0.059
	1	0.91 (0.83–1.01)	0.04	-1.84	0.066
Interactions (regularity # continuity)	1#1	Reference			
	2#2	0.98 (0.86–1.12)	0.07	-0.30	0.761
	2#3	1.00 (0.84–1.18)	0.09	-0.05	0.958
	2#4	1.01 (0.88–1.16)	0.07	0.15	0.879
	3#2	1.03 (0.90–1.18)	0.07	0.38	0.703
	3#3	1.03 (0.87–1.23)	0.09	0.36	0.718
	3#4	0.95 (0.83–1.09)	0.07	-0.70	0.482
	4#2	1.05 (0.92–1.21)	0.07	0.73	0.468

		Haz ratio (95% CI)	SE	z	p
	4#3	1.02 (0.86–1.22)	0.09	0.24	0.814
	4#4	1.05 (0.91–1.20)	0.07	0.64	0.521
	5#2	0.93 (0.81–1.08)	0.07	-0.93	0.352
	5#3	0.93 (0.77–1.11)	0.09	-0.81	0.416
	5#4	0.92 (0.80–1.05)	0.06	-1.20	0.229
Frequency	3-5	Reference			
	6-9	0.93 (0.89–0.98)	0.02	-2.87	0.004
	10-14	0.90 (0.86–0.95)	0.03	-3.61	<0.001
	15-19	0.90 (0.84–0.96)	0.03	-3.09	0.002
	>19	0.83 (0.77–0.89)	0.03	-5.21	<0.001
RxRisk categories	0	Reference			
	1-2	1.43	0.05	10.18	<0.001
	3-5	1.10	0.03	3.18	0.001
	>5	0.92	0.03	-2.89	0.004
Work status - retired	No	Reference			
	Yes	0.82 (0.79–0.86)	0.02	-9.38	<0.001
Highest qualification	None	Reference			
	School	0.99 (0.93–1.05)	0.03	-0.39	0.695
	High school	1.11 (1.03–1.19)	0.04	2.73	0.006
	Trade or apprentice	1.08 (1.01–1.15)	0.04	2.29	0.022
	Certificate / diploma	1.13 (1.06–1.20)	0.04	3.86	<0.001
	University	1.33 (1.25–1.41)	0.04	8.95	<0.001
	Missing	1.15 (1.01–1.32)	0.08	2.04	0.041
High blood pressure	No	Reference			
	Yes	0.86 (0.83–0.89)	0.02	-8.66	<0.001
CVD status	High risk	Reference			
	Confirmed	1.01 (0.96–1.06)	0.02	0.36	0.719
Heart condition	No	Reference			
	Yes	0.85 (0.81–0.90)	0.02	-6.18	<0.001

Stratified by age, other language spoken at home, prescriber of first statin in exposure year (GP or other), SEIFA

9.4.3.3.2 Potential statin users

Results of the model of statin initiation among potential users, including interactions between regularity and continuity, are displayed in Table 9-8. Once again, the addition of interaction terms led to larger standard errors for the main effects of regularity and continuity. The interaction was statistically significant according to the joint test (Wald test $\chi^2(12)=25.08$, $p=0.014$). There were three significant interaction effects out of 12 – odds ratios less than one on levels 3/3 and 5/3 of regularity / continuity, respectively; and an odds ratio above one on level 4/4 of regularity/continuity; the other nine interactions were non-significant. This provides limited evidence that the positive effect of continuity on adherence reduces at higher levels of regularity (that is, substitution occurs), except for perfect continuity which may be associated with increased initiation at higher levels of regularity. The predicted likelihoods of initiation in each group, derived via the `-margins-` command, are displayed in Figure 9-8. The figure presents a positive slope for the lowest level of continuity (increasing likelihood of initiation with increasing regularity) which is not observed for the high continuity group, providing some evidence of a substitution effect. Note that although slopes appear different most data points are not statistically significant, and those that are significant do not follow clear patterns. For example, in the perfect continuity group the interaction with the second highest level of regularity was significant, but no interaction was reported for the highest regularity group.

Table 9-8: Results of model including interaction, cohort of potential users

		OR (95% CI)	SE	Z	p
Regularity	Least regular	Reference			
	2	1.06 (0.92–1.22)	0.08	0.77	0.440
	3	1.10 (0.95–1.27)	0.08	1.21	0.225
	4	1.13 (0.97–1.31)	0.09	1.58	0.115
	Most regular	1.27 (1.08–1.49)	0.10	2.90	0.004
Continuity	0–0.05	Reference			
	0.05–0.75	1.07 (0.89–1.27)	0.10	0.71	0.481
	0.75–0.99	1.48 (1.18–1.84)	0.17	3.43	0.001
	1	0.88 (0.74–1.06)	0.08	-1.34	0.179
Interaction (regularity# continuity)	1#1	Reference			
	2#2	1.09 (0.86–1.39)	0.13	0.72	0.474
	2#3	0.77 (0.56–1.05)	0.12	-1.65	0.099
	2#4	1.26 (0.99–1.61)	0.16	1.88	0.060

		OR (95% CI)	SE	Z	p
	3#2	1.05 (0.83–1.34)	0.13	0.42	0.674
	3#3	<i>0.73 (0.54–0.98)</i>	<i>0.11</i>	<i>-2.08</i>	<i>0.038</i>
	3#4	1.21 (0.95–1.54)	0.15	1.57	0.116
	4#2	0.93 (0.73–1.19)	0.12	-0.56	0.576
	4#3	0.80 (0.59–1.09)	0.12	-1.43	0.154
	4#4	<i>1.28 (1.01–1.63)</i>	<i>0.15</i>	<i>2.06</i>	<i>0.039</i>
	5#2	0.94 (0.73–1.20)	0.12	-0.51	0.609
	5#3	<i>0.58 (0.43–0.80)</i>	<i>0.09</i>	<i>-3.38</i>	<i>0.001</i>
	5#4	1.19 (0.94–1.51)	0.14	1.45	0.146
Frequency	3–5	Reference			
	6–9	1.21 (1.12–1.31)	0.05	4.68	<0.001
	10–14	1.32 (1.21–1.45)	0.60	6.14	<0.001
	15–19	1.17 (1.04–1.31)	0.07	2.72	<0.006
	>19	1.08 (0.96–1.22)	0.07	1.35	0.177
Rx risk conditions	0	Reference			
	1–2	0.81 (0.73–0.89)	0.04	-4.31	<0.001
	3–5	1.61 (1.48–1.75)	0.07	10.90	<0.001
	>5	3.31 (3.01–3.63)	0.16	24.93	<0.001
CVD status	High risk	Reference			
	Confirmed CVD	2.18 (2.00–2.38)	0.10	17.71	<0.001
Heart disease	No	Reference			
	Yes	1.17 (1.06–1.28)	0.06	3.16	0.002
Diabetes	No	Reference			
	Yes	2.73 (2.53–2.96)	0.11	25.13	<0.001
High blood pressure	No	Reference			
	Yes	1.32 (1.25–1.40)	0.04	9.29	<0.001
Language other than English	No	Reference			
	Yes	1.13 (1.02–1.25)	0.06	2.39	0.017
History of stroke	No	Reference			
	Yes	0.71 (0.62–0.82)	0.05	-4.60	<0.001
Non-melanoma skin cancer	No	Reference			
	Yes	0.86 (0.80–0.91)	0.03	-4.75	<0.001
Depression	No	Reference			
	Yes	0.79 (0.73–0.86)	0.03	-5.27	<0.001
	Missing	0.99 (0.90–1.07)	0.04	-0.33	0.739

	OR (95% CI)	SE	Z	p
Constant	1.00 (0.09–0.11)	0.01	-32.37	<0.001

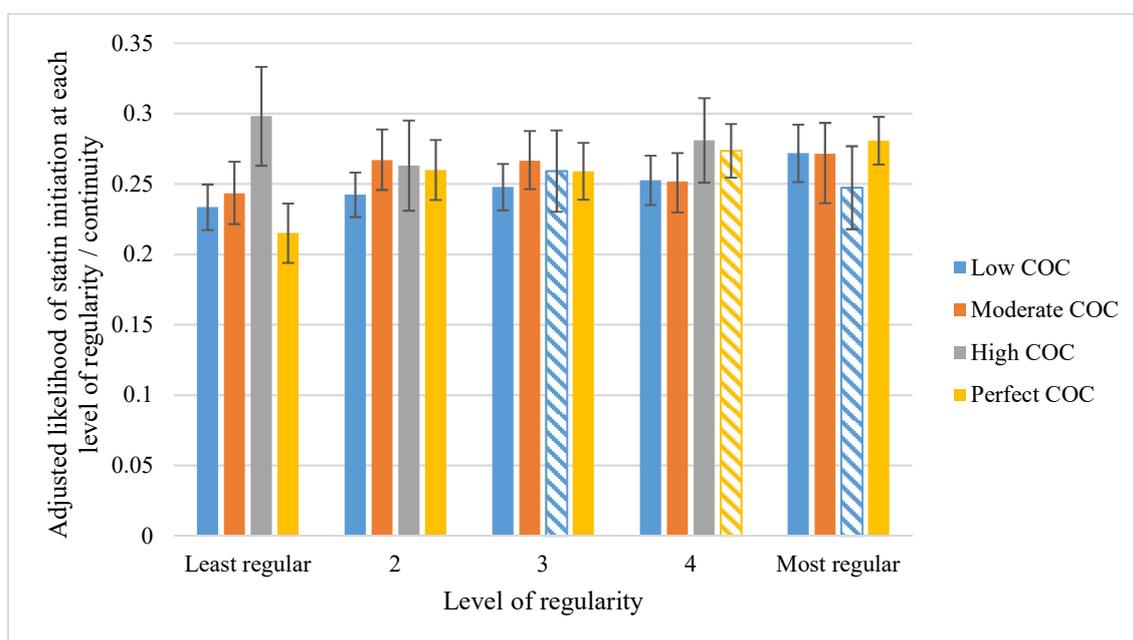


Figure 9-8: Adjusted likelihood of statin initiation according to regularity / continuity level, among a cohort of potential statin users. Striped data points indicate significant interaction terms

9.4.4 Discussion

These analyses found positive correlations between regularity and continuity of care among both existing and potential statin users.

Relationships that regularity and continuity had with patient characteristics were largely similar, and these findings were observed among both existing users and potential users. In terms of indicators of prior health status, regularity and continuity were generally higher among those with worse self-rated health and more comorbidities. Relationships with predisposing factors were similar for both exposures, with older people and women having higher regularity and continuity. In terms of other health behaviours, alcohol intake was lower among people with higher regularity / continuity in both cohorts. The same was observed for regularity in relation to smoking, however clear relationships were not present between continuity and smoking status.

The one consistent exception to these patterns was that for continuity, trends that were observed with increasing continuity tended to reverse at the highest level (perfect continuity). The most likely reason for this is that perfect continuity may be more likely to be achieved for patients having very few contacts (as they have fewer opportunities to miss seeing their usual GP), and this may in many cases reflect a minimal need for health care as opposed to a deliberate effort at achieving continuity of care by a patient / GP dyad concerned with managing the patient's health. Alternatively, low numbers of contacts may reflect a group of patients less proactive in managing their health. Existing literature does not generally discuss this issue. The group with perfect continuity are often grouped with others achieving high continuity above a given cut-off level (93), or continuity is included in models as a continuous variable (96); though some exceptions do exist in which this group is analysed separately (126). Where this perfect continuity group are not treated separately from others with high continuity there may be a risk of bias: high continuity may be assumed to lead to reduced hospital use (or other outcome under study) in this group, when in fact the low continuity level instead results from the patient being in good health, which also drives the outcome under study.

From this analysis of the relationships between regularity and continuity, and assessment of interactions between them in influencing patient outcomes, there are several important findings.

Firstly, the positive relationship between the two variables suggests that each of regularity and continuity are indicative of similar patient characteristics. However, there was little evidence that the two measures are so highly correlated as to be interchangeable, considering the small amount of variance in regularity that was explained by continuity in the linear regression model. This suggests that there is value in capturing both indicators where possible to use as explanatory factors when estimating patient health or service use outcomes.

Secondly, there was evidence to support the idea that both variables do reflect planned and proactive care by patients and / or their GPs. Regularity and continuity were highest among patients whose health was the poorest, i.e. where the need for planned and proactive care was likely the greatest. Regularity and continuity were also generally higher among patients who demonstrated healthier behaviours in terms of smoking and alcohol intake, which may indicate that regular and continuous care is more likely to be achieved by patients who take a proactive role in managing their own health. These findings are consistent with what would be expected theoretically, based on the Andersen framework of health service utilisation.

Finally, the evidence for interactions between regularity and continuity in influencing statin use outcomes was limited. In the model of statin adherence among existing users the joint test was non-significant. In the model of statin initiation among potential users the joint test was significant, though only three interaction coefficients were significant (of 12 total interaction terms), and the coefficients that were significant did not form any consistent pattern, providing only very limited evidence of a substitutive relationship.

These findings are useful both from both a research and policy perspective. In terms of policy, the lack of evidence for interactions between regularity and continuity presents the most meaningful information. This finding suggests that effects of the two exposures are additive, where the level of continuity does not influence the potential benefits achieved by achieving regular care, and vice versa. The implication is that any initiative aimed at increasing continuity is likely to be similarly effective regardless of the regularity of contact among the population subject to the initiative, and interventions aimed at increasing regularity are unlikely to be impacted by the level of continuity present. This is relevant in considering the need for targeting of policies to specific patient groups.

Of course, there may be situations where a trade-off exists between regularity and continuity. For example, a policy which aimed to ensure that a patient consistently sees their usual GP might promote continuity, but could adversely impact regularity if visits with that specific GP cannot be scheduled on a regular basis (241). In such a case benefits expected due to more continuous care may not eventuate due to the care also becoming less regular.

From a research perspective these findings support the idea of measuring both exposures to better characterise GP contact patterns. The low R^2 value estimated in the regression of regularity on continuity indicates that the two variables are not closely correlated. Hence by measuring both exposures additional information is captured, and estimations of patient health / health service use outcomes are likely to be improved. Researchers calculating measures of continuity in studies using administrative data would generally have the ability to calculate regularity, provided that information on service dates is available, so this could be incorporated into studies without difficulty.

Limitations reflect those outlined in manuscript 5, plus some additional limitations specific to the analyses presented here. Firstly, the linear regression of the log-transformed regularity score on continuity (in categories) is limited by the fact that the transformed continuity score remained non-normal (though was much closer to normal than the non-transformed score). The fact that the continuity score was in a categorical form would have the effect of pushing the R^2 value down, as some variance in the score is lost when converting from a continuous to a categorical variable. However, this is unlikely to impact findings so severely as to misinform regarding the direction of coefficients, or to have resulted in a close correlation between continuity and regularity being missed. Secondly, the assessments of relationships with patient characteristics were all univariate. Although this is useful for descriptive purposes there is a risk in each of these assessments that results are driven by confounding. For example, findings in relation to the RxRisk and MACSS comorbidity indices may have been confounded by age, as comorbidity increases with increasing age (13).

9.5 Analysis 3: Statin use as a mediator of hospital / ED outcomes

9.5.1 Introduction

The value in understanding associations between regularity / continuity and statin use, as described in manuscript 5, is in the expectation that this will ultimately impact on patient health and hospital / ED use. Chapter 8 demonstrated that among people with T2DM, associations with process of care outcomes (pathology monitoring) did not translate into improvements in evaluated health as indicated by HbA1c level. This reflects the findings of other continuity of care studies described in section 2.2.2.8. Studies assessing continuity of care and hospital / ED use outcomes generally report substantial negative associations (section 2.2.2.3) and similar associations have been reported in studies of regularity (section 2.2.2.7.1); hence there is some disconnect between findings regarding hospital / ED use and measures of evaluated patient health. If these exposures do not positively influence objective measures of patient health, the likelihood that negative associations with hospitalisation outcomes reflect a causal relationship is reduced.

The analysis of statin use provides an opportunity to further assess causal pathways by performing mediation analysis. That is, the role of medication adherence as a mediator of hospital / ED outcomes can be assessed to test the type of causal pathway commonly assumed to exist in the continuity of care literature and outlined in the Andersen model of health service use (section 2.2.1.2). Mediation analysis allows for the estimation of indirect and direct effects. An indirect effect, or mediated effect, is the effect of a cause on an outcome through a mediator of interest, while a direct effect is any effect of the exposure on an outcome that is not via the mediator (250) (note that although these are referred to as direct effects, they may actually be via an unobserved mediator). Incorporating intermediate outcomes (mediators) and downstream outcomes into a single analysis is advantageous as this allows an estimation of the proportion of the effect operating via the mediator, and improves understanding of potential causal pathways by testing the potential underlying mechanisms. Substantial indirect effects via the statin use mediator would provide stronger evidence for a causal link between continuity / regularity and hospital / ED use outcomes.

9.5.2 Methods

Most methods are explained in manuscript 5. A brief overview of the most important points is provided here, along with an explanation of the methods applicable to the mediation analysis.

9.5.2.1 Data

Data used in these analyses are from the 45 and Up Study, administered by the Sax Institute. These data are explained in detail in section 3.2.2.

9.5.2.2 Cohort

The cohort selection is explained in manuscript 5. The cohort consists of individuals with high absolute CVD risk, which refers to a greater than 15% likelihood of a cardiovascular event within the following five years. This cohort includes people with existing CVD, among whom statin use would represent secondary prevention, and people at risk of developing CVD, among whom statin use would represent primary prevention. The cohort is further divided into those who have never used statins (potential users) and those taking statins through the exposure period (existing users).

9.5.2.3 Exposures

The exposures, regularity and continuity, are described in manuscript 5. Regularity was assessed based on the Modified Regularity index, converted into quintiles from least to most regular. Continuity was measured using the Continuity of Care index, with categories of low (0–0.49), moderate (0.5–0.74), high (0.75–0.99) and perfect (1) continuity.

9.5.2.4 Mediator

The mediating variable was use of statins. In manuscript 5, for the cohort of existing statin users, statin use was assessed using a time to event analysis, in which case the statin use outcome was time to non-adherence, with non-adherence defined as the first day of any 30-day period without statins in supply. In mediation analysis this is unsuitable as (i) outcomes (hospitalisation) need to be measured following the measurement of the mediator and exposures, hence the three-year period over which time to non-adherence was measured puts too long a period between exposure and outcome, and (ii) the methods used require a continuous or binary mediator variable (so do not suit a time-to-event analysis). Statin adherence was instead assessed using the medication possession ratio (MPR), which provides a value from zero to one stating the proportion of days during the measurement period that the patient had statins in supply, based on dispensing records (251).

The MPR was calculated as follows. After each recorded statin dispensation, the patient was in supply for a number of days based on the quantity dispensed (in Australia, the patient is usually in supply for 30 days as most statins come in packets of 30 tablets). If the patient did not record another dispensation prior to the date that the current supply was scheduled to end, they were considered without supply until the next recorded dispensation. Where a script was dispensed prior to the previous dispensation ending (less than 30 days since the previous dispensation) overlapping days were carried forward. When patients were in hospital they were assumed to be receiving statins via the hospital pharmacy and the end date of the active dispensation was adjusted accordingly. The number of days with statins in supply was divided by the number of days in the measurement period (in this case, 365 days) to determine the MPR.

For the cohort of potential statin users the mediating variable was initiation of statins, reflecting the outcome analysed in manuscript 5.

9.5.2.5 Outcomes

Outcomes were hospitalisations and ED presentations for cardiovascular conditions, analysed separately. As the NSW Admitted Patients Data Collection (APDC) records diagnoses using ICD-10-AM, those hospitalisations flagged as outcomes were those with a primary or secondary diagnosis code of I00–I99, i.e. Diseases of the Circulatory System. NSW ED data use both ICD-9 and SNOMED coding to capture diagnoses, with individual hospital EDs using either one or the other system. ICD-9 codes flagged were codes 390–459, Diseases of the Circulatory System. SNOMED codes were those equivalent to the ICD-10-AM codes I00–I99, determined based on the SNOMED mapping tool (252). Hospitalisation and ED presentations for cardiovascular conditions were assessed separately, with each treated as a binary variable indicating any admission / presentation in the outcome period.

9.5.2.6 Covariates

Covariates include those as described in the manuscript, which were selected via a stepwise selection process. Whereas in standard observational studies unbiased estimates rely on the assumption of no unmeasured exposure–outcome confounding, further assumptions apply to mediation analysis. The assumption of no unmeasured exposure–outcome confounding remains relevant, with additional assumptions of no unmeasured mediator–outcome confounding, and no unmeasured exposure–mediator confounding (253). The covariates previously selected as described in the methods of manuscript 5 were selected based on the exposure–outcome relationship being assessed in that manuscript, which is the exposure–mediator relationship in the current analysis. It is likely that many of these covariates will also act as controls for the exposure–outcome relationship, for example measures of patient health (comorbidity measured via the RxRisk index, frequency of GP contact, high blood pressure and heart disease) which are likely to be associated with both regularity / continuity and hospitalisation outcomes. To improve control of potential confounding of the mediator–outcome relationship two additional variables were included as confounders in the mediation analysis. These were smoking status and physical exercise. These were considered potential confounders due to known associations with cardiovascular health outcomes (254, 255) and the high likelihood that they were associated with medication adherence (256), as both are markers of patient health behaviours.

The specific forms of covariates differ here in comparison to the forms described in manuscript 5, as the mediation analysis method used did not support the use of categorical variables. The forms of covariates are described in Table 9-9.

Table 9-9: Covariates included in mediation analysis

Covariate	Form
Frequency	Count of GP visits during exposure period
RxRisk comorbidities	Count of comorbidities in five years to end of exposure period
Age	Continuous
Working status	Binary, 0 = working / studying, 1 = fully retired
High blood pressure	Binary, 0 = never diagnosed, 1 = diagnosed
Language spoken at home	Binary, 0 = English, 1 = other
Condition cohort	Binary, 0 = primary prevention, 1 = secondary prevention
Heart disease	Binary, 0 = never diagnosed, 1 = diagnosed
Vigorous exercise	Binary, 0 = none, 1 = any in the week prior to survey
Smoker	Binary, 0 = never / past smoker, 1 = current smoker
Regularity (models with COC as mediator)	Converted into quintiles, then used as a continuous variable
COC (models with regularity as mediator)	Continuous

9.5.2.7 Analysis

Traditionally, mediation analysis in the health sciences has been performed using a method called the difference method (253). In this method, two regressions are run separately. In regression 1, the outcome is regressed on the exposure and covariates, producing an exposure coefficient α_1 . In regression 2, the outcome is regressed on the exposure, the mediator, and covariates, producing an exposure coefficient β_1 . If β_1 is smaller than α_1 , and the effect of the exposure diminishes after controlling for the mediator, this is thought to indicate mediation. The indirect or mediated effect is given by $\alpha_1 - \beta_1$, and β_1 is interpreted as the direct effect (250, 257).

A similar method is the product approach (258). Under the product approach the outcome is regressed on the exposure, mediator and covariates, producing an exposure coefficient α_2 . The mediator is then regressed on the exposure and covariates, producing a mediator coefficient β_2 and an exposure coefficient β_1 . The indirect effect is the product of β_2 and α_2 , while the direct effect is given by β_1 (250, 257). Although these methods are well suited to research involving continuous outcomes, they typically produce biased results where binary outcomes are assessed (253). These methods have also been criticised for a lack of consideration of the effects of confounders, limiting the ability to form any causal interpretation (250, 257). More recently developed methods are now considered more appropriate for many mediation analyses (259).

These methods utilise a counterfactual framework to define natural direct effects and natural indirect effects which sum to the total effect (259). An overview of the counterfactual framework is as follows.

Where X is the exposure (continuity of care), M is the mediator (statin use) and Y is the outcome (cardiovascular hospitalisation):

$Y(x)$ is the outcome Y when X is set to x

$M(x)$ is the outcome M when X is set to x

$Y(x, m)$ is the outcome Y when $X=x$ and $M=m$

$E(Y)$ refers to the expected value of Y

The controlled direct effect (CDE) compares the outcomes under treatment level $X=1$ vs $X=0$, fixing M to m (the change in outcome if the mediator was fixed at m but the population changes from unexposed to exposed, or the effect of the exposure on the outcome not via the mediator) (253):

$$CDE(m) = E(Y(1, m)) - E(Y(0, m))$$

The CDE(m) may differ depending on the level at which M is set.

The “natural direct effect” (NDE) compares outcomes under treatment level $X=1$ vs $X=0$, fixing M to $M(0)$ (i.e. for each individual the mediator takes the value it would take in the absence of the exposure):

$$NDE_0 = E(Y(1, M(0))) - E(Y(0, M(0)))$$

The natural indirect effect (NIE) compares outcomes under treatment level $M=M(1)$ vs $M=M(0)$, fixing $X=1$ (the change in outcome if all individuals are exposed but the mediator changes from the level it would take if all people are unexposed, to the value if all people are exposed) (260):

$$NIE_I = E(Y(1, M(1))) - E(Y(1, M(0)))$$

The total causal effect (TCE) is

$$TCE = E(Y(1)) - E(Y(0)) = NDE + NIE$$

The proportion of mediation can be calculated by:

$$PM = NIE / TCE$$

The NDE and NIE are of interest in understanding the actions of potential causal mechanisms (mediators) and the importance of different pathways.

The mediation analysis was performed using Stata's `–paramed–` command (261). As the `–paramed–` package allows for a single exposure, the effects of regularity and continuity were assessed in separate models. In each case the variable not included as an exposure was instead included as a covariate. The `–paramed–` package does not support inclusion of factor variables, instead it requires that two levels of the exposure be defined (baseline and alternative treatment levels), meaning the results then reflect the difference in outcome between these two levels of exposure. For regularity the baseline treatment level was defined as a value of one (i.e. the least regular quintile) while the alternative treatment level was five (i.e. most regular). The controlled direct effect was estimated at $MPR=(0.845)$, which was the mean value of the mediator. For continuity the baseline treatment level was zero and the alternative was one (i.e. perfect continuity, with all visits to the same GP). Standard errors and confidence intervals were derived via bootstrapping with 500 replications, results tables report bias-corrected confidence intervals.

9.5.2.8 Design (timeframes)

Exposures were measured from July 2011 to June 2012, as in manuscript 5. For the timing of the mediator and outcome two approaches were considered. The first approach was to measure the mediator through the same period as the exposures, and measure the outcomes in the following year, from July 2012 to June 2013. The second approach was to use three separate time periods, to measure the mediator from July 2012 to June 2013, and the outcomes from July 2013 to June 2014. Designs similar to approach 1 have been used before (262) for similar reasons. These approaches are explained in Table 9-10.

Table 9-10: Approaches to the timing of measurement of exposure, mediator and outcome

	Period 1 July 2011-June 2012	Period 2 July 2012-June 2013	Period 3 July 2013-June 2014
Approach 1	Measure exposure Measure mediator	Measure outcome	-
Approach 2	Measure exposure	Measure mediator	Measure outcome

The first approach was selected as the main analysis as mediators should generally be measured close in time to exposures, to reduce the risk that any mediator–outcome confounder is affected by the exposure, an assumption necessary for estimation of an unbiased NIE and NDE (253). The disadvantage of this approach is the risk of reverse confounding (statin adherence leading to changes in regularity / continuity), though this was considered less likely than the reverse causation that may occur when primary care exposures and hospitalisation outcomes are measured concurrently. Although the second approach (three separate time periods) reduces the risk of reverse confounding in the exposure–mediator relationship, it is potentially problematic in the measurement of direct effects as it introduces a one-year gap between exposure and outcome measurement, which may potentially lead to associations being missed if these are not sustained over more than one year. Approach 2 was used as a sensitivity analysis / robustness check. As the mediation analysis procedure used involves regression of the mediator on the exposure, the mediator–exposure coefficients reported were compared for the two approaches to assess the likelihood that reverse confounding influenced the exposure–mediator relationship (a similar exposure–mediator relationship in both approaches would indicate that reverse causation was unlikely).

9.5.3 Results

Among 29,782 existing statin users, the mean MPR in 2011–12 was 0.845, with 9,691 (32.5%) having complete coverage, where statins were in supply through the entire year. Cardiovascular hospitalisations were recorded among 2,687 (9.02%) during 2012–13, and cardiovascular ED presentations among 942 (3.16%). Note this cohort size is slightly smaller than that reported in manuscript 5, due to small numbers who did not respond in the 45 and Up survey to the additional covariates used here.

9.5.3.1 Existing statin users

9.5.3.1.1 Hospitalisation outcomes

Table 9-11 below presents outputs from models with cardiovascular hospitalisation as the outcome, with regularity as the exposure.

Part 1 shows that regularity had a significant negative association on cardiovascular hospitalisations, as did MPR, while controlling for each other and other covariates. A change in regularity from least to most regular was associated with a reduction in hospitalisations (coef -0.037, 95% CI -0.065 to -0.005), while a change in MPR from zero to one (i.e. from fully non-adherent to fully adherent) was associated with fewer hospitalisations (coef -0.389, 95% CI -0.554 to -0.234). In part 2 we see that regularity had a positive association with MPR as expected, a change in regularity from least to most regular was associated with an increase in MPR (coef 0.01, 95% CI 0.008–0.012) in MPR.

Table 9-11: Hospitalisation outcomes (2012–13) on regularity (2011–12) and statin adherence (2011–12)

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	-0.037	0.015	-2.49	0.013	-0.067	-0.008
MPR	-0.389	0.082	-4.77	<0.001	-0.549	-0.229
COC	0.082	0.076	1.08	0.281	-0.067	0.231
Frequency	0.022	0.003	8.94	<0.001	0.017	0.027
RxRisk comorbidities in previous five years	0.089	0.008	11.74	<0.001	0.074	0.104
Age	0.014	0.005	3.03	0.002	0.005	0.023
Retired (ref. not retired)	-0.107	0.048	-2.22	0.026	-0.201	-0.012
High blood pressure (ref. never diagnosed)	0.080	0.044	1.81	0.071	-0.007	0.166
Lang. other than English at home (ref. English)	-0.155	0.075	-2.07	0.038	-0.302	-0.008
Statins for secondary prevention (ref. primary)	0.595	0.056	10.53	<0.001	0.484	0.705
Heart disease diagnosis (ref. never diagnosed)	0.207	0.052	3.95	<0.001	0.104	0.310

Vigorous exercise at least weekly (ref. none)	-0.078	0.042	-1.89	0.059	-0.160	0.003
Current smoker (ref. never / past smoker)	0.063	0.079	0.79	0.427	-0.092	0.217
Constant	-4.120	0.293	-14.04	<0.001	-4.696	-3.545

Part 2: Mediator on exposure and covariates

	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	0.010	0.001	10.35	<0.001	0.008	0.012
COC	0.023	0.005	4.74	<0.001	0.014	0.033
Frequency	-0.001	0.000	-4.72	<0.001	-0.001	-0.001
RxRisk comorbidities in previous five years	0.004	0.001	8.36	<0.001	0.003	0.006
Age	0.003	0.000	10.23	<0.001	0.002	0.004
Retired (ref. not retired)	0.032	0.003	9.98	<0.001	0.026	0.038
High blood pressure (ref. never diagnosed)	0.027	0.003	9.29	<0.001	0.021	0.033
Lang. other than English at home (ref. English)	-0.040	0.005	-8.33	<0.001	-0.049	-0.031
Statins for secondary prevention (ref. primary)	0.007	0.004	1.99	0.046	0.000	0.015
Heart disease diagnosis (ref. never diagnosed)	0.017	0.004	4.32	<0.001	0.009	0.025
Vigorous exercise at least weekly (ref. none)	-0.002	0.003	-0.89	0.371	-0.008	0.003
Current smoker (ref. never / past smoker)	-0.031	0.005	-5.78	<0.001	-0.041	-0.020
Constant	0.554	0.019	29.32	<0.001	0.517	0.591

As displayed in the effects summary in Table 9-12, the total effect of regularity on hospitalisation was a 15.3% reduction (OR 0.847, 95% CI 0.761–0.953), compared to the baseline regularity level (least regular quintile) the alternative (most regular) was associated with 15.3% lower chance of cardiovascular hospitalisation. Note that although the effects summaries are listed under the heading “coefficient” (consistent with the output of the `-paramed-` command used) these results are interpreted as an odds ratio, with a value of one indicating no association. The NIE was a 1.6% reduction in hospitalisation (95% CI 0.976–0.991). The NDE was a 13.9% reduction in hospitalisation (95% CI 0.778–0.972). The proportion of the effect mediated by statin adherence was therefore $NIE / TE = 1.6 / 15.3 = 10.5\%$.

Table 9-12 presents effects summaries of all models, with full outputs of these analyses in Appendix F.

Part 1, results of models using approach 1 (exposure and mediator measured in year 1, outcome in year 2)			
	Controlled direct effect	Natural indirect effect	Total effect
Model 1: Regularity as exposure, outcome of cardiovascular hospitalisation	0.861 (0.778, 0.972)	0.984 (0.976, 0.991)	0.847 (0.761, 0.953)
Model 2: CoC as exposure, outcome of hospitalisation	1.085 (0.953, 1.314)	0.991 (0.984, 0.996)	1.075 (0.942, 1.307)
Model 3: Regularity as exposure, outcome of ED presentation	0.824 (0.371, 0.993)	0.978 (0.967, 0.990)	0.806 (0.650, 0.968)
Model 4: CoC as exposure, outcome of ED presentations	0.973 (0.790, 1.236)	0.988 (0.980, 0.994)	0.962 (0.775, 1.218)
Part 2, results of models using approach 2 (exposure measured in year 1, mediator in year 2, outcome in year 2)			
	Controlled direct effect	Natural indirect effect	Total effect
Model 5: Regularity as exposure, outcome of cardiovascular hospitalisation	0.951 (0.835, 1.072)	0.988 (0.981, 0.994)	0.940 (0.828, 1.058)
Model 6: CoC as exposure, outcome of hospitalisation	1.004 (0.850, 1.149)	0.990 (0.981, 0.995)	0.994 (0.839, 1.141)
Model 7: Regularity as exposure, outcome of ED presentation	0.935 (0.760, 1.140)	0.989 (0.980, 0.997)	0.925 (0.752, 1.127)
Model 8: CoC as exposure, outcome of ED presentations	0.788 (0.626, 0.978)	0.990 (0.981, 0.998)	0.780 (0.615, 0.977)

Model 2 presents results relating to the COC exposure, with cardiovascular hospitalisation as the outcome, from the main analysis (where exposure and mediator are measured concurrently). For this exposure the NIE suggested a small but statistically significant reduction in hospitalisation via the statin adherence mediator (OR 0.991, 95% CI 0.984–0.996). The CDE was positive, though this was not significant, as was the total effect (TE).

9.5.3.1.2 Emergency Department outcomes

The outcome of cardiovascular ED attendance was recorded for 942 (3.16%) cohort members. When ED attendance was the outcome of analysis, rather than cardiovascular hospitalisation, the NIE results were similar. For both exposures the NIE indicated a small, significant reduction in hospitalisation via the mediator, and the confidence intervals suggested no significant difference between results observed for cardiovascular ED presentations and the equivalent model with cardiovascular hospitalisation outcome (for example, model 1 compared to model 3 or model 2 compared to model 4). CDEs for this outcome consistently differed, being lower than those reported for hospitalisations in all cases, indicating a more substantial negative direct effect, though again confidence intervals overlapped substantially between each ED outcome model and the equivalent hospitalisation outcome model.

9.5.3.1.3 Sensitivity analysis – different time lags

Some differences in results were observed when all measurements were lagged (approach 2 in Table 9-12, models 5 to 8) as opposed to the main analysis where exposures and mediators were measured concurrently. Firstly, the regression of the mediator on the exposure gave similar results for both approaches (full model outputs in Appendix **FError! Reference source not found.**). For example, the coefficient for regularity in the mediator model was 0.010 (95% CI 0.008–0.012) under approach 1, and 0.010 (CI 0.008–0.013) under approach 2; for COC the coefficient was 0.023 (95% CI 0.014–0.033) under approach 1 and 0.036 (CI 0.024–0.048) under approach 2. This suggests that reverse causation was likely not a major issue in the main analysis.

In general, NIEs generally had slight reductions in magnitude under approach 2, though these remained significant in all cases. CDEs also generally showed reductions in magnitude; in most cases these lost significance, with the result that the proportion mediated increased (due mainly to reductions in direct effects). The one exception was the model with COC as the exposure and ED presentations as the outcome, for which the CDE was large, significant negative association under approach 2 (model 8), compared to the non-significant association observed under approach 1 (model 4).

9.5.3.2 Potential users

Effects summaries relating to the cohort of potential statin users (those not already using statins during the exposure period) are presented in Table 9-13, with full outputs of these models in Appendix F. Among this cohort there were 1,825 cohort members (6.29%) with a cardiovascular hospitalisation during follow-up, and 591 (2.04%) with a cardiovascular ED presentation. The results relating to hospitalisation differed compared to those observed among existing statin users. No significant associations were observed in the model with regularity as the exposure. In the model with COC all effects were also non-significant. For the models with ED use as the outcome both exposures had a negative but very small mediated effect, while moderately sized non-mediated effects were not significant. As indicated in the full model outputs (Appendix F), both regularity and COC were positively associated with the likelihood of initiation in the following year in the regression of the mediator on outcomes. In the regressions of outcomes on mediator, exposure and covariates, neither regularity nor continuity were significantly associated with either outcome, while statin initiation had a marginally non-significant negative association with ED presentations in the following year ($p=0.077$).

Table 9-13: Mediation analysis effects summaries, cohort of potential statin users

Model 1: Hospitalisation as outcome, regularity as exposure					
	Estimate	Bias	Bootstrap SE	Lower CI	Upper CI
CDE	1.005	-0.001	0.074	0.868	1.169
NDE	1.005	-0.001	0.074	0.868	1.169
NIE	1.001	0.000	0.001	0.999	1.004
MTE	1.005	-0.001	0.074	0.868	1.168
Model 2: Hospitalisation as outcome, COC as exposure					
CDE	0.896	0.003	0.077	0.748	1.050
NDE	0.896	0.003	0.077	0.748	1.050
NIE	1.001	0.000	0.002	0.999	1.006
MTE	0.898	0.003	0.077	0.751	1.053
Model 3: ED presentation as outcome, regularity as exposure					
CDE	0.862	0.007	0.105	0.673	1.076
NDE	0.862	0.007	0.105	0.673	1.076
NIE	0.998	0.000	0.002	0.992	0.999
MTE	0.860	0.008	0.104	0.670	1.075
Model 4: ED presentation as outcome, COC as exposure					
CDE	0.898	0.005	0.142	0.665	1.248
NDE	0.898	0.005	0.142	0.665	1.248
NIE	0.996	0.000	0.003	0.988	0.999
MTE	0.894	0.005	0.141	0.664	1.246

9.5.4 Summary

In summary, the total effect of regular GP contacts was a reduction in cardiovascular hospitalisation and ED presentation, and a small proportion of this effect was mediated via improved adherence with statin medication. Continuity had similar effects via the mediator, although total effects were non-significant.

This leads to the question of what accounts for the direct effect, or the proportion not mediated. There are two factors that could account for this. Firstly, there would be mediators other than medication adherence. These could include, for example, the conduct of monitoring tests. These are difficult to assess well using the administrative data available, as in many cases the item codes used to indicate completion of a cholesterol test are also used for many other tests which happen to attract the same reimbursement, so it is not clear what test has actually been performed (for example Medicare Benefits Schedule item 66500 (263)). Similarly, regularity / continuity may support improvements in adherence to lifestyle advice such as diet and exercise which would then mediate relationships with hospitalisation outcomes, though data for these were only available at the baseline survey, hence changes following a period of regular / irregular GP contact cannot be observed. Secondly, these effects may result from confounding by unobservable factors.

Results relating to COC were less clear than those relating to regularity, in that a positive CDE was observed in the model with cardiovascular hospitalisation as the outcome (though the NIEs were generally similar to those reported for regularity, and the positive CDE was not significant). The somewhat inconsistent CDEs for the COC outcome may in part result from the non-linear nature of this exposure (the group with a COC of exactly one may just reflect a lower number of GP contacts in this group and hence a lower likelihood of ever missing seeing the usual GP, rather than a deliberate attempt to maintain continuity). The `-paramed-` package used in Stata for this analysis does not allow this group to be separated from others with high continuity.

What this mediation analysis does suggest, is that the pathways that researchers generally describe when measuring associations between continuity and hospitalisation outcomes are plausible (reflecting the Andersen framework), with some evidence to support improved medication adherence as a mechanism of action. This specific pathway does, however, mediate only a small proportion of any effect so further work may be required to determine which other mediators may exist and to develop a better understanding of causal pathways. Though relationships were observed in the cohort of existing statin users, these generally were not observed among potential users, apart from very small associations with reduced ED presentations via the statin initiation mediator. The lack of significant associations in this cohort likely reflects the lower likelihood of each outcome in this group.

9.6 Chapter summary

This chapter has examined associations of regularity and continuity of care with statin use, to provide a clearer understanding of potential causal pathways influencing downstream hospitalisation and ED use outcomes. In the context of the Andersen framework of health service utilisation, regularity / continuity of care were framed as personal enabling characteristics, statin use as a personal health practice and cardiovascular hospital / ED use as reflecting evaluated patient health.

Manuscript 5 demonstrated that regularity and continuity of GP contact were each associated with improved use of statin medication among people at risk of CVD events. This association was observed in both existing statin users, who were more likely to be adherent where higher regularity and continuity were present, and among potential users, among whom initiation was more likely when higher regularity and continuity were present.

The second analysis examined associations between regularity and continuity among this cohort. This analysis showed that regularity and continuity were positively correlated, as would be expected if both measures are capturing information on the organisation of care. Similarly, both exposures had similar relationships with a range of other variables reflecting patient health, socio-demographics and behaviours, consistent with both exposures being personal enabling characteristics. There was little evidence of interactions between regularity and continuity in their associations with statin use, suggesting that any effects are additive and that there is value in measuring both exposures.

The third analysis was a mediation analysis in which statin use was treated as a mediator of cardiovascular hospitalisation / ED presentation outcomes. This analysis suggested that regularity and continuity were associated with reductions in cardiovascular hospital and ED use, however the proportion of this association mediated by improved statin use was small. This analysis provides support for the view that these exposures may have beneficial effects on downstream outcomes via process of care mediators, however these effects may be modest.

Chapter 10 Overall discussion

Continuity of care is a cornerstone of primary care and has been the subject of much research. Studies on the topic of continuity generally report this to be associated with reductions in use of hospital and emergency department services and improved patient satisfaction. However, there are major limitations to much of the published research in this area. Measures generally used to assess continuity of care are narrow and do not take into account the temporal pattern of general practitioner contacts; the likely causal pathways underpinning relationships with downstream health service use outcomes have been the subject of little research; while the study designs and analysis methods used to assess associations with downstream outcomes may in many cases be susceptible to biases. In light of these issues, there is a risk that much of the published evidence on the topic of continuity of care may be misleading or biased and the body of literature as a whole may not provide a strong foundation for the development of primary care policy. This thesis set out to address many of these gaps to provide a fuller exploration of the role of regularity of GP contacts in influencing patient health outcomes, by addressing the following objectives:

1. Describe the availability of general practice data in Australia for observational research
2. Assess indexes used to measure regularity
3. Assess associations between regularity and hospital / ED use outcomes
4. Provide an improved understanding of the possible causal pathways underlying associations between regularity and hospital / ED outcomes.

By addressing these objectives this thesis has made a significant contribution to the literature on the topic of continuity of care and filled important gaps to support the development of future primary care policy. Crucially, this thesis indicates that much of the research into the topic of continuity of care most likely overstates the benefits of continuity / regularity, which risks leading to the development of policies with limited potential to improve patient health and reduce use of tertiary health services. This thesis has gone further to demonstrate several means by which researchers in this area can improve upon the evidence they produce. This thesis has developed and applied an updated measure of regularity alongside a comparison of existing measures, which will allow researchers to more fully capture GP contact patterns. This thesis has also demonstrated the associations of regularity and continuity of GP contact with hospital and ED outcomes, including a demonstration of the degree to which these associations depend on decisions regarding study design and analysis, which has not been explored in previous literature. This thesis has investigated the role of intermediate factors (i.e. health behaviours) to more fully understand potential causal pathways underlying associations, including the use of mediation analysis to inform on the impacts of these intermediate factors on health service use outcomes, providing further policy-relevant evidence lacking from prior literature.

This chapter is set out as follows. Firstly, a brief summary of the broad findings of this thesis is provided. Secondly, the findings of this thesis are discussed in comparison to previously published research on the topic of continuity of care. The limitations of the current research are then outlined. The significance of the contribution of this thesis in terms of research and policy is discussed. Finally, some future directions for research are highlighted.

10.1 Summary of findings

This thesis made use of existing collections of administrative and clinical data to make several important findings that contribute substantially to the literature on regularity and continuity of GP contact.

The availability of clinical general practice data in Australia for use in research was reviewed in manuscript 1 (Chapter 4), extending on the more commonly used administrative data. The manuscript described the advantages of this clinical data in comparison to administrative data and the opportunities this can present for research. This paper went on to outline the means by which researchers in Australia can access general practice data, the advantages and the limitations of these collections. It was demonstrated that in recent years the potential for these GP data to support research has improved substantially, though Australia trails several other developed countries in the availability and comprehensiveness of these data. Although general practice data has previously been used by researchers in Australia, this manuscript represents the first attempt to clearly outline means by which these data may be accessed for primary care research, and has the potential to support further high-quality research in Australia into continuity of care and primary care more broadly. This manuscript, in combination with the analyses using general practice data in Chapter 8, contribute to the literature by demonstrating how these clinical data can lead to an improved understanding of potential causal pathways in comparison to studies using only administrative data. Understanding potential causal pathways is challenging in research such as this where use of health services forms both the exposure and outcome of interest, but an understanding of these pathways is essential as a basis for policy. Data which provides evaluated patient health measures can help to improve understanding.

An updated measure of regularity of GP contact was compared to two existing measures in manuscript 2 (Chapter 5) and found to be less correlated with the frequency of GP contacts, and better suited to providing unbiased measures of association with hospitalisation outcomes. Regularity and continuity were found to be correlated with each other and to have similar relationships with patient characteristics reflecting health, suggesting that both measures reflect care that is planned and proactive, in line with theory. An interaction analysis with statin use as an outcome (section 9.3) found no evidence of interactions between regularity and continuity (consistent with interaction analyses included in Chapter 7 and Chapter 9), indicating an additive rather than multiplicative or substitution relationship between them, showing that there is value in capturing both measures. These findings make a significant contribution to the literature by demonstrating firstly that regularity of GP contacts provides additional information on the pattern of GP contacts alongside more common continuity measures, and by providing an improved method to capture regularity. It has been noted that more commonly used measures of continuity are limited in the information that they capture, and that regularity may be considered an additional facet of continuity (171-173), capturing further information on GP contact patterns. With the development and publication of the modified regularity index, along with the comparison to existing continuity measures, future researchers will be better equipped to capture GP contact patterns, and hence will be able to provide improved evidence for policy makers on potential targets for intervention.

In manuscript 3 (Chapter 6), regularity of GP contacts was found through the period of 1990–2004 to be associated with reductions in hospitalisation rate and costs among a cohort of patients with and at risk of diabetes. This relationship was found to have remained relatively constant leading up to and following the introduction of the Enhanced Primary Care policy. Similarly, regularity scores remained relatively constant, with a slight reduction in regularity prior to the EPC program's introduction, and no further change following the introduction of the policy. These findings challenge prior research suggesting that at the individual level, uptake of the EPC program (179) led to more regular GP contact. This contributes to the literature by exploiting a historical policy change targeted at continuity of care to assess changes in contact patterns. These findings are extremely important with regards to the policy context, demonstrating that financial incentives did not substantially impact on regularity of care at the population level or change relationships with hospitalisation outcomes. This may indicate challenges in the development of financial incentives which lead to desired changes in both practice and outcomes at the population level, indicating the need for evaluation alongside the implementation of such policies.

In a more contemporary analysis (2005–2015) (Chapter 7), negative associations between regularity / continuity of GP contacts and hospitalisation / ED outcomes were observed, though these associations were apparent only when using a study design and statistical analysis which was susceptible to bias by reverse causation and unobserved confounders. When study design and analysis were modified to reduce these risks, negative associations diminished in magnitude or disappeared entirely. This pattern was reflected across cohorts with diabetes and six other conditions, for both unplanned hospitalisations and all-cause ED presentations as outcomes, and for both regularity and continuity of GP contact as exposures. This analysis also suggested that where negative associations between exposures and health service use outcomes existed (in random-effects estimates), these reduced in magnitude through the study period. These findings present a major contribution as they highlight the potential for study design to influence estimates of effect sizes, and an accurate understanding of effect sizes is vitally important to support the development of primary care policy. Furthermore, these findings demonstrate an area where existing literature on continuity of care can be substantially improved, in addition to providing estimates regarding effects of regularity and continuity of GP contacts across multiple conditions in the Western Australian setting.

Following this, analyses were undertaken to better understand the plausibility of causal pathways commonly assumed to underpin associations with hospitalisation outcomes (Chapter 8, manuscript 4). This analysis took advantage of the general practice clinical information system data discussed earlier. Firstly, among patients with diabetes, regularity and continuity of GP contact were found to be associated with increased use of pathology tests and this was reflected in both a reduced likelihood of underuse (a beneficial association), and an increased likelihood of overuse (a potentially harmful association) of HbA1c tests. Importantly, in this analysis regularity and continuity were not associated with improvements in evaluated patient health as reflected by the recording of glycosylated haemoglobin values in a healthy range. Finally, using linked survey and administrative data in manuscript 5 (Chapter 9), regularity and continuity were found to be associated with substantial improvements in statin use among a cohort at risk of cardiovascular events. However, when this was extended to a mediation analysis assessing cardiovascular hospitalisation and ED outcomes, improved statin use was found to mediate only a small reduction in these outcomes. Note that this does not suggest or imply that statins were not associated with reductions in hospitalisation (in fact a negative association between statin adherence and cardiovascular hospitalisation was observed), rather this suggests that the associations between regularity / continuity and cardiovascular hospitalisations were not fully mediated via statin use and instead the majority of this association resulted from alternative mediators, confounders or other factors. These analyses contribute to the literature by demonstrating both how the understanding of potential causal pathways can be improved, and by demonstrating that even where regularity and continuity of GP contact are associated with changes in processes of care, the impacts on downstream outcomes of ultimate interest may be more modest. These analyses further demonstrate how researchers in this area should modify study designs to form a fuller understanding of potential causal pathways, and also more fully inform policy by providing evidence on how health service use outcomes may be influenced by changes to regularity and continuity.

These findings set a challenge to researchers in the area of continuity of care. These studies demonstrate that there is both a need and an opportunity for researchers in this field to substantially improve upon the work being undertaken, to improve the quality of the evidence available and produce a stronger basis for primary care policy. Findings throughout this thesis indicate that much of the research on the topic of continuity of care is likely to overstate the potential for benefit. If the body of evidence is biased as the findings here suggest, there is a risk that policy makers pursue interventions which have little chance of producing the benefits expected. This can lead to a lack of allocative efficiency as resources used to promote policy or intervention in this area could have greater benefit elsewhere. At worst, this may lead to patient harm if policies promoting continuity or regularity have adverse impacts on other aspects of the organisation of care (e.g. rapid access, or access to a wider variety of expertise).

10.1.1 Findings in the context of existing literature

Literature assessing associations between continuity of care and hospital / ED outcomes has been discussed in section 2.2.2.4. Direct comparisons to existing studies are challenging due to the range of settings these studies have been conducted in, the variety of outcomes used, differences in time periods, study designs, analyses and other factors. This literature has generally reported substantial negative associations between continuity and outcomes related to hospital / ED use despite the heterogeneous nature of studies. In some cases the effect estimates reported are extremely large, contrasting with the findings of this thesis. For example, a Taiwanese study reported that those with high continuity had 0.41 times the odds of avoidable hospitalisation than those with low continuity (134); a study in the United States of America reported that children with high continuity had 0.65 times the odds of ED use compared to those with low continuity (138); a study in Hong Kong reported that those with a regular doctor had 0.46 times the odds of ED use and 0.48 times the odds of hospital admission compared to those without (128). Effect sizes are not always so large, for example one study conducted in Australians with diabetes reported a more modest effect size, with a high continuity group (reference low) reporting 0.92 times the rate of hospitalisation (118). Similarly modest results were reported in a study of older patients in the USA, where the low continuity group reported 1.06 times the odds of an ED presentation and 1.04 times the odds of hospitalisation compared to those with very high continuity (93).

As discussed in section 2.2.2.4, despite the vast quantity of literature assessing continuity of care and tertiary health service use, most use multivariable regression analyses meaning there may be some risk of confounding by unobserved variables, while many studies are additionally at risk of reverse causation. The inclusion of appropriate covariates in models helps to reduce these risks, though given these studies have measures of health service use as both the exposures and outcomes of interest these biases may be especially concerning. Despite this, relatively few papers have used designs or analyses which attempt to improve causal estimates. One study has directly compared a design using lagged outcomes to a design with unlagged outcomes, providing some insight into the potential impact of reverse causation. A few further papers described below have used alternative methods that reduce the risk of confounding by unobserved variables, to provide effect estimates more likely to reflect causal relationships.

The study comparing unlagged to lagged outcomes in assessing relationships between continuity of care and ED use (96), similar to the comparisons made between lagged and unlagged outcomes in Chapter 7, was conducted in the USA. This study reported negative associations with ED use in the unlagged analysis which, when lagged, disappeared (outcome of one ED presentation) or became positive (outcome of multiple ED presentations). This is consistent with findings reported in Chapter 7 and reaffirms the view that some of the literature on the topic of continuity of care may be overstating potential benefits on account of the study designs selected. Note though that in another study the same authors assessed hospitalisation outcomes with a lagged outcome and reported a substantial negative association (97).

A study set in California assessed the impact of a policy change which provided financial incentives to practices for allocating patients to specific providers and ensuring that the allocated provider did in fact provide the patient's care (152). This design improves effect estimates by reducing risks of unobserved confounding as the intervention was pseudo-randomised, where changes in continuity resulted from an exogenous factor (policy change) rather than some unobserved difference between individuals. This intervention led to a substantial change in visit patterns (42% increase in probability of patients adhering to their primary provider). However, adhering to the primary provider had only a modest effect on outcomes – having all visits to the allocated provider (versus none) was associated with a 2.1% decrease in hospitalisation and a 1.7% increase in ED presentations. These effect sizes are similar to the reductions in hospital and ED use mediated by improved statin adherence reported in section 9.5. Although the study from California and the mediation analysis in section 9.5 use different methodologies, both studies extend on existing literature by using approaches which aim to provide estimates that are closer to causal. The similarities in effect estimates reported in the quasi-experimental work in California support the modest effect sizes observed in this thesis.

Two studies in the United Kingdom assessed the impact of a similar policy change under which general practices were incentivised to allocate each patient to a usual provider (150, 151). In this case the policy did not lead to increased continuity (150) or reduced hospitalisation (151). This policy did not require practices to actually ensure patients were seen by their usual provider, which may explain the lack of any effect.

Two studies have attempted to improve causal estimates by using instrumental variable analysis. These studies reported that increased continuity of care was associated with improved use of preventive health services (157) and reductions in ED use (136). The estimation of causal estimates via IV analysis depends on the use of appropriate instruments; concerns over the instruments used in each of these studies have been discussed in section 2.2.2.5. Specifically, it is likely that the instruments used in each of these studies would have influenced outcomes through means other than the explanatory variable of interest (continuity) which would present a major violation of IV analysis. Although these studies reported moderate effect sizes compared to some of the literature described earlier (for example a change in continuity from zero to one associated with a 7.6% reduction in ED use and 14.8% reduction in hospitalisation (136)) these violations limit comparability.

Finally, one study has used a modelling approach similar to the hybrid approach used in Chapter 7, in a study of continuity of care in serious mental illness (125). This study found that continuity was associated with reductions in ED presentation of more than 10% and in hospitalisation of more than 20% for a range of conditions assessed. This contrasts with findings in this thesis which suggested that similarly assessed measures of continuity (within-person coefficients in Chapter 7) did not have negative associations with hospitalisation and ED use outcomes. Note that definitions of continuity of care are substantially different in the context of mental health compared to primary care (84), so comparisons between settings are challenging. Note also that authors of this study did compare their findings to a random-effects model and reported that the choice of study design did influence results, as was observed in Chapter 7. Although the effect estimates reported from this study differed from those reported in this thesis, one finding was consistent, i.e. that the choice of statistical analysis used can have a major impact on the effect estimates produced. This has clear implications for policy: if there is uncertainty over the effect sizes reported from a single study, the potential for benefit from any given policy is uncertain. Furthermore, effect estimates are sensitive to study design and analysis but only a single analysis is reported, this may provide a false impression of potential impact of a policy change as the potential uncertainty is not presented to policy makers.

This thesis additionally included sensitivity analyses assessing the robustness of relationships reported to the choice of continuity measure used. These analyses, reported in sections 8.4 and 9.3, indicated that the choice of which of the most common continuity measures was used (UPC and COC) did not make substantial differences to the effect estimates produced, in cohorts with type 2 diabetes and at risk of cardiovascular events, respectively. Although these two measures are conceptually different – UPC captures the proportion of visits made to the usual provider, while COC captures the dispersion across providers – it is perhaps unsurprising that the measures produce similar effect estimates. A patient (or group of patients) who have a high proportion of visits to their usual provider (i.e. a high UPC) would be unlikely to have a great dispersion of care across providers (low COC), compared to a patient who had relatively few visits to their usual provider (low UPC). This view is supported by analysis from the United States which has demonstrated very high correlations between continuity measures in cohorts with chronic diseases (170). Sensitivity analyses similar to those included here (i.e. assessing a continuity – outcome relationship, and comparing two or more continuity measures) have been reported previously and consistently indicate the choice of continuity measure makes little difference to effect estimates (93, 122, 133, 180-182).

In comparison to the literature assessing measures of continuity, a smaller body of literature has assessed regularity of GP contacts. In one study in the USA regular primary care contacts were found to be associated with earlier breast cancer detection (172) though this study did not extend to assess how this may have influenced cancer outcomes. This study did adopt a lagged design in that the outcome (cancer stage at diagnosis) was assessed after the measurement of exposures. Other research in Australia has assessed associations between regularity of GP contact and outcomes among clinical cohorts. These studies have suggested more regular GP contacts were associated with reduced risk of hospitalisation and mortality among older patients with respiratory diseases (hazard ratio (HR) for chronic respiratory disease hospitalisation in highest regularity quintile 0.77, 95% CI 0.68–0.86) (175), older patients with ischaemic heart disease (HR for all-cause mortality in highest regularity quartile 0.71, 95% CI 0.63–0.82) (176), and reduced mortality among older patients with epilepsy (HR for all-cause death in most regular quartile 0.42, 95% CI 0.23–0.78) (177). These studies used survival analyses meaning the risk of reverse causation was removed, though potential for confounding by unobserved variables may have remained, and there is additional potential for estimates to be influenced by unmeasured changes in regularity through a long follow-up period (11 years). These studies ran from 1992 to 2006 so it is also possible that negative associations observed may have diminished in the time since.

Further comparisons can be made to literature assessing associations between continuity and processes of care or disease control outcomes, as reported in Chapter 8 and Chapter 9 of this thesis. As discussed in section 2.2.2.8, there has been less literature published concerning the impacts of continuity of care on these outcomes in comparison to the literature assessing downstream health service use outcomes, and evidence concerning such outcomes has been mixed (142). Some studies have assessed associations between continuity of care and medication use outcomes, finding beneficial associations in terms of reductions in medication duplication (180) and use of potentially inappropriate medications (181), while studies of statin use outcomes have reported both positive results (182) and no effect (183). The current study found a positive association between regularity / continuity and statin use, consistent with one prior Australian study assessing continuity. This thesis extends on previous literature by additionally assessing effects of regularity on this outcome and by incorporating statin use into a mediation analysis assessing hospitalisation outcomes. Although researchers have discussed such processes of care as likely mediating hospitalisation outcomes, this thesis is the first work to assess the impact of such intermediate factors via mediation analysis. This analysis found that despite there being a substantial association between regularity / continuity and hospitalisation outcomes, only a small portion was via this mediator i.e. the most likely causal pathway. The major implication of this is that policy efforts to increase regularity or continuity may be expected to lead to much smaller patient benefits than suggested by much existing research.

Similarly, previous studies have produced mixed evidence for improvement in processes of care in terms of patient monitoring. Studies have demonstrated continuity of care as being associated with improvements in testing of blood pressure and cholesterol (166, 184), mammography (89, 166), and vaccinations (166), while studies of pathology testing among patients with diabetes have reported both improvements in monitoring (185) and no effect (186). In the few studies assessing the results on pathology tests, providing an objective measure of disease control, two have reported continuity as associated with improvements in glycosylated haemoglobin (185, 187) with others reporting no effect (188, 189) and a worsening in HbA1c (190). This thesis extended the existing body of work by exploring both process of care and clinical outcomes in relation to both continuity and regularity. This provides evidence for the first time regarding the impacts of regularity on such processes and clinical measures, as well as extending on evidence regarding continuity by examining outcomes at multiple points on the hypothesised causal pathway to hospital / ED use. Findings were generally consistent with the literature described in that although regularity / continuity were associated with a reduced likelihood of HbA1c tests being missed (and an increased likelihood of overtesting) the evidence was more limited in terms of patient health outcomes. This reinforces the need for research in this area to more fully examine the causal pathways via which downstream outcomes are assumed to be impacted. In the absence of such research, policy makers are left to rely on measures of association with downstream outcomes which are at risk of bias by reverse causation, unobserved confounders or other issues.

In summary, although direct comparisons between the findings of this thesis and other literature on continuity of care are challenging on account of differences between settings, study designs, analysis techniques and other factors, some broad comparisons can be made. The findings of this thesis suggest that associations between regularity / continuity of care and downstream health and hospitalisation outcomes are likely more modest than reported in the majority of the continuity of care literature, and this is supported by the few studies which extend beyond standard multivariable methods. The comparisons here between lagged and unlagged outcomes are reflected in the one published study that reported similar comparisons, while the one study to exploit policy change to apply a quasi-experimental study reported very modest results compared to most studies, as seen in this thesis. Choice of analytic design has also been demonstrated in one further study to substantially alter effect estimates, though this is not generally reported. Finally, although past studies have demonstrated associations between continuity and improved processes of care, similar to those seen here, evidence for translation into improved health status has been weaker. This thesis has demonstrated multiple approaches by which the most commonly used methods in this area can be improved upon, and consistently finds that effect estimates reported in many published studies are likely to overstate the potential for continuity of care to benefit patients. The most significant implication of this is any policies which target continuity or regularity in the expectation that patient outcomes will significantly improve is likely to lead to disappointing results.

10.2 Limitations

Limitations relevant to each individual analysis are presented within the relevant chapters and included published papers, so this section focuses on broader overall limitations of the study.

Firstly, although this thesis attempts to improve on existing literature by improving the understanding of potential causal pathways and using analyses which remove likely sources of bias, the thesis still ultimately consists of a collection of observational studies and causation cannot be proven in any case. What this thesis does represent is examples of how understandings of relationships may be improved using observational methods in a context where conducting trials is unlikely to be practical.

There are some discrepancies in findings between different analyses which are challenging to interpret. For example, the mediation analysis in 9.5 reported regularity and continuity as being associated with small, significant reductions in hospitalisation and ED use; the analysis of HbA1c outcomes in Chapter 8 reported modest non-significant improvements in patient health; while the analysis in Chapter 7 reported significant between-person reductions in hospitalisation / ED use, which did not appear in the within-person effects. Although these analyses are consistent in that they suggest much smaller effects than reported in the majority of existing literature, the small discrepancies between them make it difficult to suggest that a certain effect size exists in the associations between regularity / continuity and outcomes.

Generalisability is a major concern in health service research studies. There are several features of the Australian health system that need to be kept in mind when considering how findings may translate elsewhere. In Australia GPs can be accessed for free (though some choose to charge additional co-payments), while ED attendances are free, and prescriptions have a fixed subsidised cost with safety nets in place to prevent excessive out of pocket spending. Patients are free to visit the practice / GP of their choice and may change GPs at any time, as no formal registration exists. Finally, general practice operates on a fee-for-service basis which is known to influence care patterns. This thesis does not suggest that the findings reported here will necessarily be observed elsewhere. However, some of the broad conclusions (namely that researchers should attempt to assess intermediate outcomes to better understand potential causal pathways, and that choices of research design and analysis should be explored more fully in studies) apply across settings.

The reliance on existing data for secondary purposes has some limitations. For example, administrative data typically lack some detailed clinical information. The accuracy and reliability of data likely differs between data sources. As some of the administrative data (for example, Medicare Benefits Schedule and hospital separations) are used for reimbursement and are subject to audits, data quality is likely higher than, for example, diagnoses recorded manually by GPs where spelling mistakes or other errors are possible. These issues are managed by only using each data source and variable for purposes where errors are unlikely to bias findings. For example, outcomes in diabetes analyses used pathology test results as these are recorded electronically at pathology labs to be transmitted to general practices, so capture is likely to be complete. Observations recorded at the practice are also available (for example blood pressure) and may provide a useful set of outcomes for similar analyses though there is a risk that these observations are more likely to be recorded by the GP where results are concerning, hence analyses using these may be biased.

There are alternative methods to those used within this thesis which can remove biases and improve the likelihood that associations observed are causal. For example, propensity score matching can improve over standard multivariate regression by reducing bias (264) and is becoming more commonly used. Propensity score matching does have important limitations. For example, it cannot account for confounding introduced by unobserved variables (264), and it is better suited to assessment of binary treatments than continuous exposures (such as those used in this thesis) though methods for continuous treatments are being developed (265). Instrumental variable analyses can resolve issues of unobserved confounding and lend to causal interpretation of associations, and could be adopted where suitable instruments are available (though finding instruments can be challenging in health services research). Even where more advanced analyses are not practical, designs and interpretations may be improved by the use of Directed Acyclic Graphs or other approaches which can support a more complete understanding of the pathways being examined, confounders requiring control and potential for influential unobserved variables (266).

Another recently developed method for estimating causal effects in observational studies is the use of Marginal Structural Models (MSM) with inverse probability treatment weights (IPTW) (267, 268). These models were first developed in 2000 specifically to resolve problems that occur when longitudinal studies are affected by time-varying covariates (269). Time-varying covariates are those variables which confound the exposure-outcome relationship, but are also influenced by previous treatment or exposure (268, 269). Such variables therefore take the role of both confounder and mediator and standard epidemiological approaches may result in biased estimates in these situations (268, 269). As an example relevant to continuity / regularity of GP contact, consider exercise habits. Someone who is health conscious may be more likely to maintain frequent exercise habits and may also be more likely to maintain continuity of care with their GP, hence this may be a confounding variable when assessing hospitalisation outcomes. Meanwhile, the relationship with the GP may mean that the patient is more likely to accept advice on the importance of exercise habits, thus this variable also mediates the impact of regularity on hospitalisation. MSM with IPTW resolves these issues by separating analysis into two stages, separating the control of confounding from the estimation of treatment effects (268, 270, 271) and in this way are analogous to RCTs. The Andersen model of use of health services (Figure 2-2) does include feedback loops that indicate many potential covariates may be impacted by prior exposure (86), suggesting that time-dependent covariates may be an issue in studies of continuity of care.

The general approach of MSM with IPTW is to produce and compare groups who are identical in every way except treatment status (268). Confounders are balanced across levels of treatment prior to modelling of outcomes. This is done by assigning a weight to each observation in the sample to obtain a balanced (re-weighted) sample with respect to treatment status and outcomes can then be compared between these groups (268). Treatment weights are the inverse of each individual's probability of treatment given their covariate history at each point in time (268). Censoring is treated as another form of time-dependent confounding and censoring weights are produced in a similar way. These two sets of weights are then combined to produce a weighted pseudo-population in which the distribution of covariates is balanced between treated and control (or exposed / unexposed) groups (268, 270). The weighted sample can then be used for causal estimation using standard crude analyses (269, 271) and various diagnostics are available to assess balance between groups on the observed covariates (270). Weighting can be applied for binary or continuous treatments using logistic or ordinary least squares regression, respectively (269, 271). The major limitation of MSM with IPTW is that the causal interpretation only holds when the assumption of no unmeasured confounding is met (268, 270), which is a difficult assumption to satisfy when administrative data are used as potential confounders may be unobserved.

To my knowledge there is only one study on the topic of continuity of care which uses this approach, published in 2021 (272). Although the original paper describing MSM with IPTW outlines how the models are suitable for ordinal or continuous treatments / exposures (269), most papers describing and applying the methods concern binary treatments, possibly because the counterfactual framework used is more readily understood and applied in these cases. The one paper on continuity of care using these methods applies a binary transformation of a continuous continuity measure (273), resulting in loss of some information. It is possible that in the future a greater application to non-binary exposures will see these approaches used more often in the continuity of care literature.

This thesis adopts the Andersen model of health service use as a framework both to explain existing literature in this area and to frame the analyses included. Although the framework describes a range of factors potentially impacting on use of health services, the scope of this thesis is limited to the investigation of regularity and continuity as enabling factors. The thesis does not intend to provide an analysis of all enabling factors or an assessment of all potential influences on hospital / ED use. Other important enabling factors at the contextual level include the organisation of medical services, the mix of providers available (85), health policies at different levels, financial characteristics, and the distribution of services and health professionals (86). Enabling characteristics at the personal level are measures reflecting the individuals' capacity to access these services including income and insurance, ability to travel (85), and other factors.

It is important to note that although this thesis outlines areas where much of the empirical literature on continuity of care can potentially be improved, this does not mean to diminish the value of continuity of care as a fundamental component of primary care. This scope of this thesis is limited to the indicators of continuity commonly applied using administrative or clinical data collections, in response to the large body of literature taking such an approach. The relatively narrow focus of these measures in comparison to the broader definitions of continuity have been discussed in section 2.2.2.6. The measures of regularity used here expand on common continuity measures while keeping within this scope. The value of continuity as a concept may be further assessed using measures which capture further information on the quality of the patient-provider relationships. Qualitative work has been conducted to understand potential benefits of continuity of care from the perspectives of patients and physicians. A recent review and synthesis of this literature identified that the impacts of continuity fell into six broad themes (274). The benefits of continuity, according to both patients and physicians, included the opportunity for person-centred care, an increased quality of care (for physicians, an improved ability to tailor advice, and for patients, an increased likelihood of following this advice), and a greater confidence in medical decision making. Patients and doctors did note drawbacks of continuity including trade-offs with access, and a risk of overfamiliarity leading to complacency and missed diagnoses, while physicians noted potential issues with boundaries and anonymity. Finally, physicians noted that continuity of care could foster greater joy and meaning in their work (274).

10.3 Relevance to future research

The findings of this thesis suggest several areas where the research into continuity of care may be improved upon, and point towards future research directions

10.3.1 Enhancements to current research approaches

Firstly, researchers in the area of continuity of care should consider assessing regularity of GP contact alongside more commonly used measures of continuity. Where administrative data are used and GP visit dates included (as is the case with most of the studies in this area) additionally measuring regularity is straightforward. This thesis has significantly contributed to this area by being the first to provide a comparison of different regularity scores available including the development of the modified regularity index, highlighting advantage and disadvantages of each method, providing guidance to other researchers who may want to more fully capture patterns of GP contact. This work has additionally contributed by demonstrating the lack of evidence for interactions between these measures, suggesting that there are differences in the information captured by the regularity metric in comparison to more commonly used continuity measures.

Secondly researchers should, where possible, take advantage of data captured in general practice clinical information systems. These data can provide for an improved understanding of outcomes by providing more objective measures of patient health status and behaviours than typically available in hospital and primary care administrative data. These data collections may also capture a broader variety of clinical information than available in any single administrative data collection. Where studies involve measuring use of health services as both the exposures (regularity / continuity) and outcomes (hospital / ED use) of interest, additionally producing evidence with more objective assessment of patient health can help form a fuller understanding of impacts.

Researchers should empirically test the steps on causal pathways that they hypothesise to underlie relationships with downstream health service use outcomes. In this thesis intermediate outcomes of medication adherence and appropriateness of pathology testing have been assessed. The intermediate outcomes that can be tested will vary depending on the data available in different settings and the recommended medication / testing regimes for different conditions. The importance of this is highlighted by the mediation analysis which reported a substantial effect of regularity and continuity on statin use and on hospitalisation / ED outcomes, but a much smaller effect on hospitalisation / ED outcomes when statin use was formally incorporated as a mediator, when the fuller causal pathway was tested. Similarly, when diabetes outcomes were tested in manuscript 4 it was found that generally positive effects on diabetes management (increased pathology testing) did not translate into significant improvements in health status (pathology test results).

Finally, where researchers intend to assess downstream health outcomes, this thesis demonstrates that the choice of study design and statistical analysis have substantial implications on the effect sizes observed. Most existing literature does not address this issue. In terms of study design, the choice of lagged / unlagged outcomes is important, with this thesis demonstrating that unlagged designs resulted in smaller effect estimates than unlagged. It is a concern that many studies in this area report unlagged analyses without discussion or justification of this choice. Where administrative data are used it is likely that in most cases researchers would be able to access multiple years of data to support lagging of outcomes (whether as the primary analysis or sensitivity analysis). Similarly, effect sizes were reduced when analyses took advantage of the longitudinal nature of the administrative data to report within-person effects, controlling for all time-invariant confounders (including unobserved confounders). Standard multivariate regression models, which are used in the majority of studies in this area, reported larger effect sizes in these analyses but are at greater risk of confounding. This thesis demonstrates that researchers should, at a minimum, report alternative methods as sensitivity analyses.

Although researchers do typically describe the limitations of the methods selected for a particular study, this can have the effect of shifting the burden of understanding these limitations on to the reader, who may be relying on the evidence for important policy decisions and who may be less well equipped to understand these limitations than the researcher producing the evidence. Readers and policy makers may be aided by the presentation in papers of multiple analyses using different study designs to provide a fuller picture of the uncertainty regarding associations. The presentation of uncertainty introduced by sampling variability is routine and well understood (estimates with p-values or confidence intervals). More explicitly presenting the degree of uncertainty introduced by additional factors (study design / analysis) can potentially better inform readers and policy makers as to where health system performance may be improved.

Improved reporting of the uncertainty introduced by these issues may be facilitated by updates to reporting guidelines. The Strengthening the REporting of Observational Studies in Epidemiology (STROBE) guidelines require that researchers report the study design and analysis used without suggesting that researcher justify the choices made (275). The Reporting of studies Conducted using Observational Routinely-collected Data (RECORD) guidelines, being an extension of the STROBE guidelines, have similar suggestions (276). Although the guidelines suggest reporting results of sensitivity analyses there could be potential to go further in suggesting that researchers explicitly compare different designs and report the uncertainty resulting from these choices.

10.3.2 Future research directions

In the Australian context, it would be useful to understand relationships between the administratively derived measures of continuity / regularity and patient perceptions of continuity. As discussed in section 2.2.2.2, there has been some research comparing administrative measures to patient reported measures of continuity, but most of this has been conducted in the USA. The opportunity may now exist to compare such measures in Australia as the Australian Institute of Health and Welfare have conducted a large-scale survey into continuity and quality of care, which includes linkage to MBS data (116). As this survey additionally involves linkage to hospital and ED data, it would be possible to compare administratively derived and patient reported measures of regularity / continuity in terms of their associations with downstream outcomes, which to my knowledge has not been done before. This may also go some way to addressing the gap between the broad definitions of continuity that exist and the narrower scope of measures most commonly applied as discussed in the limitations section.

Given the findings here demonstrate an overstatement of the likely benefits of regularity / continuity in influencing patient outcomes, it is essential that any policies introduced targeting these care patterns are introduced in such a way as to allow a high-quality evaluation to be run alongside. Where governments consider making changes to primary care policy or programs they should, if possible, refrain from making nationwide changes. Implementing policy within a single patient group or geographical area would allow for higher quality observational research to assess outcomes using quasi-experimental approaches (such as difference in difference methods) to inform the potential impacts prior to a wider implementation. Past policies such as the EPC program have been implemented as changes to the MBS claimable by all GPs nationwide, leaving no comparison group available. More recently, however, the Health Care Homes program has been implemented on a smaller scale with limited numbers of practices participating, which will likely allow for a comparison of patient outcomes between practices which do / do not participate in the program. This program may also support an evaluation of the value of continuity of care via assessing an intervention much broader than the administrative continuity of care measures assessed through this thesis, and closer in scope to continuity of care as generally defined.

At the individual service level, any intervention to promote regularity or continuity (e.g. a change to booking systems) requires evaluation of both changes in the intended intervention target, and the potential for unintended changes in other aspects of care. For example, an intervention promoting repeated visits to the same provider may result in access delays, if that provider has poor availability at times.

As discussed in the limitations section, analyses reported here should be repeated in other settings. Some of these analyses suggest that effects of regularity / continuity may have changed over time, potentially reflecting broader health system changes. It is likely that associations will differ in other settings and this should be tested.

10.4 Relevance to policy

This thesis has several important implications for policy and practice. Firstly, although regularity and continuity may be associated with improvements in hospital / ED outcomes, benefits are more modest than suggested by some of the existing literature in this area. A policy maker who aims to promote continuity of care in the expectation of seeing, for example, a halving of hospital or ED use among certain patient cohorts as some studies report (98, 127, 128, 132-134, 137) may be disappointed with the results of any policy change. The obvious concern with an over-estimation of benefits is that changes to practice and policy are costly to implement, and promoting one aspect of care can often come at the expense of another. For example a policy to promote continuity may conflict with a desire to provide timely access to care (84, 277, 278), trade-offs with staffing efficiency (279), or access to specialist expertise (262, 280).

Even if effect sizes of regularity / continuity of care are small at the individual level, there is potential for a substantial impact at the population level. For example, the mediation analysis in section 9.5 reported that for a change in regularity from the least regular to most regular quintile, hospitalisation reduced by 1.6%, and the equivalent change in continuity resulted in a 0.9% reduction in hospitalisation. Should this mediated effect reflect causation the potential benefit would be substantial. Considering that more than 580,000 hospitalisations are reported in Australia annually with cardiovascular disease as the principal diagnosis (281), a one per cent reduction in hospitalisation would mean almost 6,000 hospitalisations averted per year. The potential for such benefits to result from even a small effect size reinforces the need for accurate effect estimates to inform policy.

Where beneficial effects of regularity / continuity are found to exist there are several avenues via which these can be targeted. Incentives to promote continuity could be applied within Australia's fee-for-service context, for example financial rewards for practices where a certain level of continuity or regularity is achieved, similar to incentives that have been applied in other countries (150-152).

Actions to enhance continuity and regularity could alternatively come in the form of efforts to remove barriers to maintenance of contact patterns. There is a geographical maldistribution of GPs in Australia (282), with people in remote areas facing barriers in terms of travel time and costs, which may affect people's ability to maintain a regular pattern of contacts. Other barriers to maintaining regular contacts can include out-of-pocket costs (283, 284), and work commitments interfering with ability to visit the GP (283, 284).

At a local level the primary health networks recently established in Australia present an opportunity for action without requiring a prescriptive or top-heavy approach. As part of their role the PHNs provide reports to practices detailing their performance on clinical indicators in comparison to other practices in their region, as part of their role in supporting quality improvement (219, 285). Regularity and continuity measures could plausibly be calculated from existing practice data and reported to practices to inform them of their performance and allow individual practices to make changes if they consider it necessary, without interfering with practice autonomy in managing patients.

Even where evidence may indicate that a certain policy change would likely increase the regularity or continuity of care and hence reduce hospitalisations or ED presentations as a result, the translation of this evidence into policy is not straightforward. In the case of medical research, there is often a relatively linear path from development of evidence into evidence-based policy (286, 287). In Australia there is an existing framework to support this translation, with the Pharmaceutical Benefits Advisory Committee and Medical Services Advisory Committee acting as independent expert bodies to review evidence and recommend medicines and medical technologies, respectively, for public funding (288, 289). The development of evidence-based policy is less linear and greater challenges exist in translating policy research or health services research into policy. Where policy-makers make decisions, the evidence base itself is only one of many factors that influence policy settings (290). The decision-making context is as or more important than the evidence base in the development of policy (287), with practical, political and ideological factors playing key roles (290). In Australia, even though State and Federal governments both have a role in developing health policies, the contextual issues differ for each level of government, adding further complexity (286). The result is often a gap between the policies that research shows to be effective, and the policies that are enacted (291, 292). At the local level, research within Australia has indicated that the PHNs (described in section 2.1.2.2.2) show considerable variation in terms of their capacity for evidence-informed decision making; although PHNs generally had high capacity in terms of generating new internal research, there were generally lower capacities in terms of training of their staff to use evidence in policy development, and gaps in the support and tools available to access research (290).

Although many of the barriers to the translation of evidence into effective public health policy are outside of the direct control of the researcher (for example governmental priorities, election cycles), one known barrier is an insufficient evidence base (which may mean a lack of evidence, or a lack of high-quality evidence (291)). The isolation of researchers and policymakers from each other is exacerbated by the fact that policymakers are not generally trained to distinguish between good and bad data (291), which reinforces the need for researchers to produce evidence that is of the highest quality possible. In many cases, important limitations of analyses may not be understood by policymakers even if these are declared transparently within papers.

Where administrative data are used in public health research these issues are vitally important. As has been discussed through this thesis the distinction between associations and causal relationships is important to the development of policy (293) and researchers must play a role in ensuring that their research is not misunderstood by policymakers. The misuse of big data can lead to big errors, that is, the misinterpretation of unimportant associations as being causal relationships can be a cause of costly development of ineffective policies (293).

In terms of considering how research on continuity of care using administrative data can play a role in the development of public health policy, the “stages heuristic” of policy development can provide a useful framework (293). According to this framework policy development is a cycle consisting of four stages: problem identification and issue recognition, policy formulation, policy implementation and policy evaluation. At the problem identification stage the use of administrative data has played a role in demonstrating problems of, for example, increasing rates of chronic disease (294), and can also be used to demonstrate strengths, weaknesses, opportunities and threats of current policies (for example, research demonstrating current changes in primary care access or potential unintended changes in access resulting from other policies or factors (92, 94, 172, 195)). At the policy formulation stage research demonstrating associations between continuity / regularity of care and downstream health service use outcomes is potentially important (if it is of a high quality and can suggest causal relationships) as such research might influence decisions to pursue policies promoting these aspects of primary care as opposed to other priorities. The policy implementation stage can similarly apply the measures of continuity and regularity described in sections 2.2.2.6, 2.2.2.7.2 and 5.1.1 to administrative data so as to assess whether these exposures are actually changing as expected in response to any policy targeting these factors. Finally at the policy evaluation stage the effects and outcomes of policy might be assessed using approaches similar to those applied in section 9.5 both to understand if policy outcomes were achieved (i.e. reduced need for hospital / ED among specific populations) and if not, the points on the causal pathway at which problems may have occurred (i.e. patient / provider behaviour changes).

Although high-quality research is not alone enough to ensure the development of evidence-based public health policy, it is essential that the research done in this area is of the highest quality possible for there to be any possibility that effective policy is developed.

10.5 Conclusion

This thesis has highlighted multiple shortcomings of previously published literature on the topic of continuity of care, and contributed by demonstrating several areas where future research in this area can be strengthened. It is hoped that the publication of this thesis will contribute to improvements in the empirical research on regularity and continuity of care, leading to a stronger evidence base for the development of policy, a more efficient health care system, and ultimately, improvements in patient health.

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Appendix B Sensitivity analyses from chapter 5 (manuscript 2)

B.1 Introduction

One of the aims of manuscript 2 was to understand how associations between regularity and frequency differ between regularity indices, and the analyses of these associations in the main manuscript highlight differences across the indices. However, differences between indices in the group sizes at each level of regularity may impact the comparisons of coefficients between indices. That is, a comparison of coefficients of the “most regular” group on two different indices may be flawed if this group represents 25% of the cohort on one index and only 10% on another. This appendix details two sensitivity analyses which aimed to compare indices in terms of their relationships with frequency, using alternative methods which should not be influenced by different group sizes between measures.

B.2 Methods

Sensitivity analysis 1

This sensitivity analysis is referred to within manuscript 2 though data were not presented due to space constraints. In this sensitivity analysis the Bayes Information Criterion (BIC) was used to assess the overall influence of each regularity index on estimation of frequency (meaning the joint significance of each index is assessed rather than a comparison of the coefficients for individual levels of each index).

Four regressions were performed. Firstly, frequency of contacts was regressed on the set of covariates included in the models described in manuscript 2, with no measure of regularity included. Three regressions were then performed in which each regularity index was separately added to this set of covariates. BIC values from each model were compared to the model with no regularity score. A reduction in BIC indicated that the addition of a regularity index led to improved prediction of the outcome, that is, the regularity measure was associated with frequency.

Sensitivity analysis 2

In this sensitivity analysis a continuous latent variable was assumed to exist for each regularity index and was estimated based on the observed four level ordinal variable. Each regularity variable was regressed on the set of covariates listed in manuscript 2 using panel ordered probit models (`-xtoprobit-` in Stata). Continuous regularity scores were predicted using Stata's postestimation `-predict-` command, and then standardised to aid comparison between measures. Frequency was regressed on each of the standardised predicted variables using univariate panel negative binomial models (`-xtnbreg-` in Stata). Coefficients indicated associations between regularity and frequency for each index.

When using predicted regularity values from the ordered probit model as predictors in the negative binomial model, standard errors (SEs) required adjustment to account for variability in regularity values, as true values would include some random variation which is not present in the predicted values. A correction for this has been developed (295) though this is not applicable to nonlinear panel data models such as the models used here. To approximate the effect on standard errors of (correctly) adjusting for the generated regressor, pooled (cross-sectional) analysis was performed, for which this correction is available. This analysis found that the SE's, once corrected, increased approximately threefold. The standard errors on the panel models were therefore multiplied threefold to give a crude estimate of their true value.

B.3 Results

Sensitivity analysis 1

Table B-1 displays results of testing of the joint significance of each regularity index in estimating frequency, compared to a model with no regularity variable. The addition of any regularity index reduced BIC values, or improved the estimation of frequency. This reduction was smallest for the relative variance index indicating the weakest association with frequency; BIC reductions were 5.0 and 6.2 times larger for the variance and interval indices, respectively. This indicates that the relative variance index contributed the least information to the estimation of frequency, meaning the association between regularity and frequency was smallest for this index.

Table B-1: Bayes Information Criterion values recorded for models in which frequency was regressed on a set of covariates excluding any regularity index, and then the same covariates with each regularity index separately

Regularity index	BIC ¹
No regularity index	4024673
Variance index	3782615
Relative variance index	3982979
Interval index	3726634

¹ Covariates include age (continuous), gender, indigenous status (indigenous / non-indigenous or unknown), socio-economic status (quintiles based on the Socio-Economic Status For Areas – Index of Relative Social Disadvantage), accessibility (based on the Accessibility / Remoteness Index of Australia), count of specialist contacts, count of comorbid conditions in previous five years, and group (within person) means of age, count of specialist contacts and five-year comorbid condition count.

Sensitivity analysis 2

Table B-2 displays results of the regression of frequency on each of the latent regularity variables. Coefficients were comparable as each latent variable was produced through regressing the relevant ordinal regularity score on an identical set of explanatory variables and then standardising. The table shows that the coefficients for the variance and interval indices were positive, indicating a positive association between regularity and frequency. The coefficient for the relative variance index was negative, and in absolute terms, was much smaller than for the other two indices though remained statistically significant. As noted in the methods section the correction to standard errors to account for the use of a generated regressor in a second model was somewhat crude. Despite this, the coefficients for each index were significantly different from zero, and the coefficient for the relative variance remains significantly smaller than those for the variance and interval indices.

Table B-2: Comparison of associations between regularity and frequency of general practitioner contacts through prediction of latent continuous regularity variables, among a cohort of 153,414 Western Australians at risk of diabetes-related hospitalisation from 1990-2004

Regularity index	Coefficient	Standard Error ^a	95% Confidence Interval ^a
Variance index	0.252	0.003	0.246 to 0.259
Relative variance index	-0.023	0.003	-0.028 to -0.018
Interval index	0.256	0.003	0.251 to 0.263

a: Standard error and confidence intervals inflated threefold based on testing of pooled models with and without Murphy-Topel standard error correction

B.4 Summary

The association between regularity and frequency was the smallest when the relative variance index was used, consistent with the analyses reported in the manuscript. Although the analyses included in the manuscript have the most straightforward interpretation, they may be influenced by the fact that the different levels on each ordinal variable have different group sizes. These sensitivity analyses are not likely to be impacted by this issue, and report findings generally consistent with those in manuscript 2.

Appendix C Additional content from chapter 6 (manuscript 3)

C.1 Literature search details

Research question:

What literature was published between 1985 and 2004 assessing the relationship between managed versus ad hoc primary care for potentially avoidable or preventable hospitalisations/ ambulatory care sensitive chronic conditions?

Methods:

Inclusion criteria:

Population – community dwelling populations

Intervention – managed primary care for chronic conditions

Comparator – ad hoc or intermittent care

Outcome – hospitalisation for a potentially avoidable or preventable hospitalisations/
ambulatory care sensitive condition

Exclusion criteria:

Non-English articles and articles published before 1985 or after 2004.

Search strategy (adapted from (1, 2))

1. randomized controlled trial.pt.
2. exp Randomized Controlled Trials/
3. controlled clinical trial.pt.
4. randomized controlled trials.sh.
5. random allocation.sh.
6. double blind method.sh.
7. single blind method.sh.
8. or/1-7
9. (animals not human).sh.
10. 8 not 9
11. clinical trial.pt.
12. exp clinical trial/
13. ((clin\$ or doub\$ or treb\$ or trip\$) adj25 (blind\$ or mask\$)).ti,ab.
14. (clin\$ adj25 trial\$).ti,ab.
15. placebos.sh.
16. placebo\$.ti,ab.
17. random\$.ti,ab.
18. research design.sh.
19. or/11-18
20. 19 not 9
21. 20 not 10
22. exp meta-analysis/

23. exp "Review Literature"/
24. meta-analysis.pt.
25. review.pt.
26. exp "Review"/
27. "Review Literature"/
28. systematic review.mp.
29. guideline.pt.
30. exp "Practice Guideline"/
31. or/22-30
32. 31 not 9
33. comparative study.sh.
34. exp evaluation studies/
35. follow up studies.sh.
36. prospective studies.sh.
37. (control\$ or prospective\$ or volunteer\$).ti,ab.
38. or/33-37
39. 38 not 9
40. 39 not (32 or 21 or 10)
41. 40 or 32 or 21 or 10
42. exp Hospitalization/
43. hospitalisation.mp.
44. exp Patient Admission/
45. exp Health Services Accessibility/
46. exp Emergency Service, Hospital/
47. emergency department.mp.
48. ambulatory care utilization.mp.
49. ambulatory care utilisation.mp.
50. or/42-49
51. (avoid* or inappropriate or unnecessary or prevent* or unexpected).mp.
52. adverse event.mp.
53. severe adverse events.mp.
54. adverse outcomes.mp.
55. exp Drug Toxicity/
56. exp Health Services Misuse/

57. ambulatory care sensitive conditions.mp.
58. acsc.mp.
59. exp risk factors/
60. admission risk.mp.
61. patient risk.mp.
62. predictor.mp.
63. determinant.mp.
64. or/51-63
65. exp Ambulatory Care/
66. exp Primary Health Care/
67. exp Family Practice/
68. exp Physicians, Family/
69. exp Continuity of Patient care/
70. continuity of care.mp.
71. (continuity adj5 provider).mp.
72. (continuity adj5 doctor).mp.
73. general practitioner.mp.
74. exp Chronic Disease/
75. exp Managed Care Programs/
76. or/65-75
77. 50 and 64
78. 76 and 77
79. 41 and 78
80. limit 79 to yr="1985-2004"

Results

The search returned 2,414 unduplicated records. The selection flow diagram is provided in Figure 1. Twenty-five studies fulfilled eligibility criteria (3-26); these are displayed by year of publication in Figure 2.

Figure 1. Study selection flow diagram.

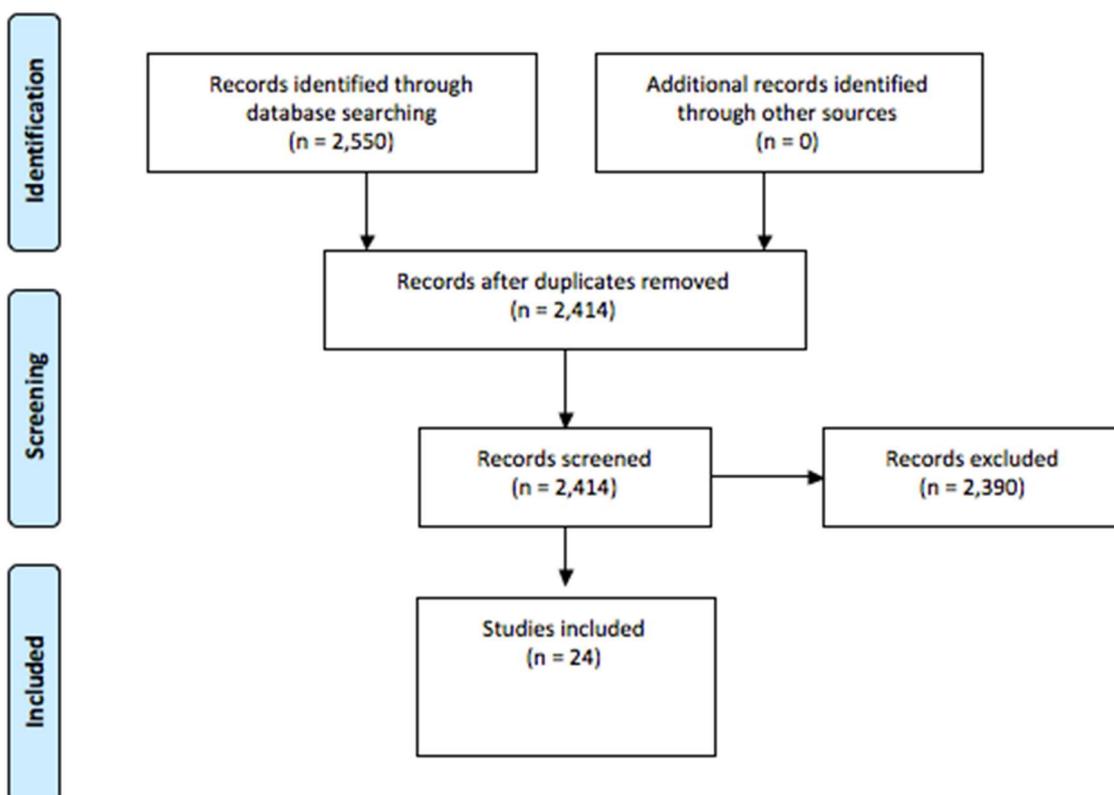
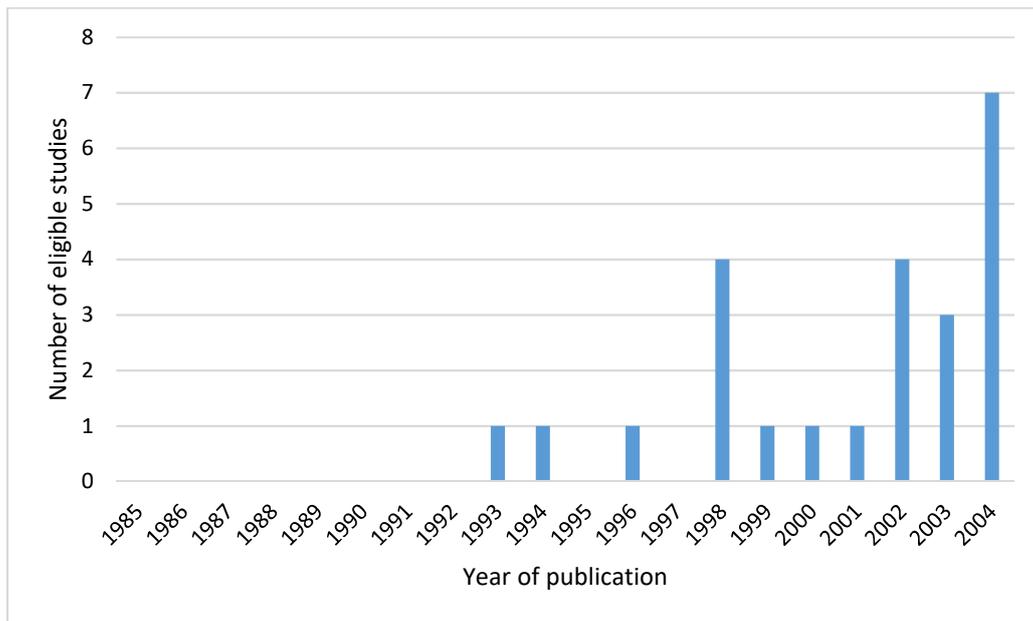


Figure 2. Number of eligible studies by year of publication.



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C.2 Additional tables regarding hospitalisation count outcome

Table C-1: Output of zero-inflated negative binomial model with diabetes-related admission as dependent variable

Variable	IRR	SE	z	p	
Least regular	Ref				
2nd least regular	1.01	0.11	0.06	0.950	
3	0.96	0.09	-0.49	0.625	
4	0.95	0.13	-0.35	0.727	
5	1.04	0.17	0.27	0.786	
6	0.94	0.09	-0.57	0.569	
7	1.03	0.12	0.23	0.819	
8	0.85	0.08	-1.81	0.070	
9	0.94	0.09	-0.66	0.510	
Regularity	Most regular	0.84	0.08	-1.84	0.066
	1	Ref			
	2	0.80	0.08	-2.25	0.024
Era	3	0.66	0.07	-3.97	<0.001
	Least regular # era 1	Ref			
	Second least regular # era 2	0.86	0.12	-1.10	0.270
	Second least regular # era 3	1.01	0.14	0.08	0.934
	3 # era 2	1.11	0.14	0.77	0.439
	3 # era 3	0.98	0.11	-0.15	0.878
	4 # era 2	0.95	0.15	-0.34	0.733
	4 # era 3	1.05	0.16	0.29	0.771
	5 # era 2	0.89	0.16	-0.65	0.517
	5 # era 3	0.90	0.16	-0.58	0.560
Regularity x Era interaction	6 # era 2	0.97	0.13	-0.20	0.844
	6 # era 3	1.03	0.13	0.21	0.830

Variable		IRR	SE	z	p
	7 # era 2	0.91	0.14	-0.64	0.523
	7 # era 3	0.97	0.14	-0.24	0.811
	8 # era 2	1.09	0.14	0.73	0.466
	8 # era 3	1.09	0.13	0.78	0.436
	9 # era 2	0.86	0.10	-1.31	0.191
	9 # era 3	0.93	0.11	-0.65	0.518
	Most regular # era 2	0.99	0.12	-0.07	0.940
	Most regular # era 3	1.12	0.14	0.89	0.371
	0	Ref			
	1	2.05	0.07	22.14	<0.001
	2	2.08	0.11	14.26	<0.001
	3	3.51	0.27	16.25	<0.001
Three-year hospitalisation history (count)	4	4.16	0.46	12.95	<0.001
	5 plus	55.49	4.43	50.31	<0.001
Frequency		1.01	0.00	4.27	<0.001
	Lowest	Ref			
	2	1.13	0.06	2.30	0.022
	3	1.05	0.05	1.11	0.266
	4	1.15	0.06	2.80	0.005
Three-year frequency	Highest	1.08	0.06	1.32	0.185
	Lowest	Ref			
	2	0.98	0.04	-0.57	0.571
	3	0.97	0.04	-0.82	0.414
	4	0.96	0.04	-0.97	0.33
	Highest	1.05	0.05	1.03	0.304
Three-year regularity	Missing (in any year)	1.26	0.19	1.51	0.131
Specialist visits (t)		1.00	0.00	-1.00	0.319
Five-year comorbidity history		0.92	0.01	-11.82	<0.000
Previous diabetes diagnosis (HMDS)		1.22	0.05	5.41	<0.000
Previous diabetes cycle of care (MBS)		0.94	0.07	-0.85	0.394
Previous HbA1c test (MBS)		1.11	0.04	2.77	0.006
Multiple HbA1c tests in previous six months		1.13	0.05	2.59	0.009
Previous OGTT outside pregnancy		0.83	0.03	-4.99	<0.000
Years available for ascertainment of condition		0.97	0.01	-4.94	<0.000
	Risk of diabetes				
Diabetes risk	Confirmed diabetes	1.07	0.06	1.33	0.182
Age		1.24	0.02	14.20	<0.001
Age²		1.00	0.00	-0.25	0.801
Male		1.28	0.03	9.86	<0.001
Indigenous		2.00	0.15	9.12	<0.001
	Highest disadvantage	1.12	0.04	3.09	0.002
	High disadvantage	1.08	0.04	1.97	0.049
Socioeconomic status	Moderate disadvantage	1.03	0.04	0.65	0.513
	Less disadvantage	1.04	0.04	0.93	0.355
	Least disadvantage	Ref			
Accessibility	Highly accessible	Ref			

Variable	IRR	SE	z	p
Accessible	0.94	0.05	-1.12	0.261
Moderately accessible	1.02	0.05	0.43	0.670
Remote	1.05	0.09	0.63	0.528
Very remote	1.30	0.12	2.83	0.005
Unknown	1.29	0.21	1.58	0.115
Mundlak age	0.83	0.01	-22.34	<0.001
Mundlak regularity	0.99	0.01	-0.51	0.607
Mundlak frequency	1.00	0.00	-1.32	0.187
Mundlak specialist visits	1.03	0.00	7.26	<0.001
Mundlak comorbidity history	1.38	0.01	30.30	<0.001
Constant	0.00	0.00	-33.4	<0.001
Ln(time out of hospital)	1.00		(exposure)	
Constant	-25.2	0.03	-911.94	<0.001
Lnalpha	1.70	0.02	69.73	<0.001
alpha	5.46	0.13		

Table C-2: Associations between regularity of GP contact and hospitalisation count outcome by era, cohort who did not migrate to / from study area during study period

Full study period (1990–91 to 2002–03)			
Regularity	N¹	IRR²	95% CI
Least regular		Reference category	
2	46,135	1.007	0.954, 1.063
3	46,136	1.002	0.950, 1.058
4	46,136	0.971	0.927, 1.016
5	46,135	0.967	0.923, 1.014
6	46,137	0.975	0.928, 1.024
7	46,136	0.992	0.943, 1.043
8	46,136	0.983	0.927, 1.042
9	46,136	0.946	0.901, 0.993
Most regular	46,136	0.947	0.901, 0.995
Era 1 (1991–92 to 1993–94)			
Regularity	N	IRR	95% CI
Least regular		Reference category	
2	5,280	1.031	0.884, 1.203
3	4,560	1.057	0.886, 1.261
4	4,355	0.935	0.841, 1.040
5	4,209	0.959	0.862, 1.068
6	4,251	0.982	0.868, 1.111
7	4,218	1.041	0.889, 1.220
8	4,166	0.936	0.840, 1.043
9	4,284	0.994	0.880, 1.123
Most regular	4,366	0.914	0.820, 1.019
Era 2 (1994–95 to 1998–9)			
Regularity	N	IRR	95% CI
Least regular		Reference category	
2	17,377	0.957	0.886, 1.034
3	16,579	1.006	0.920, 1.100
4	16,488	0.954	0.886, 1.028
5	16,381	0.967	0.894, 1.045
6	15,961	0.933	0.871, 1.000
7	15,790	0.943	0.880, 1.010
8	15,606	0.987	0.897, 1.087
9	15,271	0.924	0.861, 0.992
Most regular	15,268	0.919	0.855, 0.988
Era 3 (1999–00 to 2002–03)			

Regularity	N	IRR	95% CI
Least regular		Reference category	
2	23,478	1.039	0.955, 1.130
3	24,997	0.985	0.919, 1.055
4	25,293	0.993	0.927, 1.063
5	25,545	0.970	0.907, 1.038
6	25,925	1.004	0.929, 1.085
7	26,128	1.015	0.939, 1.098
8	26,364	0.994	0.917, 1.078
9	26,581	0.948	0.886, 1.014
Most regular	26,502	0.977	0.905, 1.055

C.3 Additional tables regarding hospitalisation cost outcome

Table C-3: Output of Cragg-hurdle model with cumulated diabetes-related hospitalisation cost as dependent variable

Variable		Coef.	SE	z	p
	Least regular	Ref			
	2nd least regular	-0.04	0.05	-0.77	0.439
	3	-0.01	0.04	-0.21	0.835
	4	0.03	0.05	0.66	0.509
	5	-0.06	0.04	-1.36	0.175
	6	0.01	0.04	0.18	0.861
	7	-0.04	0.04	-1.00	0.318
	8	-0.05	0.04	-1.12	0.261
	9	0.00	0.04	0.10	0.916
Regularity	Most regular	-0.06	0.04	-1.43	0.153
	1	Ref			
	2	-0.10	0.04	-2.56	0.01
Era	3	-0.18	0.04	-4.37	<0.001
	Least regular # era 1	Ref			
	Second least regular # era 2	0.04	0.05	0.73	0.463
	Second least regular # era 3	0.03	0.05	0.55	0.581
	3 # era 2	-0.04	0.05	-0.76	0.447
	3 # era 3	0.04	0.05	0.77	0.439
	4 # era 2	-0.03	0.05	-0.66	0.512
	4 # era 3	0.00	0.05	-0.07	0.943
	5 # era 2	0.03	0.05	0.59	0.553
	5 # era 3	-0.01	0.05	-0.11	0.915
	6 # era 2	0.07	0.05	1.36	0.174
	6 # era 3	-0.01	0.05	-0.10	0.919
	7 # era 2	-0.08	0.05	-1.59	0.111
	7 # era 3	-0.08	0.05	-1.60	0.109
	8 # era 2	-0.03	0.05	-0.67	0.504
	8 # era 3	-0.10	0.05	-2.08	0.038
	9 # era 2	-0.03	0.05	-0.64	0.523
	9 # era 3	-0.03	0.05	-0.69	0.487
Regularity x Era interaction	Most regular # era 2	-0.11	0.05	-2.17	0.030
	Most regular # era 3	0.04	0.05	0.74	0.458
	0	Ref			
	1	0.00	0.01	0.37	0.708
	2	0.15	0.01	11.85	<0.001
Three-year hospitalisation history (count)	3	0.22	0.02	12.67	<0.001
	4	0.28	0.02	11.88	<0.001

Variable		Coef.	SE	z	p
	5 plus	0.91	0.03	29.10	<0.001
Frequency		0.00	0.00	-1.13	0.257
	Lowest	Ref			
	2	0.00	0.00	-1.13	0.257
	3	-0.03	0.02	-1.64	0.1
	4	-0.07	0.02	-3.55	<0.001
Three-year frequency	Highest	-0.09	0.02	-4.60	<0.001
	Lowest	Ref			
	2	-0.03	0.01	-2.62	0.009
	3	-0.04	0.01	-3.16	0.002
	4	-0.02	0.01	-1.75	0.079
	Highest	-0.01	0.02	-0.82	0.415
Three-year regularity	Missing (in any year)	-0.05	0.04	-1.32	0.188
Specialist visits (t)		-0.01	0.00	-6.67	<0.001
Five-year comorbidity history		0.00	0.00	-2.36	0.018
Previous diabetes diagnosis (HMDS)		0.03	0.01	2.21	0.027
Previous diabetes cycle of care (MBS)		-0.02	0.02	-1.03	0.305
Previous HbA1c test (MBS)		0.02	0.01	1.60	0.11
Multiple HbA1c tests in previous six months		-0.01	0.01	-0.46	0.648
Previous OGTT outside pregnancy		-0.09	0.01	-7.00	<0.001
Years available for ascertainment of condition		-0.01	0.00	-2.38	0.017
	Risk of diabetes	Ref			
Diabetes risk	Confirmed diabetes	0.02	0.02	1.39	0.164
Age		0.07	0.00	18.99	<0.001
Age²		0.00	0.00	6.70	<0.001
Male		0.19	0.01	4.71	<0.001
Indigenous		0.12	0.02	4.71	<0.001
	Highest disadvantage	0.00	0.01	-0.30	0.767
	High disadvantage	-0.01	0.01	-0.62	0.537
Socioeconomic status	Moderate disadvantage	0.01	0.01	0.41	0.68
	Less disadvantage	-0.01	0.01	-0.37	0.701
	Least disadvantage	Ref			
	Highly accessible	Ref			
	Accessible	-0.10	0.02	-5.99	<0.001
Accessibility	Moderately accessible	-0.08	0.02	-4.49	<0.001
	Remote	-0.05	0.03	-1.50	0.134
	Very remote	-0.03	0.03	-0.87	0.387
	Unknown	0.02	0.07	0.26	0.797
Mundlak age		-0.05	0.00	-20.31	<0.001
Mundlak regularity		-0.01	0.00	-2.93	0.003
Mundlak frequency		0.00	0.00	2.31	0.021
Mundlak specialist visits		0.01	0.00	4.71	<0.001
Mundlak comorbidity history		0.03	0.00	12.33	<0.001
Constant		0.00	0.00	-33.40	<0.001
Ln(time out of hospital)		1.00		(exposure)	
Constant		8.31	0.08	99.97	<0.001

Variable		Coef.	SE	z	p
Outcome model					
Variable		Coef.	SE	z	p
	Least regular	Ref			
	2nd least regular	-0.03	0.03	-0.83	0.409
	3	-0.02	0.03	-0.78	0.436
	4	-0.05	0.03	-1.69	0.092
	5	-0.04	0.03	-1.26	0.206
	6	-0.04	0.03	-1.37	0.170
	7	-0.02	0.03	-0.75	0.450
	8	-0.06	0.03	-2.00	0.045
	9	-0.06	0.03	-1.80	0.072
Regularity	Most regular	-0.10	0.03	-3.03	0.002
	1	Ref			
	2	-0.12	0.03	-4.76	<0.001
Era	3	-0.22	0.03	-8.34	<0.001
	Least regular # era 1	Ref			
	Second least regular # era 2	-0.02	0.04	-0.45	0.652
	Second least regular # era 3	0.00	0.04	-0.11	0.914
	3 # era 2	0.03	0.04	0.80	0.423
	3 # era 3	0.01	0.04	0.24	0.808
	4 # era 2	-0.01	0.04	-0.31	0.754
	4 # era 3	-0.01	0.04	-0.17	0.863
	5 # era 2	0.02	0.04	0.53	0.596
	5 # era 3	-0.02	0.04	-0.52	0.603
	6 # era 2	0.02	0.04	0.59	0.556
	6 # era 3	0.01	0.04	0.38	0.705
	7 # era 2	0.02	0.04	0.44	0.66
	7 # era 3	0.05	0.04	1.38	0.166
	8 # era 2	0.03	0.03	0.84	0.401
	8 # era 3	0.04	0.04	1.06	0.289
	9 # era 2	0.02	0.04	0.65	0.513
	9 # era 3	0.05	0.03	1.39	0.166
Regularity x Era interaction	Most regular # era 2	0.02	0.03	0.51	0.614
	Most regular # era 3	0.04	0.04	1.14	0.255
Frequency		0.00	0.00	2.35	0.019
	Lowest	Ref			
	2	0.04	0.01	3.59	<0.001
	3	0.05	0.01	4.56	<0.001
	4	0.06	0.01	5.47	<0.001
Three-year frequency	Highest	0.02	0.01	1.57	<0.001
	0	Ref			
Three-year hospitalisation history (count)	1	0.36	0.01	52.40	<0.001
	2	0.30	0.01	32.10	<0.001
	3	0.49	0.01	34.21	<0.001

Variable		Coef.	SE	z	p
	4	0.64	0.02	31.41	<0.001
	5 plus	0.96	0.02	46.92	<0.001
	Lowest	Ref			
	2	0.00	0.01	0.56	0.573
	3	0.01	0.01	1.44	0.15
	4	0.01	0.01	1.63	0.103
	Highest	0.04	0.01	3.59	<0.001
Three-year regularity	Missing (in any year)	0.09	0.02	3.79	<0.001
Specialist visits (t)		0.00	0.00	-8.58	<0.001
Previous diabetes diagnosis (HMDS)		0.11	0.01	13.84	<0.001
Multiple previous HbA1c tests in previous six months		0.11	0.01	13.93	<0.001
Previous OGTT outside pregnancy		-0.06	0.01	-9.51	<0.001
Years available for ascertainment of condition		-0.02	0.00	-12.37	<0.001
	Risk of diabetes	Ref			
Diabetes risk	Confirmed diabetes	0.00	0.01	0.12	0.905
Age		0.08	0.00	33.25	<0.001
Age²		0.00	0.00	-2.11	0.035
Male		0.07	0.01	14.74	<0.001
Indigenous		0.23	0.01	15.70	<0.001
	Highest disadvantage	0.05	0.01	6.79	<0.001
	High disadvantage	0.03	0.01	4.20	<0.001
Socioeconomic status	Moderate disadvantage	0.02	0.01	2.48	0.013
	Less disadvantage	0.02	0.01	1.83	0.067
	Least disadvantage	Ref			
	Highly accessible	Ref			
	Accessible	0.02	0.01	2.16	0.031
Accessibility	Moderately accessible	0.07	0.01	6.01	<0.001
	Remote	0.04	0.02	1.85	0.064
	Very remote	0.14	0.02	7.70	<0.001
	Unknown	0.12	0.04	3.06	0.002
Mundlak age		-0.06	0.00	-35.25	<0.001
Mundlak regularity		0.00	0.00	-1.42	0.155
Mundlak frequency		0.00	0.00	5.95	<0.001
Mundlak specialist visits		0.02	0.00	17.12	<0.001
Mundlak comorbidity history		0.11	0.00	79.18	<0.001
Constant		-2.72	0.05	-52.72	<0.001
Insigma	Constant	-0.14	0.00	-36.89	<0.001
	Sigma	0.87	0.00		

Table C-4: Associations between regularity of GP contact and hospitalisation cost (\$AUD2017) outcome by era, cohort who did not migrate to / from study area during study period

Full study period (1990–91 to 2002–03)

Regularity	N ²	Change	95% CI
Least regular		Reference category	
2	46,135	-11.32	-66.30, 43.66
3	46,136	-32.24	-86.68, 22.19
4	46,136	-34.65	-88.94, 19.65
5	46,135	-60.30	-114.22, -6.38
6	46,137	-65.67	-119.95, -11.38
7	46,136	-57.71	-112.56, -2.87
8	46,136	-59.31	-115.49, -3.14
9	46,136	-89.69	-146.40, -32.95
Most regular	46,136	-109.95	-169.64, -50.26

Era 1 (1991–92 to 1993–94)

Regularity	N	Change	95% CI
Least regular		Reference category	
2	5,280	-43.42	-213.77, 126.93
3	4,560	-24.15	-194.42, 146.13
4	4,355	-38.53	-203.37, 126.31
5	4,209	-26.17	-192.46, 140.12
6	4,251	-76.66	-241.55, 88.23
7	4,218	-30.50	-197.07, 136.06
8	4,166	-87.97	-247.82, 71.89
9	4,284	-25.59	-192.96, 141.77
Most regular	4,366	-213.42	-370.71, 56.13

Era 2 (1994–95 to 1998–99)

Regularity	N	Change	95% CI
Least regular		Reference category	
2	17,377	-24.84	-116.17, 66.50
3	16,579	15.04	-76.43, 106.51
4	16,488	-44.95	-132.86, 42.95
5	16,381	-65.49	-152.93, 21.96
6	15,961	-63.09	-152.29, 26.11
7	15,790	-63.85	-152.14, 24.43
8	15,606	-79.13	-168.83, 10.57
9	15,271	-98.80	-184.66, -6.94
Most regular	15,268	-126.89	-220.18, -33.60

Era 3 (1999–00 to 2002–03)

Regularity	N	Change	95% CI
Least regular		Reference category	

2	23,478	2.65	-72.08, 77.38
3	24,997	-67.51	-140.11, 5.08
4	25,293	-29.44	-102.46, 43.57
5	25,545	-65.56	-137.25, 6.14
6	25,925	-67.75	-139.10, 3.61
7	26,128	-60.93	-132.67, 10.80
8	26,364	-42.44	-115.78, 30.90
9	26,581	-101.33	-173.94, -28.72
Most regular	26,502	-78.41	-154.95, -1.88

Appendix D Additional tables from Chapter 7

D.1 Blood diseases

Table D-1: Unlagged random effects model, cohort with past hospitalisation for blood diseases

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Regularity	0.916	0.911	0.922	0.928	0.924	0.933	
COC	0.947	0.941	0.953	0.931	0.927	0.936	
Era	0.968	0.940	0.997	1.003	0.982	1.025	
Regularity * Era	1.019	1.011	1.027	1.011	1.005	1.017	
COC * Era	1.022	1.014	1.030	1.017	1.011	1.024	
GP management plan	1.002	0.982	1.023	0.977	0.961	0.992	
GP management plan * Era	1.023	0.999	1.048	1.039	1.019	1.058	
Frequency	3–4	Reference		Reference			
	5–6	1.159	1.134	1.185	1.178	1.160	1.196
	7–9	1.395	1.366	1.425	1.410	1.389	1.431
	10–19	1.931	1.893	1.969	1.907	1.880	1.935
	20 plus	2.844	2.781	2.908	2.813	2.765	2.862
Specialist visits	0	Reference		Reference			
	1–2	0.995	0.981	1.009	1.017	1.006	1.028
	3–6	1.134	1.115	1.153	1.104	1.090	1.118
	7–9	1.456	1.421	1.492	1.281	1.256	1.306
	10 plus	2.588	2.535	2.641	1.803	1.771	1.836
Age	18–44	Reference		Reference			
	45–54	1.053	1.027	1.079	0.837	0.822	0.852
	55–64	1.096	1.069	1.123	0.772	0.758	0.787
	65–74	1.200	1.172	1.230	0.773	0.759	0.788
	75–84	1.633	1.594	1.672	0.972	0.953	0.990
85 plus	2.719	2.646	2.795	1.482	1.449	1.516	
Sex	Female	Reference		Reference			

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
	Male	1.302	1.281	1.323	1.205	1.188	1.221
Indigenous status	Non-indig.	Reference			Reference		
	Indigenous	2.857	2.764	2.954	2.804	2.731	2.879
SEIFA	Least disadv.	Reference			Reference		
	Low disadv.	1.086	1.063	1.110	1.133	1.113	1.153
	Mod disadv.	1.146	1.122	1.170	1.264	1.243	1.285
	High disadv.	1.177	1.153	1.201	1.335	1.313	1.357
	Highest disadv.	1.240	1.210	1.271	1.364	1.338	1.391
SEIFA	Missing	1.358	1.069	1.725	1.346	1.128	1.606
ARIA	Major cities	Reference			Reference		
	Inner regional	0.895	0.876	0.913	1.094	1.077	1.111
	Outer regional	1.045	1.018	1.073	1.427	1.399	1.455
	Remote	1.073	1.017	1.132	1.485	1.430	1.542
	Very remote	1.168	1.126	1.213	1.787	1.741	1.835
	Missing	0.877	0.689	1.118	1.002	0.838	1.199
MACSS	0	Reference			Reference		
	1–2	1.057	1.010	1.107	1.021	0.991	1.052
	3–4	1.162	1.119	1.207	1.080	1.054	1.107
	5–9	1.637	1.580	1.695	1.285	1.255	1.315
	10–98	2.550	2.458	2.646	1.729	1.686	1.773
	99 plus	2.099	2.019	2.182	1.471	1.432	1.510
Years in cohort		1.022	1.020	1.024	1.012	1.011	1.014
Constant		0.001	0.001	0.001	0.001	0.001	0.001
Ln_r		3.792	3.727	3.858	3.669	3.615	3.723
Ln_s		1.394	1.364	1.424	1.799	1.767	1.832

Table D-2: Lagged random effects model, cohort with past hospitalisation for blood diseases

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity		0.995	0.989	1.001	1.001	0.997	1.006
COC		0.980	0.974	0.987	0.960	0.956	0.965
Era		0.910	0.883	0.937	0.939	0.918	0.960
Regularity * Era		1.016	1.009	1.024	1.011	1.005	1.017
COC * Era		1.029	1.021	1.037	1.029	1.022	1.035
GP management plan		1.040	1.020	1.061	1.017	1.000	1.033
GP mgmt plan * Era		1.056	1.032	1.081	1.064	1.043	1.084
Frequency	3–4	Reference			Reference		

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
	5–6	1.124	1.101	1.147	1.101	1.084	1.118
	7–9	1.268	1.243	1.294	1.221	1.203	1.239
	10–19	1.567	1.538	1.597	1.438	1.417	1.459
	20 plus	1.969	1.926	2.013	1.761	1.731	1.792
Specialist visits	0	Reference			Reference		
	1–2	0.961	0.948	0.975	0.971	0.961	0.981
	3–6	1.006	0.990	1.022	0.989	0.977	1.002
	7–9	1.115	1.088	1.142	1.056	1.035	1.077
	10 plus	1.386	1.357	1.415	1.183	1.161	1.206
	Age	18–44	Reference			Reference	
45–54		1.094	1.067	1.121	0.876	0.859	0.892
55–64		1.248	1.217	1.279	0.875	0.859	0.892
65–74		1.564	1.526	1.602	0.982	0.964	1.001
75–84		2.303	2.248	2.359	1.327	1.301	1.352
85 plus		3.767	3.665	3.871	2.019	1.973	2.065
Sex		Female	Reference			Reference	
	Male	1.330	1.303	1.352	1.211	1.195	1.228
Indigenous status	Non-indig.	Reference			Reference		
	Indigenous	2.945	2.846	3.046	2.884	2.807	2.962
SEIFA	Least disadv.	Reference			Reference		
	Low disadv.	1.091	1.068	1.115	1.135	1.115	1.155
	Mod disadv.	1.119	1.096	1.142	1.245	1.224	1.266
	High disadv.	1.184	1.160	1.208	1.319	1.297	1.341
	Highest disadv.	1.233	1.203	1.264	1.360	1.333	1.387
	Missing	1.482	1.176	1.869	1.418	1.188	1.693
	ARIA	Major cities	Reference			Reference	
Inner regional		0.886	0.868	0.904	1.086	1.068	1.103
Outer regional		0.963	0.938	0.989	1.330	1.303	1.357
Remote		1.005	0.952	1.062	1.369	1.316	1.423
Very remote		1.072	1.032	1.114	1.556	1.514	1.599
Missing		0.727	0.575	0.920	0.874	0.730	1.047
MACSS	0	Reference			Reference		
	1–2	1.057	1.011	1.105	1.034	1.003	1.065
	3–4	1.163	1.121	1.207	1.101	1.073	1.129
	5–9	1.664	1.607	1.722	1.363	1.331	1.396
	10–98	2.531	2.441	2.624	1.850	1.803	1.898
	99 plus	1.994	1.919	2.071	1.528	1.487	1.570
Years in cohort	1.026	1.024	1.028	1.016	1.014	1.018	
Constant	0.000	0.000	0.001	0.001	0.001	0.001	

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Ln_r	3.667	3.605	3.731	3.456	3.406	3.506
Ln_s	1.359	1.330	1.388	1.747	1.716	1.780

Table D-3: Lagged hybrid model, cohort with past hospitalisation for blood diseases

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity		1.027	1.020	1.035	1.026	1.020	1.032
COC		1.015	1.007	1.024	1.006	0.999	1.012
Era		0.808	0.777	0.840	0.859	0.835	0.884
Regularity * Era		0.998	0.989	1.008	1.001	0.993	1.008
COC * Era		1.006	0.994	1.017	1.009	1.000	1.018
Mean regularity		0.933	0.924	0.943	0.951	0.943	0.959
Mean reg * Era		1.045	1.032	1.059	1.026	1.016	1.037
Mean COC		0.940	0.931	0.949	0.899	0.892	0.906
Mean COC * Era		1.048	1.036	1.059	1.046	1.037	1.055
GP management plan		1.044	1.024	1.064	1.019	1.002	1.035
GP management plan * Era		1.051	1.024	1.076	1.060	1.002	1.080
Frequency	3–4	Reference			Reference		
	5–6	1.130	1.107	1.154	1.107	1.090	1.124
	7–9	1.280	1.255	1.305	1.231	1.213	1.250
	10–19	1.593	1.563	1.623	1.461	1.440	1.482
	20 plus	2.011	1.967	2.056	1.797	1.766	1.829
Specialist visits	0	Reference			Reference		
	1–2	0.961	0.947	0.974	0.969	0.959	0.980
	3–6	1.004	0.989	1.021	0.987	0.975	1.000
	7–9	1.113	1.087	1.140	1.053	1.032	1.075
	10 plus	1.384	1.355	1.414	1.181	1.159	1.203
Age	18–44	Reference			Reference		
	45–54	1.118	1.090	1.146	0.901	0.885	0.918
	55–64	1.294	1.262	1.327	0.919	0.901	0.937
	65–74	1.638	1.598	1.679	1.047	1.027	1.068
	75–84	2.425	2.366	2.486	1.427	1.399	1.455
	85 plus	3.956	3.847	4.068	2.169	2.119	2.220
Sex	Female	Reference			Reference		
	Male	1.332	1.310	1.354	1.219	1.202	1.236
Indigenous status	Non-indig.	Reference			Reference		
	Indigenous	2.875	2.779	2.975	2.783	2.709	2.859
SEIFA	Least disadv.	Reference			Reference		
	Low disadv.	1.093	1.070	1.117	1.139	1.119	1.159
	Mod disadv.	1.122	1.100	1.145	1.250	1.230	1.272
	High disadv.	1.183	1.159	1.207	1.319	1.297	1.341

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
	Highest disadv.	1.236	1.205	1.267	1.363	1.336	1.391
	Missing	1.492	1.183	1.880	1.432	1.200	1.709
ARIA	Major cities	Reference			Reference		
	Inner regional	0.878	0.860	0.896	1.073	1.056	1.090
	Outer regional	0.952	0.927	0.978	1.312	1.285	1.338
	Remote	0.994	0.941	1.050	1.349	1.298	1.403
	Very remote	1.048	1.009	1.088	1.510	1.469	1.552
	Missing	0.719	0.568	0.909	0.861	0.720	1.031
	0	Reference			Reference		
MACSS conditions	1–2	1.057	1.011	1.105	1.035	1.004	1.066
	3–4	1.164	1.122	1.208	1.103	1.075	1.131
	5–9	1.668	1.612	1.727	1.369	1.337	1.402
	10–98	2.538	2.447	2.631	1.861	1.814	1.909
	99 plus	1.995	1.920	2.072	1.531	1.491	1.574
Years in cohort	1.026	1.024	1.028	1.016	1.014	1.017	
Constant	0.001	0.001	0.001	0.001	0.001	0.002	
Ln_r	3.686	3.623	3.750	3.495	3.444	3.547	
Ln_s	1.363	1.334	1.393	1.771	1.739	1.804	

D.2 Cardiovascular

Table D-4: Unlagged random effects model, cohort with past hospitalisation for cardiovascular conditions

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity		0.912	0.909	0.916	0.924	0.922	0.927
COC		0.955	0.952	0.959	0.938	0.935	0.941
Era		0.964	0.947	0.981	1.010	0.997	1.023
Regularity * Era		1.012	1.008	1.017	1.006	1.003	1.010
COC * Era		1.017	1.012	1.022	1.014	1.010	1.017
GP management plan		1.005	0.994	1.017	0.975	0.967	0.984
GP management plan * Era		1.012	0.998	1.026	1.025	1.014	1.036
Frequency	3–4	Reference			Reference		
	5–6	1.199	1.183	1.215	1.180	1.169	1.191
	7–9	1.519	1.500	1.538	1.468	1.455	1.481
	10–19	2.198	2.172	2.224	2.037	2.020	2.055
	20 plus	3.373	3.327	3.420	3.076	3.044	3.108
Specialist visits	0	Reference			Reference		
	1–2	1.019	1.010	1.027	1.030	1.024	1.036
	3–6	1.252	1.240	1.264	1.168	1.160	1.176

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
	7-9	1.735	1.711	1.759	1.419	1.403	1.435
	10 plus	3.073	3.035	3.111	1.979	1.958	2.000
Age	18-44	Reference			Reference		
	45-54	0.891	0.877	0.905	0.771	0.763	0.780
	55-64	0.828	0.815	0.840	0.655	0.648	0.662
	65-74	0.894	0.880	0.907	0.633	0.626	0.640
	75-84	1.294	1.274	1.314	0.799	0.789	0.808
	85 plus	2.348	2.306	2.391	1.284	1.265	1.302
	Sex	Female	Reference			Reference	
Male		1.138	1.127	1.148	1.098	1.090	1.106
Indigenous status	Non-indig.	Reference			Reference		
	Indigenous	2.971	2.901	3.042	2.515	2.467	2.563
SEIFA	Least disadv.	Reference			Reference		
	Low disadv.	1.118	1.104	1.132	1.178	1.166	1.190
	Mod disadv.	1.184	1.170	1.198	1.322	1.309	1.335
	High disadv.	1.221	1.207	1.236	1.424	1.411	1.438
	Highest disadv.	1.283	1.264	1.303	1.448	1.432	1.465
	Missing	1.278	1.129	1.445	1.350	1.238	1.471
	ARIA	Major cities	Reference			Reference	
Inner regional		0.932	0.921	0.943	1.139	1.129	1.149
Outer regional		1.120	1.103	1.138	1.553	1.535	1.571
Remote		1.148	1.113	1.184	1.635	1.601	1.670
Very remote		1.268	1.238	1.298	2.026	1.993	2.059
Missing		0.913	0.805	1.034	1.043	0.955	1.138
MACSS	0	Reference			Reference		
	1-2	1.010	0.989	1.032	1.005	0.991	1.020
	3-4	1.081	1.062	1.101	1.048	1.035	1.061
	5-9	1.400	1.376	1.424	1.219	1.205	1.234
	10-98	2.157	2.117	2.198	1.620	1.599	1.641
	99 plus	1.588	1.556	1.620	1.332	1.314	1.351
Years in cohort	1.023	1.022	1.024	1.016	1.015	1.016	
Constant	0.001	0.001	0.001	0.002	0.002	0.002	
Ln_r	5.019	4.962	5.075	4.537	4.497	4.578	
Ln_s	1.441	1.422	1.460	1.782	1.764	1.801	

Table D-5: Lagged random effects model, cohort with past hospitalisation for cardiovascular conditions

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Regularity	1.001	0.997	1.004	1.002	1.000	1.005	
COC	0.991	0.987	0.994	0.970	0.968	0.973	
Era	0.901	0.885	0.917	0.948	0.936	0.961	
Regularity * Era	1.006	1.002	1.011	1.004	1.000	1.007	
COC * Era	1.019	1.015	1.024	1.020	1.017	1.024	
GP management plan	1.061	1.049	1.073	1.037	1.028	1.046	
GP management plan * Era	1.041	1.027	1.055	1.043	1.032	1.054	
Frequency	3–4	Reference		Reference			
	5–6	1.139	1.125	1.153	1.105	1.095	1.115
	7–9	1.305	1.290	1.320	1.228	1.218	1.239
	10–19	1.642	1.624	1.660	1.456	1.444	1.468
	20 plus	2.111	2.083	2.139	1.796	1.777	1.815
Specialist visits	0	Reference		Reference			
	1–2	0.946	0.939	0.954	0.959	0.953	0.965
	3–6	0.990	0.981	0.999	0.982	0.975	0.989
	7–9	1.098	1.083	1.114	1.043	1.031	1.055
	10 plus	1.350	1.333	1.368	1.164	1.151	1.177
Age	18–44	Reference		Reference			
	45–54	0.923	0.909	0.938	0.804	0.795	0.813
	55–64	0.925	0.911	0.940	0.725	0.717	0.734
	65–74	1.174	1.156	1.192	0.796	0.786	0.805
	75–84	1.896	1.867	1.926	1.112	1.099	1.126
	85 plus	3.401	3.341	3.463	1.800	1.775	1.826
Sex	Female	Reference		Reference			
	Male	1.119	1.109	1.129	1.060	1.052	1.068
Indigenous status	Non-indig.	Reference		Reference			
	Indigenous	2.975	2.904	3.047	2.576	2.526	2.626
SEIFA	Least disadv.	Reference		Reference			
	Low disadv.	1.118	1.104	1.132	1.166	1.154	1.177
	Mod disadv.	1.171	1.158	1.185	1.306	1.293	1.319
	High disadv.	1.230	1.216	1.245	1.392	1.379	1.405
	Highest disadv.	1.272	1.253	1.291	1.426	1.410	1.443
	Missing	1.147	1.012	1.299	1.253	1.148	1.368
ARIA	Major cities	Reference		Reference			
	Inner regional	0.930	0.919	0.941	1.131	1.121	1.141
	Outer regional	1.017	1.002	1.033	1.419	1.403	1.436
	Remote	1.040	1.008	1.073	1.468	1.436	1.500

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Very remote	1.159	1.132	1.187	1.740	1.711	1.769
Missing	0.946	0.834	1.074	1.032	0.944	1.128
0	Reference			Reference		
1–2	1.012	0.992	1.033	1.026	1.011	1.041
3–4	1.103	1.084	1.123	1.084	1.070	1.097
5–9	1.486	1.462	1.510	1.309	1.293	1.324
10–98	2.234	2.194	2.275	1.723	1.700	1.747
MACSS 99 plus	1.586	1.555	1.617	1.382	1.362	1.402
Years in cohort	1.033	1.032	1.034	1.023	1.022	1.024
Constant	0.001	0.001	0.001	0.001	0.001	0.001
Ln_r	4.464	4.416	4.512	4.016	3.981	4.051
Ln_s	1.452	1.433	1.472	1.746	1.727	1.764

Table D-6: Lagged hybrid model, cohort with past hospitalisation for cardiovascular conditions

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity	1.030	1.026	1.034	1.028	1.024	1.031
COC	1.014	1.009	1.019	1.009	1.005	1.013
Era	0.837	0.817	0.858	0.883	0.867	0.899
Regularity * Era	0.999	0.994	1.005	0.999	0.995	1.004
COC * Era	1.006	1.000	1.013	1.006	1.001	1.011
Mean regularity	0.937	0.932	0.943	0.945	0.941	0.950
Mean reg * Era	1.019	1.011	1.027	1.010	1.004	1.016
Mean COC	0.963	0.957	0.968	0.914	0.910	0.918
Mean COC * Era	1.032	1.026	1.039	1.036	1.031	1.042
GP management plan	1.061	1.049	1.073	1.036	1.027	1.045
GP management plan * Era	1.041	1.049	1.056	1.044	1.027	1.056
3–4	Reference			Reference		
5–6	1.145	1.132	1.159	1.112	1.103	1.122
7–9	1.318	1.303	1.333	1.241	1.231	1.252
10–19	1.670	1.651	1.689	1.483	1.470	1.495
Frequency 20 plus	2.159	2.130	2.188	1.839	1.820	1.858
0	Reference			Reference		
1–2	0.946	0.939	0.954	0.958	0.952	0.964
3–6	0.989	0.980	0.998	0.980	0.973	0.987
7–9	1.097	1.082	1.113	1.041	1.029	1.053
Specialist visits 10 plus	1.350	1.332	1.368	1.162	1.149	1.176
18–44	Reference			Reference		
45–54	0.939	0.924	0.954	0.824	0.815	0.833
Age 55–64	0.952	0.937	0.967	0.757	0.749	0.766

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
	65–74	1.219	1.200	1.238	0.843	0.833	0.853
	75–84	1.981	1.949	2.012	1.191	1.176	1.205
	85 plus	3.548	3.484	3.613	1.928	1.900	1.956
Sex	Female	Reference			Reference		
	Male	1.118	1.108	1.128	1.066	1.058	1.073
Indigenous status	Non-indig.	Reference			Reference		
	Indigenous	2.916	2.847	2.987	2.489	2.442	2.538
SEIFA	Least disadv.	Reference			Reference		
	Low disadv.	1.120	1.106	1.134	1.170	1.159	1.182
	Mod disadv.	1.174	1.160	1.188	1.312	1.299	1.324
	High disadv.	1.229	1.215	1.243	1.393	1.379	1.406
	Highest disadv.	1.275	1.256	1.294	1.432	1.416	1.449
	Missing	1.148	1.014	1.301	1.253	1.148	1.368
ARIA	Major cities	Reference			Reference		
	Inner regional	0.924	0.913	0.934	1.120	1.110	1.130
	Outer regional	1.009	0.994	1.025	1.401	1.385	1.417
	Remote	1.029	0.997	1.062	1.445	1.414	1.477
	Very remote	1.134	1.107	1.161	1.685	1.657	1.714
	Missing	0.941	0.829	1.068	1.027	0.939	1.123
MACSS conditions	0	Reference			Reference		
	1–2	1.012	0.992	1.033	1.026	1.011	1.041
	3–4	1.103	1.084	1.122	1.084	1.070	1.097
	5–9	1.487	1.463	1.511	1.311	1.296	1.327
	10–98	2.235	2.195	2.276	1.729	1.706	1.752
	99 plus	1.584	1.554	1.616	1.381	1.362	1.401
Years in cohort	1.033	1.032	1.034	1.022	1.022	1.023	
Constant	0.001	0.001	0.001	0.002	0.002	0.002	
Ln_r	4.487	4.438	4.535	4.064	4.028	4.100	
Ln_s	1.458	1.439	1.478	1.771	1.752	1.790	

D.3 Central Nervous System

Table D-7: Unlagged random effects model, cohort with past hospitalisation for central nervous system diseases

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Regularity	0.915	0.912	0.919	0.930	0.927	0.932	
COC	0.942	0.938	0.946	0.927	0.924	0.930	
Era	0.903	0.886	0.921	0.955	0.942	0.969	
Regularity * Era	1.015	1.010	1.020	1.005	1.002	1.009	
COC * Era	1.027	1.021	1.032	1.023	1.019	1.027	
GP management plan	1.023	1.010	1.037	0.990	0.980	1.000	
GP management plan * Era	1.014	0.998	1.030	1.031	1.018	1.043	
Frequency	3-4	Reference		Reference			
	5-6	1.191	1.174	1.208	1.178	1.166	1.189
	7-9	1.483	1.462	1.503	1.434	1.420	1.447
	10-19	2.142	2.115	2.170	1.998	1.980	2.016
	20 plus	3.032	3.258	3.358	3.032	2.999	3.066
Specialist visits	0	Reference		Reference			
	1-2	0.984	0.974	0.993	1.005	0.998	1.012
	3-6	1.179	1.166	1.191	1.127	1.118	1.136
	7-9	1.628	1.603	1.654	1.359	1.342	1.376
	10 plus	2.903	2.863	2.942	1.913	1.891	1.936
Age	18-44	Reference		Reference			
	45-54	0.874	0.860	0.889	0.750	0.742	0.759
	55-64	0.791	0.778	0.803	0.615	0.608	0.623
	65-74	0.843	0.830	0.856	0.573	0.567	0.580
	75-84	1.195	1.177	1.213	0.706	0.698	0.714
	85 plus	2.088	2.051	2.125	1.103	1.087	1.118
Sex	Female	Reference		Reference			
	Male	1.171	1.160	1.183	1.130	1.121	1.139
Indigenous status	Non-indig.	Reference		Reference			
	Indigenous	2.907	2.833	2.984	2.452	2.402	2.502
SEIFA	Least disadv.	Reference		Reference			
	Low disadv.	1.095	1.080	1.110	1.156	1.143	1.168
	Mod disadv.	1.155	1.141	1.171	1.291	1.278	1.304
	High disadv.	1.181	1.166	1.197	1.387	1.373	1.401
	Highest disadv.	1.255	1.235	1.275	1.423	1.406	1.441
	Missing	1.156	0.997	1.340	1.255	1.135	1.388
ARIA	Major cities	Reference		Reference			
	Inner regional	0.926	0.915	0.938	1.147	1.136	1.158

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Outer regional	1.117	1.098	1.136	1.560	1.541	1.579
Remote	1.140	1.102	1.180	1.673	1.635	1.711
Very remote	1.221	1.190	1.253	2.013	1.978	2.048
Missing	0.988	0.851	1.148	1.066	0.963	1.181
0	Reference			Reference		
1–2	0.989	0.968	1.011	0.981	0.967	0.995
3–4	1.144	1.122	1.167	1.084	1.070	1.098
5–9	1.532	1.504	1.561	1.289	1.273	1.305
10–98	2.436	2.387	2.486	1.742	1.718	1.767
MACSS 99 plus	1.606	1.571	1.641	1.321	1.301	1.341
Years in cohort	1.029	1.028	1.030	1.021	1.020	1.022
Constant	0.001	0.001	0.001	0.002	0.002	0.002
Ln_r	5.007	4.946	5.069	4.454	4.411	4.497
Ln_s	1.457	1.436	1.479	1.817	1.797	1.838

Table D-8: Lagged random effects model, cohort with past hospitalisation for central nervous system diseases

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity	1.005	1.001	1.009	1.006	1.003	1.009
COC	0.984	0.980	0.988	0.963	0.960	0.966
Era	0.873	0.856	0.890	0.910	0.897	0.923
Regularity * Era	1.006	1.001	1.011	1.004	1.000	1.007
COC * Era	1.026	1.020	1.031	1.028	1.024	1.031
GP management plan	1.062	1.049	1.076	1.035	1.025	1.046
GP management plan * Era	1.045	1.029	1.061	1.055	1.043	1.068
3–4	Reference			Reference		
5–6	1.147	1.132	1.162	1.103	1.093	1.114
7–9	1.309	1.293	1.326	1.231	1.219	1.242
10–19	1.670	1.650	1.690	1.476	1.463	1.489
Frequency 20 plus	2.188	2.157	2.220	1.854	1.833	1.875
0	Reference			Reference		
1–2	0.929	0.921	0.938	0.951	0.945	0.957
3–6	0.963	0.953	0.973	0.968	0.960	0.976
7–9	1.072	1.055	1.089	1.033	1.019	1.046
Specialist visits 10 plus	1.321	1.302	1.340	1.154	1.140	1.169
18–44	Reference			Reference		
45–54	0.917	0.902	0.933	0.791	0.782	0.800
55–64	0.903	0.889	0.918	0.688	0.680	0.696
65–74	1.116	1.099	1.134	0.722	0.713	0.730
Age 75–84	1.734	1.708	1.761	0.974	0.963	0.986

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
	85 plus	3.009	2.957	3.061	1.537	1.516	1.559
Sex	Female	Reference			Reference		
	Male	1.168	1.157	1.179	1.099	1.090	1.108
Indigenous status	Non-indig.	Reference			Reference		
	Indigenous	2.919	2.844	2.995	2.494	2.443	2.546
SEIFA	Least disadv.	Reference			Reference		
	Low disadv.	1.101	1.087	1.116	1.138	1.125	1.150
	Mod disadv.	1.146	1.132	1.161	1.279	1.265	1.292
	High disadv.	1.191	1.177	1.207	1.358	1.344	1.372
	Highest disadv.	1.243	1.224	1.263	1.404	1.387	1.422
	Missing	1.075	0.927	1.247	1.177	1.063	1.303
ARIA	Major cities	Reference			Reference		
	Inner regional	0.929	0.918	0.941	1.142	1.131	1.153
	Outer regional	1.024	1.007	1.041	1.441	1.424	1.460
	Remote	1.049	1.014	1.085	1.497	1.463	1.533
	Very remote	1.129	1.100	1.158	1.752	1.721	1.784
	Missing	1.010	0.869	1.173	1.068	0.963	1.185
MACSS	0	Reference			Reference		
	1–2	0.995	0.975	1.016	0.978	0.964	0.992
	3–4	1.166	1.144	1.188	1.115	1.100	1.129
	5–9	1.608	1.580	1.637	1.360	1.343	1.377
	10–98	2.480	2.431	2.529	1.828	1.802	1.855
	99 plus	1.609	1.575	1.643	1.355	1.335	1.376
Years in cohort	1.036	1.034	1.037	1.025	1.024	1.026	
Constant	0.001	0.001	0.001	0.001	0.001	0.001	
Ln_r	4.543	4.489	4.596	3.989	3.951	4.026	
Ln_s	1.475	1.453	1.497	1.780	1.760	1.801	

Table D-9: Lagged hybrid model, cohort with past hospitalisation for central nervous system diseases

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity	1.034	1.029	1.039	1.029	1.025	1.032
COC	1.016	1.010	1.021	1.008	1.004	1.012
Era	0.787	0.767	0.808	0.831	0.815	0.847
Regularity * Era	0.995	0.989	1.001	0.998	0.993	1.002
COC * Era	1.006	0.999	1.013	1.009	1.004	1.014
Mean regularity	0.947	0.941	0.954	0.956	0.951	0.961

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Mean reg * Era	1.027	1.018	1.035	1.013	1.006	1.019	
Mean COC	0.946	0.940	0.952	0.900	0.895	0.904	
Mean COC * Era	1.044	1.037	1.052	1.049	1.043	1.055	
GP management plan	1.063	1.050	1.077	1.035	1.025	1.046	
GP management plan * Era	1.043	1.050	1.059	1.055	1.025	1.068	
Frequency	3-4	Reference		Reference			
	5-6	1.153	1.138	1.168	1.110	1.100	1.121
	7-9	1.321	1.304	1.338	1.243	1.231	1.254
	10-19	1.696	1.676	1.717	1.500	1.487	1.514
	20 plus	2.233	2.201	2.266	1.894	1.872	1.915
Specialist visits	0	Reference		Reference			
	1-2	0.929	0.920	0.937	0.950	0.943	0.956
	3-6	0.962	0.952	0.972	0.966	0.958	0.974
	7-9	1.070	1.054	1.087	1.030	1.017	1.044
	10 plus	1.320	1.301	1.339	1.153	1.139	1.167
Age	18-44	Reference		Reference			
	45-54	0.934	0.918	0.949	0.812	0.802	0.821
	55-64	0.930	0.915	0.945	0.718	0.709	0.727
	65-74	1.160	1.142	1.179	0.765	0.756	0.774
	75-84	1.815	1.787	1.843	1.044	1.031	1.056
85 plus	3.145	3.090	3.201	1.648	1.625	1.672	
Sex	Female	Reference		Reference			
	Male	1.168	1.156	1.179	1.104	1.095	1.112
Indigenous status	Non-indig.	Reference		Reference			
	Indigenous	2.856	2.782	2.931	2.411	2.362	2.462
SEIFA	Least disadv.	Reference		Reference			
	Low disadv.	1.104	1.089	1.118	1.142	1.129	1.154
	Mod disadv.	1.149	1.135	1.164	1.284	1.271	1.297
	High disadv.	1.190	1.175	1.205	1.357	1.343	1.371
	Highest disadv.	1.246	1.226	1.266	1.408	1.391	1.426
	Missing	1.072	0.924	1.243	1.173	1.059	1.299
ARIA	Major cities	Reference		Reference			
	Inner regional	0.922	0.910	0.933	1.130	1.119	1.141
	Outer regional	1.014	0.997	1.031	1.423	1.406	1.441
	Remote	1.038	1.003	1.074	1.476	1.442	1.511
	Very remote	1.101	1.073	1.131	1.696	1.666	1.727
	Missing	1.009	0.868	1.172	1.067	0.962	1.183
	0	Reference		Reference			

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
MACSS conditions	1–2	0.996	0.975	1.016	0.979	0.965	0.993
	3–4	1.166	1.144	1.188	1.116	1.101	1.130
	5–9	1.610	1.581	1.639	1.363	1.346	1.381
	10–98	2.482	2.433	2.531	1.835	1.809	1.862
	99 plus	1.608	1.574	1.642	1.356	1.335	1.377
Years in cohort	1.035	1.034	1.037	1.025	1.024	1.026	
Constant	0.001	0.001	0.001	0.002	0.002	0.002	
Ln_r	4.564	4.510	4.618	4.035	3.997	4.073	
Ln_s	1.479	1.458	1.502	1.805	1.784	1.827	

D.4 Diabetes

Table D-10: Unlagged random effects model, cohort with / at risk of diabetes

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Regularity	0.908	0.904	0.912	0.922	0.919	0.925	
COC	0.936	0.931	0.940	0.921	0.918	0.925	
Era	1.085	1.059	1.111	1.061	1.043	1.079	
Regularity * Era	1.015	1.008	1.021	1.009	1.005	1.014	
COC * Era	1.018	1.011	1.024	1.019	1.014	1.023	
GP management plan	0.918	0.905	0.931	0.927	0.917	0.936	
GP management plan * Era	0.975	0.957	0.992	1.000	0.987	1.013	
Frequency	3–4	Reference		Reference			
	5–6	1.163	1.142	1.185	1.151	1.136	1.165
	7–9	1.464	1.439	1.490	1.417	1.400	1.434
	10–19	2.120	2.085	2.155	1.977	1.954	2.000
	20 plus	3.340	3.277	3.405	3.063	3.020	3.106
Specialist visits	0	Reference		Reference			
	1–2	1.023	1.011	1.035	1.028	1.019	1.036
	3–6	1.228	1.212	1.244	1.149	1.138	1.160
	7–9	1.652	1.621	1.685	1.380	1.359	1.402
	10 plus	2.845	2.797	2.895	1.925	1.897	1.954
Age	18–44	Reference		Reference			
	45–54	0.914	0.894	0.933	0.807	0.796	0.819
	55–64	0.849	0.831	0.867	0.679	0.669	0.690
	65–74	0.909	0.889	0.928	0.646	0.636	0.656
	75–84	1.301	1.273	1.330	0.802	0.789	0.816
	85 plus	2.348	2.286	2.412	1.291	1.263	1.319
Sex	Female	Reference		Reference			
	Male	1.106	1.093	1.120	1.061	1.050	1.071
	Non-indig.	Reference		Reference			

		Hospitalisations			ED presentations		
Variable		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Indigenous status	Indigenous	2.294	2.236	2.354	2.200	2.156	2.244
	Least disadv.	Reference			Reference		
	Low disadv.	1.074	1.055	1.094	1.135	1.119	1.151
	Mod disadv.	1.109	1.090	1.128	1.243	1.227	1.260
	High disadv.	1.111	1.092	1.130	1.304	1.287	1.321
	Highest disadv.	1.162	1.139	1.185	1.321	1.301	1.341
SEIFA	Missing	1.220	1.041	1.428	1.310	1.173	1.463
	Major cities	Reference			Reference		
	Inner regional	0.927	0.912	0.942	1.142	1.128	1.156
	Outer regional	1.124	1.101	1.147	1.578	1.554	1.601
	Remote	1.131	1.086	1.177	1.673	1.629	1.718
	Very remote	1.225	1.191	1.261	1.924	1.886	1.962
ARIA	Missing	0.949	0.808	1.114	1.058	0.946	1.185
	0	Reference			Reference		
	1–2	0.921	0.900	0.943	0.956	0.941	0.971
	3–4	0.902	0.884	0.920	0.959	0.947	0.972
	5–9	1.031	1.013	1.049	1.040	1.027	1.053
	10–98	1.542	1.511	1.574	1.369	1.348	1.389
MACSS	99 plus	1.259	1.233	1.285	1.151	1.134	1.167
HbA1c		0.928	0.910	0.947	0.906	0.892	0.921
Cycle of care		0.848	0.838	0.859	0.898	0.890	0.907
Two HbA1c <6 months		0.816	0.806	0.827	0.885	0.876	0.894
Diabetes hospitalisation		3.094	3.052	3.137	1.904	1.885	1.923
Glucose impairment admission		1.953	1.885	2.023	1.457	1.415	1.501
Constant		0.001	0.001	0.001	0.002	0.002	0.002
Ln_r		5.285	5.202	5.368	4.817	4.757	4.877
Ln_s		1.562	1.535	1.590	1.974	1.946	2.002

Table D-11: Lagged random effects model, cohort with / at risk of diabetes

		Hospitalisations			ED presentations		
Variable		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity		0.997	0.993	1.002	1.001	0.997	1.004
COC		0.975	0.970	0.980	0.957	0.953	0.960
Era		1.053	1.028	1.079	1.024	1.007	1.043
Regularity * Era		1.006	1.000	1.012	1.004	0.999	1.008
COC * Era		1.015	1.009	1.022	1.022	1.017	1.027
GP management plan		0.987	0.973	1.000	0.992	0.982	1.003

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
GP management plan * Era	1.010	0.993	1.028	1.029	1.015	1.043
3-4	Reference			Reference		
5-6	1.079	1.061	1.097	1.058	1.045	1.070
7-9	1.230	1.210	1.250	1.173	1.160	1.187
10-19	1.530	1.506	1.553	1.391	1.375	1.407
Frequency 20 plus	2.040	2.003	2.078	1.765	1.740	1.790
0	Reference			Reference		
1-2	0.947	0.937	0.957	0.969	0.961	0.977
3-6	0.997	0.984	1.010	0.993	0.984	1.003
Specialist visits 7-9	1.099	1.077	1.121	1.056	1.039	1.073
10 plus	1.356	1.332	1.382	1.184	1.165	1.203
18-44	Reference			Reference		
45-54	0.929	0.909	0.949	0.830	0.818	0.843
55-64	0.924	0.905	0.943	0.736	0.725	0.747
65-74	1.146	1.122	1.171	0.783	0.771	0.795
75-84	1.838	1.798	1.879	1.087	1.069	1.105
Age 85 plus	3.339	3.253	3.428	1.788	1.751	1.827
Female	Reference			Reference		
Sex Male	1.101	1.088	1.114	1.032	1.022	1.042
Non-indig.	Reference			Reference		
Indigenous status Indigenous	2.491	2.428	2.556	2.336	2.289	2.384
Least disadv.	Reference			Reference		
Low disadv.	1.089	1.071	1.109	1.128	1.112	1.144
Mod disadv.	1.130	1.111	1.148	1.247	1.231	1.264
High disadv.	1.150	1.131	1.169	1.294	1.277	1.311
Highest disadv.	1.190	1.167	1.213	1.328	1.307	1.348
SEIFA Missing	1.165	0.991	1.369	1.209	1.076	1.357
Major cities	Reference			Reference		
Inner regional	0.925	0.910	0.939	1.129	1.116	1.143
Outer regional	1.034	1.013	1.055	1.455	1.433	1.477
Remote	1.033	0.992	1.075	1.487	1.446	1.528
Very remote	1.121	1.090	1.153	1.669	1.636	1.704
ARIA Missing	0.931	0.790	1.096	1.056	0.939	1.189
0	Reference			Reference		
1-2	1.018	0.996	1.041	1.023	1.007	1.040
3-4	1.087	1.067	1.108	1.086	1.071	1.100
5-9	1.410	1.386	1.434	1.273	1.257	1.289
10-98	2.138	2.095	2.181	1.696	1.670	1.722
MACSS 99 plus	1.215	1.191	1.240	1.156	1.139	1.173

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
HbA1c	0.861	0.844	0.879	0.870	0.856	0.884
Cycle of care	0.955	0.944	0.967	0.966	0.956	0.975
Two HbA1c <6 months	1.004	0.992	1.017	0.998	0.988	1.008
Diabetes hospitalisation	1.515	1.496	1.535	1.313	1.300	1.327
Glucose impairment admission	1.229	1.185	1.274	1.160	1.126	1.196
Constant	0.001	0.001	0.001	0.001	0.001	0.002
Ln_r	4.499	4.433	4.566	4.044	3.995	4.093
Ln_s	1.574	1.545	1.604	1.892	1.864	1.920

Table D-12: Lagged hybrid model, cohort with / at risk of diabetes

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Regularity	1.031	1.025	1.036	1.029	1.025	1.033	
COC	1.010	1.003	1.017	1.006	1.002	1.011	
Era	0.961	0.930	0.993	0.916	0.894	0.938	
Regularity * Era	0.996	0.989	1.004	0.997	0.991	1.003	
COC * Era	1.009	1.000	1.018	1.010	1.003	1.017	
Mean regularity	0.922	0.914	0.929	0.933	0.927	0.939	
Mean reg * Era	1.032	1.021	1.043	1.022	1.014	1.030	
Mean COC	0.925	0.918	0.932	0.879	0.874	0.884	
Mean COC * Era	1.024	1.015	1.033	1.041	1.035	1.048	
GP management plan	0.983	0.969	0.996	0.987	0.976	0.997	
GP management plan * Era	1.012	0.969	1.030	1.033	0.976	1.047	
Frequency	3-4	Reference		Reference			
	5-6	1.085	1.067	1.104	1.065	1.052	1.078
	7-9	1.241	1.222	1.261	1.184	1.171	1.198
	10-19	1.555	1.532	1.579	1.415	1.399	1.431
	20 plus	2.085	2.047	2.124	1.803	1.777	1.829
Specialist visits	0	Reference		Reference			
	1-2	0.946	0.935	0.956	0.967	0.959	0.975
	3-6	0.994	0.981	1.007	0.989	0.980	0.999
	7-9	1.095	1.073	1.117	1.051	1.034	1.068
	10 plus	1.351	1.327	1.376	1.177	1.158	1.196
Age	18-44	Reference		Reference			
	45-54	0.951	0.931	0.972	0.855	0.842	0.868
	55-64	0.961	0.941	0.982	0.774	0.762	0.786
	65-74	1.208	1.183	1.235	0.837	0.824	0.850
	75-84	1.954	1.912	1.998	1.174	1.155	1.194
	85 plus	3.550	3.456	3.645	1.932	1.891	1.974
Sex	Female	Reference		Reference			
	Male	1.102	1.089	1.115	1.039	1.028	1.049

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Indigenous status	Non-indig.	Reference			Reference		
	Indigenous	2.390	2.329	2.452	2.206	2.161	2.252
	Least disadv.	Reference			Reference		
	Low disadv.	1.092	1.074	1.112	1.133	1.117	1.149
	Mod disadv.	1.133	1.114	1.151	1.254	1.237	1.271
	High disadv.	1.146	1.128	1.165	1.292	1.276	1.309
	Highest disadv.	1.190	1.168	1.214	1.330	1.309	1.350
SEIFA	Missing	1.153	0.981	1.355	1.203	1.072	1.350
ARIA	Major cities	Reference			Reference		
	Inner regional	0.914	0.900	0.929	1.114	1.101	1.127
	Outer regional	1.018	0.997	1.039	1.427	1.405	1.448
	Remote	1.013	0.973	1.054	1.451	1.411	1.491
	Very remote	1.075	1.045	1.106	1.588	1.556	1.621
	Missing	0.933	0.792	1.098	1.052	0.935	1.184
MACSS conditions	0	Reference			Reference		
	1–2	1.015	0.992	1.038	1.019	1.003	1.036
	3–4	1.082	1.062	1.103	1.080	1.066	1.095
	5–9	1.400	1.377	1.424	1.265	1.249	1.280
	10–98	2.119	2.076	2.162	1.683	1.657	1.709
	99 plus	1.201	1.177	1.226	1.143	1.127	1.160
HbA1c	0.861	0.843	0.879	0.871	0.857	0.885	
Cycle of care	0.956	0.945	0.968	0.967	0.958	0.976	
Two HbA1c <6 months	1.014	1.001	1.026	1.009	0.999	1.019	
Diabetes hospitalisation	1.521	1.502	1.541	1.320	1.307	1.334	
Glucose impairment admission	0.001	0.001	0.001	0.002	0.002	0.002	
Constant	4.530	4.463	4.598	4.111	4.061	4.161	
Ln_r	1.585	1.555	1.614	1.933	1.904	1.962	
Ln_s	1.000	1.000	1.000	1.000	1.000	1.000	

D.5 Digestive

Table D-13: Unlagged random effects model, cohort with past hospitalisation for digestive diseases

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity		0.912	0.909	0.915	0.931	0.929	0.933

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
COC	0.958	0.955	0.961	0.940	0.938	0.942	
Era	0.958	0.944	0.972	1.016	1.006	1.026	
Regularity * Era	1.017	1.012	1.021	1.007	1.004	1.010	
COC * Era	1.022	1.018	1.026	1.015	1.012	1.018	
GP management plan	1.039	1.028	1.051	0.990	0.982	0.999	
GP management plan * Era	0.995	0.981	1.008	1.015	1.005	1.025	
Frequency	3–4	Reference		Reference			
	5–6	1.280	1.266	1.294	1.227	1.219	1.236
	7–9	1.665	1.648	1.683	1.541	1.531	1.551
	10–19	2.473	2.449	2.498	2.180	2.166	2.194
	20 plus	3.881	3.835	3.929	3.356	3.327	3.384
Specialist visits	0	Reference		Reference			
	1–2	1.100	1.092	1.108	1.066	1.061	1.071
	3–6	1.404	1.392	1.416	1.228	1.221	1.235
	7–9	2.005	1.980	2.031	1.511	1.497	1.526
	10 plus	3.552	3.511	3.593	2.103	2.083	2.123
Age	18–44	Reference		Reference			
	45–54	0.930	0.920	0.941	0.773	0.767	0.778
	55–64	0.876	0.867	0.886	0.659	0.654	0.664
	65–74	0.944	0.934	0.955	0.629	0.624	0.634
	75–84	1.408	1.391	1.425	0.809	0.801	0.816
	85 plus	2.722	2.679	2.765	1.364	1.347	1.382
Sex	Female	Reference		Reference			
	Male	1.214	1.204	1.223	1.164	1.158	1.171
Indigenous status	Non-indig.	Reference		Reference			
	Indigenous	3.304	3.236	3.374	2.709	2.667	2.753
SEIFA	Least disadv.	Reference		Reference			
	Low disadv.	1.109	1.098	1.121	1.174	1.165	1.183
	Mod disadv.	1.183	1.171	1.195	1.336	1.326	1.346
	High disadv.	1.227	1.215	1.240	1.446	1.435	1.456
	Highest disadv.	1.306	1.289	1.323	1.474	1.460	1.487
	Missing	1.353	1.214	1.509	1.327	1.236	1.424
ARIA	Major cities	Reference		Reference			
	Inner regional	0.960	0.950	0.970	1.223	1.215	1.232
	Outer regional	1.175	1.160	1.191	1.698	1.683	1.713
	Remote	1.230	1.197	1.264	1.815	1.784	1.845
	Very remote	1.360	1.333	1.387	2.279	2.251	2.307
	Missing	0.857	0.767	0.957	1.055	0.982	1.133
MACSS	0	Reference		Reference			

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
1-2	0.976	0.961	0.991	0.985	0.976	0.994
3-4	1.126	1.110	1.141	1.075	1.066	1.084
5-9	1.503	1.484	1.523	1.247	1.237	1.258
10-98	2.391	2.354	2.429	1.674	1.656	1.692
99 plus	1.528	1.503	1.554	1.264	1.251	1.277
Years in cohort	1.012	1.011	1.013	1.007	1.006	1.007
Constant	0.001	0.001	0.001	0.001	0.001	0.001
Ln_r	5.597	5.542	5.652	4.981	4.946	5.017
Ln_s	1.325	1.310	1.340	1.698	1.684	1.712

Table D-14: Lagged random effects model, cohort with past hospitalisation for digestive diseases

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Regularity	1.004	1.001	1.007	1.006	1.003	1.008	
COC	0.991	0.988	0.994	0.968	0.966	0.970	
Era	0.903	0.889	0.917	0.954	0.944	0.963	
Regularity * Era	1.009	1.005	1.013	1.005	1.002	1.008	
COC * Era	1.018	1.014	1.022	1.019	1.016	1.022	
GP management plan	1.089	1.077	1.101	1.056	1.047	1.065	
GP management plan * Era	1.029	1.016	1.043	1.035	1.025	1.045	
Frequency	3-4	Reference		Reference			
	5-6	1.174	1.162	1.186	1.120	1.113	1.127
	7-9	1.372	1.358	1.385	1.261	1.252	1.269
	10-19	1.772	1.756	1.789	1.513	1.503	1.523
	20 plus	2.340	2.312	2.369	1.890	1.873	1.907
Specialist visits	0	Reference		Reference			
	1-2	0.966	0.959	0.973	0.972	0.967	0.977
	3-6	1.029	1.021	1.038	1.001	0.995	1.007
	7-9	1.162	1.146	1.177	1.076	1.064	1.087
	10 plus	1.450	1.432	1.468	1.210	1.197	1.223
Age	18-44	Reference		Reference			
	45-54	0.983	0.972	0.994	0.817	0.811	0.824
	55-64	1.011	1.000	1.022	0.743	0.737	0.749
	65-74	1.285	1.271	1.300	0.810	0.803	0.816
	75-84	2.164	2.138	2.190	1.172	1.161	1.183
	85 plus	4.113	4.050	4.177	1.990	1.964	2.015
Sex	Female	Reference		Reference			
	Male	1.155	1.146	1.164	1.085	1.078	1.091
Indigenous status	Non-indig.	Reference		Reference			
	Indigenous	3.256	3.189	3.325	2.739	2.695	2.784

		Hospitalisations			ED presentations		
Variable		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
SEIFA	Least disadv.	Reference			Reference		
	Low disadv.	1.128	1.116	1.140	1.167	1.157	1.176
	Mod disadv.	1.191	1.179	1.203	1.328	1.318	1.338
	High disadv.	1.252	1.240	1.265	1.421	1.410	1.432
	Highest disadv.	1.310	1.293	1.327	1.469	1.455	1.483
	Missing	1.244	1.114	1.391	1.284	1.194	1.380
ARIA	Major cities	Reference			Reference		
	Inner regional	0.943	0.933	0.952	1.201	1.193	1.210
	Outer regional	1.050	1.036	1.064	1.532	1.518	1.546
	Remote	1.073	1.043	1.103	1.590	1.563	1.619
	Very remote	1.219	1.194	1.244	1.935	1.910	1.960
	Missing	0.891	0.796	0.997	1.031	0.958	1.110
MACSS	0	Reference			Reference		
	1–2	1.004	0.988	1.019	1.002	0.992	1.011
	3–4	1.186	1.170	1.203	1.125	1.116	1.135
	5–9	1.680	1.658	1.702	1.362	1.350	1.374
	10–98	2.613	2.573	2.654	1.821	1.801	1.841
	99 plus	1.633	1.606	1.660	1.343	1.328	1.357
Years in cohort	1.022	1.021	1.023	1.013	1.012	1.013	
Constant	0.000	0.000	0.000	0.001	0.001	0.001	
Ln_r	4.844	4.798	4.890	4.284	4.254	4.314	
Ln_s	1.327	1.311	1.343	1.608	1.595	1.622	

Table D-15: Lagged hybrid model, cohort with past hospitalisation for digestive diseases

		Hospitalisations			ED presentations		
Variable		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity		1.033	1.029	1.037	1.028	1.025	1.030
COC		1.017	1.012	1.021	1.009	1.006	1.013
Era		0.832	0.815	0.849	0.888	0.876	0.900
Regularity * Era		0.999	0.994	1.004	1.000	0.997	1.004
COC * Era		1.003	0.997	1.008	1.004	1.000	1.008
Mean regularity		0.943	0.938	0.948	0.956	0.952	0.960
Mean reg * Era		1.026	1.019	1.033	1.013	1.008	1.017
Mean COC		0.962	0.958	0.967	0.910	0.906	0.913
Mean COC * Era		1.032	1.027	1.038	1.036	1.032	1.040
GP management plan		1.092	1.080	1.104	1.058	1.049	1.067
GP management plan * Era		1.026	1.080	1.039	1.033	1.049	1.043

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Frequency	3–4	Reference		Reference			
	5–6	1.180	1.168	1.192	1.126	1.119	1.133
	7–9	1.385	1.371	1.398	1.272	1.264	1.280
	10–19	1.801	1.783	1.818	1.537	1.527	1.547
	20 plus	2.392	2.364	2.421	1.931	1.914	1.948
	Specialist visits	0	Reference		Reference		
1–2		0.965	0.959	0.972	0.971	0.967	0.976
3–6		1.029	1.020	1.037	1.000	0.994	1.006
7–9		1.162	1.146	1.177	1.075	1.064	1.086
10 plus		1.450	1.432	1.469	1.210	1.197	1.223
Age		18–44	Reference		Reference		
	45–54	1.000	0.988	1.011	0.840	0.834	0.846
	55–64	1.040	1.029	1.052	0.778	0.772	0.784
	65–74	1.335	1.320	1.351	0.860	0.853	0.868
	75–84	2.262	2.234	2.291	1.259	1.247	1.271
	85 plus	4.293	4.226	4.361	2.138	2.110	2.166
	Sex	Female	Reference		Reference		
Male		1.154	1.145	1.163	1.091	1.085	1.098
Indigenous status	Non-indig.	Reference		Reference			
	Indigenous	3.201	3.134	3.269	2.662	2.619	2.705
SEIFA	Least disadv.	Reference		Reference			
	Low disadv.	1.130	1.118	1.142	1.171	1.161	1.180
	Mod disadv.	1.194	1.182	1.206	1.334	1.324	1.344
	High disadv.	1.250	1.238	1.263	1.422	1.411	1.433
	Highest disadv.	1.312	1.295	1.329	1.474	1.461	1.488
	Missing	1.246	1.115	1.392	1.286	1.196	1.383
	ARIA	Major cities	Reference		Reference		
Inner regional		0.938	0.928	0.947	1.191	1.183	1.200
Outer regional		1.044	1.031	1.059	1.520	1.506	1.534
Remote		1.066	1.037	1.096	1.577	1.550	1.605
Very remote		1.199	1.175	1.224	1.890	1.866	1.915
Missing		0.888	0.794	0.994	1.029	0.956	1.107
MACSS conditions		0	Reference		Reference		
	1–2	1.004	0.988	1.019	1.001	0.991	1.011
	3–4	1.188	1.172	1.204	1.127	1.118	1.137
	5–9	1.685	1.663	1.707	1.368	1.356	1.380
	10–98	2.624	2.583	2.664	1.833	1.813	1.853
	99 plus	1.635	1.608	1.662	1.344	1.330	1.359

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Years in cohort	1.022	1.021	1.023	1.012	1.012	1.013
Constant	0.000	0.000	0.001	0.001	0.001	0.001
Ln_r	4.865	4.819	4.911	4.329	4.299	4.360
Ln_s	1.332	1.316	1.348	1.631	1.617	1.645

D.6 Genitourinary

Table D-16: Unlagged random effects model, cohort with past hospitalisation for genitourinary diseases

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Regularity	0.920	0.917	0.924	0.936	0.933	0.938	
COC	0.955	0.951	0.959	0.937	0.935	0.940	
Era	0.970	0.952	0.988	1.007	0.995	1.020	
Regularity * Era	1.017	1.012	1.022	1.008	1.005	1.012	
COC * Era	1.021	1.016	1.026	1.019	1.015	1.023	
GP management plan	1.032	1.018	1.047	0.988	0.978	0.998	
GP management plan * Era	0.998	0.982	1.014	1.015	1.003	1.028	
Frequency	3–4	Reference		Reference			
	5–6	1.225	1.208	1.241	1.207	1.197	1.217
	7–9	1.561	1.541	1.581	1.500	1.488	1.513
	10–19	2.259	2.231	2.287	2.091	2.074	2.108
	20 plus	3.501	3.450	3.553	3.155	3.122	3.188
Specialist visits	0	Reference		Reference			
	1–2	1.047	1.037	1.057	1.041	1.034	1.047
	3–6	1.270	1.256	1.283	1.170	1.162	1.179
	7–9	1.739	1.712	1.767	1.410	1.392	1.427
	10 plus	3.041	2.998	3.084	1.952	1.930	1.975
Age	18–44	Reference		Reference			
	45–54	0.857	0.845	0.869	0.748	0.742	0.755
	55–64	0.855	0.843	0.868	0.656	0.649	0.662
	65–74	0.973	0.959	0.988	0.650	0.643	0.657
	75–84	1.464	1.442	1.487	0.849	0.839	0.859
	85 plus	2.768	2.717	2.820	1.430	1.408	1.452
Sex	Female	Reference		Reference			
	Male	1.326	1.312	1.341	1.233	1.223	1.243
Indigenous status	Non-indig.	Reference		Reference			
	Indigenous	3.168	3.096	3.243	2.684	2.636	2.733
SEIFA	Least disadv. Low disadv.	Reference		Reference			
		1.110	1.095	1.125	1.170	1.158	1.182

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
	Mod disadv.	1.176	1.161	1.191	1.319	1.306	1.331
	High disadv.	1.204	1.189	1.220	1.413	1.400	1.427
	Highest disadv.	1.282	1.261	1.302	1.439	1.422	1.455
	Missing	1.281	1.120	1.465	1.275	1.167	1.393
ARIA	Major cities	Reference			Reference		
	Inner regional	0.937	0.925	0.949	1.172	1.161	1.182
	Outer regional	1.132	1.114	1.151	1.614	1.596	1.633
	Remote	1.188	1.149	1.229	1.720	1.683	1.757
	Very remote	1.279	1.249	1.310	2.104	2.072	2.137
	Missing	0.895	0.782	1.026	1.088	0.994	1.190
MACSS	0	Reference			Reference		
	1–2	0.980	0.960	1.001	0.984	0.971	0.997
	3–4	1.113	1.093	1.134	1.058	1.047	1.070
	5–9	1.542	1.516	1.570	1.248	1.234	1.261
	10–98	2.470	2.422	2.520	1.672	1.650	1.694
	99 plus	1.728	1.692	1.764	1.330	1.312	1.348
Years in cohort	1.013	1.012	1.014	1.007	1.006	1.008	
Constant	0.001	0.001	0.001	0.001	0.001	0.002	
Ln_r	5.045	4.985	5.106	4.535	4.494	4.576	
Ln_s	1.362	1.343	1.382	1.711	1.693	1.729	

Table D-17: Lagged random effects model, cohort with past hospitalisation for genitourinary diseases

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity		1.004	1.000	1.008	1.006	1.003	1.009
COC		0.989	0.986	0.993	0.968	0.966	0.971
Era		0.923	0.906	0.940	0.963	0.950	0.975
Regularity * Era		1.008	1.003	1.013	1.004	1.001	1.008
COC * Era		1.020	1.015	1.025	1.020	1.017	1.024
GP management plan		1.083	1.069	1.098	1.050	1.039	1.061
GP management plan * Era		1.033	1.017	1.049	1.040	1.028	1.053
Frequency	3–4	Reference			Reference		
	5–6	1.149	1.135	1.164	1.116	1.107	1.126
	7–9	1.332	1.316	1.349	1.246	1.236	1.256
	10–19	1.698	1.678	1.718	1.486	1.474	1.499
	20 plus	2.244	2.211	2.277	1.852	1.832	1.873
Specialist visits	0	Reference			Reference		
	1–2	0.953	0.945	0.962	0.961	0.956	0.967

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
	3–6	0.999	0.989	1.009	0.981	0.974	0.988
	7–9	1.129	1.111	1.147	1.062	1.048	1.076
	10 plus	1.383	1.362	1.404	1.179	1.164	1.194
Age	18–44	Reference			Reference		
	45–54	0.894	0.881	0.906	0.782	0.774	0.789
	55–64	0.956	0.943	0.970	0.726	0.719	0.734
	65–74	1.261	1.243	1.279	0.814	0.805	0.823
	75–84	2.102	2.071	2.134	1.177	1.163	1.191
	85 plus	3.900	3.829	3.972	1.992	1.962	2.022
	Sex	Female	Reference			Reference	
Male		1.324	1.310	1.338	1.201	1.191	1.212
Indigenous status	Non-indig.	Reference			Reference		
	Indigenous	3.169	3.096	3.244	2.736	2.686	2.786
SEIFA	Least disadv.	Reference			Reference		
	Low disadv.	1.117	1.102	1.132	1.158	1.146	1.170
	Mod disadv.	1.178	1.163	1.193	1.193	1.295	1.321
	High disadv.	1.230	1.214	1.245	1.386	1.373	1.400
	Highest disadv.	1.289	1.269	1.310	1.428	1.411	1.445
	Missing	1.236	1.079	1.416	1.206	1.101	1.323
ARIA	Major cities	Reference			Reference		
	Inner regional	0.926	0.915	0.938	1.153	1.143	1.164
	Outer regional	1.022	1.005	1.039	1.469	1.451	1.486
	Remote	1.031	0.996	1.066	1.515	1.482	1.549
	Very remote	1.154	1.127	1.182	1.794	1.766	1.823
	Missing	0.897	0.781	1.030	1.088	0.991	1.195
MACSS	0	Reference			Reference		
	1–2	1.012	0.991	1.034	0.998	0.984	1.011
	3–4	1.160	1.139	1.181	1.100	1.088	1.113
	5–9	1.693	1.664	1.722	1.350	1.335	1.366
	10–98	2.666	2.614	2.718	1.809	1.785	1.834
	99 plus	1.799	1.762	1.837	1.391	1.371	1.410
Years in cohort	1.019	1.018	1.020	1.011	1.010	1.012	
Constant	0.000	0.000	0.000	0.001	0.001	0.001	
Ln_r	4.569	4.517	4.623	4.031	3.996	4.067	
Ln_s	1.368	1.349	1.389	1.634	1.617	1.652	

Table D-18: Lagged hybrid model, cohort with past hospitalisation for genitourinary diseases

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Regularity	1.031	1.027	1.036	1.027	1.023	1.030	
COC	1.016	1.011	1.022	1.010	1.007	1.014	
Era	0.845	0.824	0.867	0.887	0.872	0.903	
Regularity * Era	0.997	0.991	1.003	0.998	0.994	1.003	
COC * Era	1.003	0.995	1.010	1.003	0.997	1.008	
Mean regularity	0.948	0.941	0.954	0.959	0.954	0.964	
Mean reg * Era	1.028	1.019	1.037	1.013	1.007	1.020	
Mean COC	0.959	0.953	0.965	0.908	0.903	0.912	
Mean COC * Era	1.035	1.028	1.043	1.040	1.035	1.046	
GP management plan	1.086	1.072	1.101	1.052	1.041	1.063	
GP management plan * Era	1.028	1.072	1.045	1.037	1.041	1.050	
Frequency	3–4	Reference		Reference			
	5–6	1.154	1.140	1.169	1.122	1.112	1.131
	7–9	1.343	1.326	1.359	1.256	1.245	1.266
	10–19	1.721	1.701	1.741	1.507	1.495	1.520
	20 plus	2.286	2.253	2.320	1.887	1.866	1.907
Specialist visits	0	Reference		Reference			
	1–2	0.953	0.945	0.962	0.960	0.954	0.966
	3–6	0.999	0.988	1.009	0.979	0.972	0.987
	7–9	1.129	1.110	1.147	1.061	1.047	1.075
	10 plus	1.383	1.363	1.404	1.178	1.163	1.194
Age	18–44	Reference		Reference			
	45–54	0.908	0.895	0.920	0.801	0.793	0.808
	55–64	0.983	0.969	0.997	0.758	0.750	0.766
	65–74	1.1Robins	1.289	1.328	0.864	0.854	0.873
	75–84	2.194	2.160	2.228	1.261	1.246	1.276
	85 plus	4.064	3.989	4.141	2.136	2.103	2.169
Sex	Female	Reference		Reference			
	Male	1.324	1.311	1.338	1.211	1.201	1.221
Indigenous status	Non-indig.	Reference		Reference			
	Indigenous	3.118	3.046	3.192	2.657	2.609	2.706
SEIFA	Least disadv.	Reference		Reference			
	Low disadv.	1.119	1.104	1.134	1.162	1.150	1.174
	Mod disadv.	1.180	1.166	1.196	1.314	1.301	1.327
	High disadv.	1.229	1.213	1.244	1.388	1.375	1.401
	Highest disadv.	1.291	1.270	1.311	1.432	1.415	1.449
Missing	1.237	1.079	1.417	1.210	1.103	1.326	
ARIA	Major cities	Reference		Reference			

		Hospitalisations			ED presentations		
Variable		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
	Inner regional	0.921	0.910	0.933	1.144	1.134	1.155
	Outer regional	1.017	1.000	1.034	1.456	1.439	1.473
	Remote	1.024	0.990	1.060	1.503	1.470	1.537
	Very remote	1.136	1.108	1.163	1.751	1.723	1.779
	Missing	0.894	0.779	1.026	1.083	0.987	1.189
	0	Reference			Reference		
	1–2	1.013	0.992	1.034	0.998	0.985	1.011
	3–4	1.161	1.140	1.182	1.101	1.089	1.114
	5–9	1.698	1.668	1.727	1.355	1.340	1.370
MACSS conditions	10–98	2.676	2.624	2.729	1.820	1.796	1.845
	99 plus	1.802	1.765	1.840	1.393	1.373	1.412
Years in cohort		1.019	1.017	1.020	1.011	1.010	1.012
Constant		0.001	0.001	0.001	0.002	0.002	0.002
Ln_r		4.586	4.533	4.639	4.071	4.035	4.107
Ln_s		1.373	1.353	1.393	1.655	1.637	1.673

D.7 Respiratory

Table D-19: Unlagged random effects model, cohort with past hospitalisation for respiratory disease

		Hospitalisations			ED presentations		
Variable		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity		0.908	0.906	0.910	0.930	0.929	0.931
COC		0.958	0.955	0.960	0.938	0.936	0.939
Era		0.919	0.909	0.930	0.981	0.974	0.988
Regularity * Era		1.015	1.012	1.019	1.006	1.004	1.009
COC * Era		1.023	1.019	1.026	1.015	1.013	1.017
GP management plan		1.032	1.023	1.042	0.977	0.970	0.983
GP management plan * Era		0.993	0.982	1.003	1.015	1.007	1.022
	3–4	Reference			Reference		
	5–6	1.294	1.284	1.304	1.228	1.223	1.234
	7–9	1.689	1.676	1.702	1.537	1.530	1.544
	10–19	2.501	2.482	2.519	2.153	2.143	2.163
Frequency	20 plus	3.912	3.875	3.949	3.289	3.268	3.311
	0	Reference			Reference		
	1–2	1.119	1.112	1.125	1.072	1.068	1.076
	3–6	1.433	1.424	1.443	1.236	1.231	1.242
Specialist visits	7–9	2.053	2.031	2.075	1.523	1.511	1.536
	10 plus	3.636	3.602	3.672	2.113	2.096	2.130
Age	18–44	Reference			Reference		

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
	45–54	0.898	0.891	0.905	0.747	0.743	0.751
	55–64	0.867	0.859	0.874	0.638	0.634	0.642
	65–74	0.939	0.930	0.947	0.609	0.605	0.613
	75–84	1.399	1.386	1.413	0.781	0.775	0.786
	85 plus	2.735	2.700	2.770	1.331	1.317	1.345
Sex	Female	Reference			Reference		
	Male	1.282	1.275	1.290	1.250	1.245	1.256
Indigenous status	Non-indig.	Reference			Reference		
	Indigenous	2.946	2.903	2.989	2.494	2.468	2.521
SEIFA	Least disadv.	Reference			Reference		
	Low disadv.	1.100	1.090	1.109	1.158	1.152	1.165
	Mod disadv.	1.167	1.158	1.176	1.316	1.309	1.323
	High disadv.	1.203	1.194	1.213	1.413	1.406	1.421
	Highest disadv.	1.276	1.263	1.289	1.431	1.422	1.441
	Missing	1.271	1.173	1.377	1.294	1.232	1.359
ARIA	Major cities	Reference			Reference		
	Inner regional	0.968	0.960	0.975	1.228	1.222	1.235
	Outer regional	1.179	1.167	1.191	1.734	1.723	1.746
	Remote	1.229	1.204	1.254	1.824	1.802	1.846
	Very remote	1.334	1.315	1.353	2.305	2.286	2.325
	Missing	0.902	0.831	0.979	1.072	1.019	1.127
MACSS	0	Reference			Reference		
	1–2	1.008	0.998	1.018	1.005	0.999	1.011
	3–4	1.165	1.155	1.176	1.087	1.081	1.093
	5–9	1.513	1.500	1.527	1.231	1.224	1.237
	10–98	2.305	2.279	2.332	1.614	1.601	1.627
	99 plus	1.396	1.379	1.414	1.198	1.188	1.207
Years in cohort	1.020	1.019	1.021	1.012	1.012	1.013	
Constant	0.001	0.001	0.001	0.001	0.001	0.001	
Ln_r	6.227	6.177	6.277	5.244	5.215	5.273	
Ln_s	1.357	1.344	1.369	1.764	1.753	1.775	

Table D-20: lagged random effects model, cohort with past hospitalisation for respiratory disease

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Regularity		1.000	0.998	1.003	1.003	1.001	1.005
COC		0.987	0.985	0.990	0.965	0.963	0.967

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Era	0.851	0.841	0.861	0.905	0.898	0.912	
Regularity * Era	1.008	1.005	1.011	1.005	1.003	1.007	
COC * Era	1.020	1.016	1.023	1.020	1.018	1.023	
GP management plan	1.082	1.073	1.092	1.042	1.035	1.049	
GP management plan * Era	1.030	1.019	1.041	1.038	1.030	1.046	
Frequency	3-4	Reference		Reference			
	5-6	1.172	1.164	1.181	1.112	1.107	1.118
	7-9	1.368	1.358	1.378	1.241	1.236	1.247
	10-19	1.748	1.735	1.760	1.470	1.463	1.478
	20 plus	2.292	2.270	2.315	1.821	1.808	1.833
Specialist visits	0	Reference		Reference			
	1-2	0.969	0.964	0.975	0.973	0.969	0.976
	3-6	1.030	1.023	1.037	0.999	0.994	1.004
	7-9	1.164	1.151	1.177	1.077	1.067	1.086
	10 plus	1.457	1.442	1.473	1.216	1.205	1.227
Age	18-44	Reference		Reference			
	45-54	0.961	0.953	0.969	0.793	0.789	0.798
	55-64	1.023	1.014	1.031	0.728	0.724	0.732
	65-74	1.323	1.311	1.335	0.799	0.794	0.804
	75-84	2.247	2.226	2.269	1.161	1.153	1.170
	85 plus	4.350	4.296	4.404	2.012	1.991	2.033
Sex	Female	Reference		Reference			
	Male	1.207	1.200	1.215	1.155	1.150	1.160
Indigenous status	Non-indig.	Reference		Reference			
	Indigenous	2.901	2.858	2.945	2.534	2.506	2.562
SEIFA	Least disadv.	Reference		Reference			
	Low disadv.	1.116	1.106	1.125	1.151	1.144	1.158
	Mod disadv.	1.176	1.167	1.186	1.311	1.304	1.319
	High disadv.	1.228	1.219	1.238	1.391	1.383	1.399
	Highest disadv.	1.291	1.279	1.304	1.426	1.416	1.436
	Missing	1.170	1.077	1.272	1.236	1.174	1.302
ARIA	Major cities	Reference		Reference			
	Inner regional	0.946	0.939	0.953	1.198	1.192	1.204
	Outer regional	1.045	1.034	1.056	1.552	1.541	1.562
	Remote	1.061	1.038	1.083	1.584	1.564	1.604
	Very remote	1.185	1.168	1.203	1.930	1.913	1.948
	Missing	0.940	0.864	1.023	1.065	1.011	1.123
MACSS	0	Reference		Reference			
	1-2	1.042	1.031	1.053	1.024	1.017	1.030

Variable	Hospitalisations			ED presentations		
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
3-4	1.243	1.232	1.254	1.142	1.136	1.149
5-9	1.700	1.685	1.716	1.346	1.338	1.354
10-98	2.493	2.464	2.522	1.733	1.718	1.747
99 plus	1.502	1.483	1.521	1.263	1.253	1.274
Years in cohort	1.032	1.032	1.033	1.020	1.019	1.021
Constant	0.000	0.000	0.000	0.001	0.001	0.001
Ln_r	5.180	5.141	5.220	4.424	4.400	4.448
Ln_s	1.321	1.309	1.334	1.620	1.610	1.631

Table D-21: Lagged hybrid model, cohort with past hospitalisation for respiratory disease

Variable	Hospitalisations			ED presentations			
	Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI	
Regularity	1.030	1.027	1.033	1.024	1.022	1.025	
COC	1.014	1.011	1.018	1.008	1.006	1.010	
Era	0.780	0.768	0.793	0.836	0.827	0.844	
Regularity * Era	0.999	0.995	1.003	1.000	0.997	1.003	
COC * Era	1.003	0.998	1.007	1.005	1.002	1.008	
Mean regularity	0.940	0.936	0.944	0.957	0.955	0.960	
Mean reg * Era	1.027	1.021	1.032	1.014	1.010	1.018	
Mean COC	0.956	0.952	0.959	0.902	0.900	0.904	
Mean COC * Era	1.035	1.031	1.040	1.040	1.037	1.043	
GP management plan	1.086	1.076	1.095	1.045	1.038	1.052	
GP management plan * Era	1.025	1.076	1.036	1.034	1.038	1.042	
Frequency	3-4	Reference		Reference			
	5-6	1.179	1.170	1.188	1.118	1.113	1.123
	7-9	1.381	1.371	1.391	1.252	1.246	1.258
	10-19	1.776	1.764	1.789	1.493	1.485	1.500
	20 plus	2.345	2.322	2.367	1.858	1.845	1.871
Specialist visits	0	Reference		Reference			
	1-2	0.969	0.964	0.975	0.971	0.968	0.975
	3-6	1.030	1.023	1.037	0.998	0.993	1.003
	7-9	1.164	1.151	1.177	1.076	1.066	1.085
	10 plus	1.458	1.442	1.474	1.216	1.205	1.227
Age	18-44	Reference		Reference			
	45-54	0.979	0.971	0.987	0.816	0.811	0.820
	55-64	1.055	1.046	1.064	0.764	0.759	0.768
	65-74	1.380	1.367	1.392	0.853	0.847	0.858
	75-84	2.360	2.337	2.384	1.253	1.244	1.262
	85 plus	4.560	4.503	4.619	2.173	2.150	2.196
Sex	Female	Reference		Reference			
	Male	1.206	1.199	1.213	1.162	1.157	1.168
	Non-indig.	Reference		Reference			

Variable		Hospitalisations			ED presentations		
		Coefficient	Lower CI	Upper CI	Coefficient	Lower CI	Upper CI
Indigenous status	Indigenous	2.853	2.811	2.896	2.463	2.436	2.491
	Least disadv.	Reference			Reference		
	Low disadv.	1.117	1.108	1.127	1.155	1.148	1.162
	Mod disadv.	1.179	1.170	1.188	1.318	1.310	1.325
	High disadv.	1.227	1.217	1.237	1.393	1.386	1.401
	Highest disadv.	1.293	1.280	1.306	1.432	1.422	1.441
SEIFA	Missing	1.170	1.077	1.271	1.239	1.177	1.305
	Major cities	Reference			Reference		
	Inner regional	0.941	0.934	0.949	1.189	1.183	1.195
	Outer regional	1.041	1.030	1.051	1.542	1.531	1.552
	Remote	1.054	1.032	1.077	1.574	1.554	1.594
	Very remote	1.167	1.149	1.184	1.888	1.871	1.906
ARIA	Missing	0.939	0.863	1.021	1.063	1.009	1.120
	0	Reference			Reference		
	1–2	1.042	1.032	1.053	1.023	1.017	1.030
	3–4	1.245	1.234	1.256	1.144	1.138	1.151
	5–9	1.706	1.691	1.722	1.352	1.344	1.360
MACSS conditions	10–98	2.502	2.473	2.531	1.742	1.728	1.757
	99 plus	1.501	1.482	1.520	1.262	1.252	1.273
Years in cohort		1.032	1.031	1.033	1.020	1.019	1.020
Constant		0.000	0.000	0.000	0.001	0.001	0.001
Ln_r		5.204	5.164	5.244	4.471	4.447	4.495
Ln_s		1.326	1.314	1.339	1.643	1.632	1.654

Appendix E Additional output from Chapter 8 (manuscript 4)

E.1 Steps to select cohort with type 2 diabetes

The cohort was selected based on two sources: a file recording diagnoses, and prescription data which included the variable “reason for prescription”. This procedure was developed to accurately and efficiently select the T2DM cohort from these sources, where manual checking of all records was impractical due to the large numbers of records.

Step 1: Random sample of 100,000 diagnosis records selected from 6.6 million records in diagnosis file

Step 2: All records containing the letters “diab” or “dm” flagged in the random sample of diagnosis data

Record	Diagnosis
Record 1	Peripheral vascular disease
Record 2	Diabetes
Record 3	Hypertension
Record 4	Pain
Record 5	Diabetes mellitus – Type II
Record 6	Cellulitis
Record 7	Diabetes Mellitus, Type 2
Record 8	NIDDM
Record 9	Wound care
...	
Record 100,000	Diabetes Mellitus – Type 1

Step 3: Manual flagging of which of these records indicate T2DM

Record	Diagnosis	T2DM flag
Record 2	Diabetes	✘
Record 5	Diabetes Mellitus – Type II	✓
Record 7	Diabetes Mellitus, Type 2	✓
Record 8	NIDDM	✓
...		
Record 100,000	Diabetes Mellitus – Type 1	✘

Step 4: All text strings flagged in step 3 are searched across all 6.6 million diagnosis records and “reason for prescription” field in 22 million prescription records. Where a record matches one of these strings, the individual enters the cohort as of the diagnosis / prescription date.

Person ID	Diagnosis	Diagnosis date
1	Anxiety	01/05/2009
1	Hypertension	15/12/2011
1	Dermatitis	09/09/2015
2	Insomnia	22/06/2006
2	NIDDM	05/05/2012
3	Diabetes Mellitus – Type 2	15/08/2011
...		
640,293	GORD	30/07/2006
640,293	Diabetes Mellitus – Type 2	09/12/2012
640,293	Arthritis	10/01/2014
640,293	High cholesterol	19/02/2015

Step 5: Steps 1-4 repeated with different random sample of 100,000 records

E.2 Full outputs of regression models

Table E-1: Results of multilevel logistic regression with HbA1c underuse as outcome variable, n=22,752.

Variable		OR	SE	p	Lower CI	Upper CI
Regularity	Least regular	Reference				
	2	0.81	0.04	<0.001	0.74	0.89
	3	0.75	0.04	<0.001	0.68	0.82
	4	0.80	0.04	<0.001	0.73	0.88
	Most regular	0.74	0.04	<0.001	0.67	0.81
Practice – specific UPC ¹	0–0.39	Reference				
	0.4–0.59	1.00	0.04	0.909	0.91	1.08
	0.6–0.99	1.06	0.06	0.285	0.95	1.18
	1	1.24	0.13	0.036	1.01	1.52
Frequency	3–4	Reference				
	5–9	0.76	0.03	<0.001	0.70	0.81
	10–14	0.68	0.03	<0.001	0.61	0.74
	15 plus	0.64	0.03	<0.001	0.57	0.71
CDM ² in exp period		0.53	0.02	<0.001	0.49	0.56
RxRisk condition	0	0.91	0.08	0.301	0.76	1.09
	1–2	0.80	0.04	<0.001	0.73	0.89
	3–4	0.91	0.04	0.024	0.84	0.99
	5–6	0.92	0.04	0.035	0.85	0.99
	7 plus	Reference				
HbA1c, final test in pre-exp period	Within target	Reference				
	Low	1.58	0.06	<0.001	1.46	1.71
	High	1.05	0.05	0.298	0.96	1.15
	No test	1.20	0.09	<0.001	0.83	2.18
Female		1.06	0.03	0.050	1.00	1.13
Age	20–29	2.49	0.51	<0.001	1.67	3.72
	30–39	1.62	0.15	<0.001	1.36	1.94
	40–49	1.37	0.08	<0.001	1.22	1.54
	50–59	1.06	0.05	0.145	0.98	1.16
	60–69	0.96	0.04	0.280	0.89	1.03
	70–79	Reference				
Major cities		Reference				

Variable		OR	SE	p	Lower CI	Upper CI
Patient rurality	Inner regional	1.01	0.09	0.935	0.84	1.20
	Outer regional	0.82	0.11	0.164	0.63	1.08
	Remote	1.28	0.44	0.474	0.65	2.50
	Very remote	1.45	0.73	0.463	0.54	3.91
	Missing	1.17	0.30	0.527	0.71	1.93
Smoking status	Non-smoker	Reference				
	Smoker	1.32	0.07	<0.001	1.20	1.46
	Ex-smoker	1.01	0.03	0.692	0.95	1.08
	Not stated	1.51	0.12	<0.001	1.29	1.76
Indigenous status	Not Aboriginal / TSI	Reference				
	Aboriginal / TSI	1.29	0.11	0.002	1.10	1.53
	Not stated	1.45	0.07	<0.001	1.31	1.60
Practice SEIFA ³ decile	Lowest disadvantage	2.59	0.75	0.001	1.47	4.56
	2	1.57	0.39	0.067	0.97	2.55
	3	1.74	0.39	0.013	1.12	2.68
	4	1.69	0.38	0.019	1.09	2.63
	5	2.00	0.49	0.005	1.24	3.24
	6	1.61	0.31	0.015	1.10	2.35
	7	1.68	0.47	0.065	0.97	2.91
	8	1.37	0.33	0.199	0.85	2.21
	9	1.48	0.30	0.053	1.00	2.19
	Highest disadvantage	Reference				
Practice rurality	Major cities	Reference				
	Inner regional	0.68	0.12	0.035	0.48	0.97
	Outer regional	1.00	0.22	0.988	0.64	1.55
	Remote/very remote	0.76	0.34	0.545	0.32	1.82
Number of providers	1	Reference				
	2–9	0.97	0.15	0.827	0.71	1.31
	10–19	1.04	0.18	0.822	0.74	1.46
	20 plus	1.06	0.23	0.776	0.70	1.62
Constant	1.55	0.33	0.037	1.03	2.35	
Constant (practice)	0.41	0.06		0.62	0.54	

¹ Usual Provider of Care

² Chronic Disease Management

³ Socio Economic Index for Areas – Index of Relative Social Disadvantage

Table E-2: Results of multilevel logistic regression with eGFR underuse as outcome variable, n=22,755.

Variable		OR	SE	p	Lower CI	Upper CI
Regularity	Least regular	Reference				
	2	0.81	0.04	<0.001	0.73	0.90
	3	0.79	0.04	<0.001	0.71	0.88
	4	0.74	0.04	<0.001	0.67	0.82
	Most regular	0.78	0.04	<0.001	0.70	0.86
Practice – specific UPC ¹	0–0.39	Reference				
	0.40–0.59	0.98	0.05	0.721	0.89	1.08
	0.60–0.99	1.05	0.06	0.445	0.93	1.17

Variable		OR	SE	p	Lower CI	Upper CI
	1	1.27	0.14	0.032	1.02	1.57
Frequency	3–4	Reference				
	5–9	0.71	0.03	<0.001	0.65	0.76
	10–14	0.58	0.03	<0.001	0.52	0.65
	15 plus	0.48	0.03	<0.001	0.42	0.55
CDM ² within exp period		0.62	0.02	<0.001	0.58	0.67
Rx Risk conditions	0	1.44	0.13	<0.001	1.21	1.72
	1–2	1.08	0.06	0.201	0.96	1.20
	3–4	1.00	0.05	0.936	0.90	1.10
	5–6	0.93	0.05	0.161	0.85	1.03
	7 plus	Reference				
Last pre-exp HbA1c test	Within target	Reference				
	Low	1.08	0.05	0.109	0.98	1.19
	High	1.27	0.07	<0.001	1.14	1.42
	No test	1.39	0.07	<0.001	1.26	1.54
Sex	Male	Reference				
	Female	1.08	0.04	0.024	1.01	1.16
	Not stated	2.89	3.95	0.438	0.20	42.20
Age	20–29	2.36	0.42	<0.001	1.67	3.34
	30–39	1.53	0.14	<0.001	1.29	1.83
	40–49	1.39	0.09	<0.001	1.23	1.57
	50–59	1.16	0.06	0.003	1.05	1.28
	60–69	1.01	0.04	0.905	0.92	1.10
	70 plus	Reference				
Patient rurality	Major cities	Reference				
	Inner regional	1.07	0.11	0.536	0.87	1.31
	Outer regional	0.76	0.12	0.097	0.56	1.05
	Remote	1.55	0.53	0.193	0.80	3.02
	Very remote	0.89	0.47	0.827	0.31	2.52
	Missing	1.04	0.31	0.892	0.58	1.86
Indigenous status	Not Aboriginal / TSI	Reference				
	Aboriginal / TSI	1.34	0.12	0.001	1.12	1.60
	Not stated	1.81	0.10	<0.001	1.62	2.01
Smoking status	Non smoker	Reference				
	Smoker	1.31	0.07	<0.001	1.19	1.46
	Ex-smoker	1.03	0.04	0.463	0.95	1.11
	Not stated	1.57	0.12	<0.001	1.35	1.83
Practice SEIFA ³ decile	Least disadvantage	1.63	0.66	0.226	0.74	3.60
	2	2.71	0.95	0.004	1.37	5.40
	3	1.61	0.50	0.128	0.87	2.97
	4	2.63	0.83	0.002	1.42	4.89
	5	2.60	0.90	0.005	1.33	5.11
	6	1.53	0.42	0.121	0.89	2.61
	7	1.16	0.46	0.714	0.53	2.51
	8	1.20	0.42	0.592	0.61	2.37
	9	1.51	0.43	0.143	0.87	2.63
	Most disadvantage	Reference				
Practice rurality	Major cities	Reference				
	Inner regional	0.62	0.15	0.051	0.38	1.00
	Outer regional	1.35	0.40	0.311	0.76	2.42
	Remote / very remote	0.56	0.29	0.264	0.20	1.56
	1	Reference				

Variable		OR	SE	p	Lower CI	Upper CI
Number of providers	2–9	1.21	0.24	0.356	0.81	1.79
	10–19	1.69	0.38	0.021	1.08	2.64
	20 plus	1.15	0.34	0.634	0.64	2.04
Constant		0.22	0.06	<0.001	0.13	0.38
Constant (practice)		0.87	0.11		0.68	1.10

¹ Usual Provider of Care

² Chronic Disease Management

³ Socio Economic Index for Areas – Index of Relative Social Disadvantage

Table E-3: Results of multilevel logistic regression with HbA1c overuse as outcome variable, n=22,752.

Variable		OR	SE	p	Lower CI	Upper CI
Regularity	Least regular	Reference				
	2	1.14	0.08	0.050	1.00	1.31
	3	1.12	0.08	0.098	0.98	1.28
	4	1.18	0.08	0.015	1.03	1.35
	Most regular	1.20	0.08	0.009	1.05	1.38
Practice – specific UPC ¹ cat	0–0.39	Reference				
	0.40–0.59	1.01	0.06	0.836	0.90	1.14
	0.60–0.99	0.98	0.08	0.782	0.84	1.14
	1	0.87	0.13	0.337	0.64	1.16
Frequency	3–4	Reference				
	5–9	1.39	0.08	<0.001	1.24	1.55
	10–14	1.62	0.11	<0.001	1.41	1.86
	15 plus	2.21	0.16	<0.001	1.91	2.55
CDM ² in exp period		1.48	0.08	<0.001	1.34	1.64
RxRisk conditions	0	0.82	0.12	0.179	0.62	1.09
	1–2	0.83	0.06	0.018	0.72	0.97
	3–4	0.94	0.06	0.282	0.83	1.06
	5–6	0.98	0.06	0.702	0.88	1.09
	7 plus	Reference				
Last pre-exp HbA1c test	Within target	Reference				
	Low	0.58	0.03	<0.001	0.52	0.66
	High	1.19	0.07	0.005	1.05	1.34
	No pre test	0.70	0.04	<0.001	0.62	0.79
Sex	Male	Reference				
	Female	0.92	0.04	0.057	0.84	1.00
Age	20–29	1.46	0.34	0.108	0.92	2.31
	30–39	0.88	0.12	0.351	0.67	1.15
	40–49	0.81	0.07	0.016	0.69	0.96
	50–59	0.88	0.05	0.033	0.77	0.99
	60–69	0.89	0.05	0.021	0.80	0.98
	70 plus	Reference				
Patient rurality	Major cities	Reference				
	Inner regional	0.86	0.11	0.228	0.67	1.10
	Outer regional	0.86	0.17	0.456	0.59	1.27
	Remote	1.24	0.56	0.641	0.51	3.03
	Very remote	1.03	0.70	0.960	0.27	3.90
	Missing	0.81	0.32	0.596	0.37	1.76
Indigenous status	Not Aboriginal / TSI	Reference				
	Aboriginal / TSI	1.04	0.12	0.705	0.84	1.30

Variable		OR	SE	p	Lower CI	Upper CI
	Not stated	0.70	0.05	<0.001	0.61	0.82
Smoking status	Non smoker	Reference				
	Smoker	0.83	0.06	0.012	0.72	0.96
	Ex-smoker	1.05	0.05	0.283	0.96	1.15
	Not stated	0.92	0.11	0.458	0.73	1.15
Practice SEIFA ³ decile	Least disadvantage	0.50	0.18	0.049	0.25	1.00
	2	1.44	0.42	0.213	0.81	2.54
	3	0.79	0.21	0.361	0.47	1.32
	4	0.92	0.25	0.756	0.54	1.56
	5	0.64	0.19	0.131	0.36	1.14
	6	0.79	0.18	0.307	0.50	1.24
	7	0.73	0.24	0.330	0.38	1.38
	8	0.90	0.26	0.708	0.51	1.58
	9	0.87	0.21	0.561	0.54	1.40
	Most	Reference				
Practice rurality	Major cities	Reference				
	Inner regional	1.67	0.37	0.022	1.08	2.58
	Outer regional	1.25	0.35	0.441	0.71	2.18
	Remote / very remote	1.77	0.99	0.001	0.59	5.27
Number of providers	1	Reference				
	2–9	1.35	0.27	0.126	0.92	2.00
	10–19	1.20	0.27	0.411	0.78	1.86
	20 plus	1.19	0.32	0.517	0.70	2.01
Constant		0.09	0.03	<0.001	0.05	0.16
Constant (practice)		0.52	0.07		0.40	0.68

¹ Usual Provider of Care

² Chronic Disease Management

³ Socio Economic Index for Areas – Index of Relative Social Disadvantage

Table E-4: Results of multilevel logistic regression, odds of recording a HbA1c value within target range on the first test during follow-up, n=18,348.

Variable		OR	SE	p	Lower CI	Upper CI
Regularity	Least regular	Reference				
	2	1.08	0.06	0.135	0.98	1.20
	3	1.10	0.06	0.080	0.99	1.22
	4	1.01	0.05	0.880	0.91	1.12
	Most regular	1.06	0.06	0.253	0.96	1.19
Practice – specific UPC ¹	0–0.39	Reference				
	0.40–0.59	0.92	0.04	0.091	0.84	1.01
	0.60–0.99	0.93	0.05	0.237	0.84	1.05
	1	1.01	0.08	0.922	0.86	1.19
Frequency	3–4	Reference				
	5–9	1.03	0.04	0.466	0.95	1.12
	10–14	0.98	0.05	0.646	0.88	1.09
	15 plus	0.88	0.05	0.042	0.78	1.00
CDM ² in exposure period		1.07	0.04	0.077	0.99	1.15
Rx Risk conditions	0	1.27	0.13	0.022	1.03	1.56
	1–2	1.15	0.07	0.013	1.03	1.29
	3–4	1.12	0.05	0.025	1.01	1.23
	5–6	1.05	0.05	0.313	0.96	1.15
	7 plus	Reference				
	Within target	Reference				

Variable		OR	SE	p	Lower CI	Upper CI
Last pre-exp HbA1c result	Low	0.21	0.01	<0.001	0.19	0.23
	High	0.41	0.02	<0.001	0.37	0.45
	No test	0.42	0.02	<0.001	0.38	0.46
Sex	Male	Reference				
	Female	0.97	0.03	0.425	0.91	1.04
Age	20–29	0.68	0.16	0.106	0.43	1.08
	30–39	0.67	0.07	<0.001	0.55	0.83
	40–49	0.72	0.05	<0.001	0.63	0.82
	50–59	0.87	0.04	0.004	0.79	0.96
	60–69	0.93	0.04	0.092	0.86	1.01
	70 plus	Reference				
Patient rurality	Major cities	Reference				
	Inner regional	0.97	0.10	0.752	0.79	1.19
	Outer regional	1.08	0.18	0.619	0.79	1.49
	Remote	1.10	0.39	0.777	0.55	2.20
	Very remote	1.26	0.55	0.591	0.54	2.97
	Missing	1.10	0.31	0.741	0.63	1.90
Indigenous status	Not Aboriginal / TSI	Reference				
	Aboriginal / TSI	0.77	0.08	0.010	0.64	0.94
	Not stated	1.03	0.05	0.540	0.93	1.15
Practice SEIFA ³ Decile	Least disadvantage	0.95	0.09	0.577	0.79	1.14
	2	0.95	0.09	0.586	0.79	1.14
	3	1.09	0.09	0.312	0.92	1.28
	4	1.13	0.10	0.159	0.95	1.33
	5	0.95	0.09	0.611	0.79	1.15
	6	1.00	0.08	0.962	0.86	1.16
	7	1.06	0.10	0.576	0.87	1.28
	8	0.99	0.09	0.980	0.84	1.19
	9	1.08	0.09	0.338	0.92	1.26
	Most disadvantage	Reference				
Practice rurality	Major cities	Reference				
	Inner regional	0.86	0.10	0.180	0.69	1.07
	Outer regional	0.91	0.16	0.582	0.65	1.27
	Remote	1.02	0.38	0.948	0.50	2.11
Number of providers	1	Reference				
	2–9	1.12	0.09	0.170	0.95	1.32
	10–19	1.06	0.10	0.499	0.89	1.28
	20 plus	1.07	0.11	0.476	0.88	1.30
Constant		0.99	0.13	0.947	0.76	1.29
Constant (practice)		0.01	0.01		0.00	0.04

¹ Usual Provider of Care

² Chronic Disease Management

³ Socio Economic Index for Areas – Index of Relative Social Disadvantage

E.3 Sensitivity analyses relating to cohort of all people with diabetes

Table E-5: Characteristics of the cohort with Type 1 and/or 2 Diabetes Mellitus and the practices contributing data

Variable		N	%
<i>Socio-demographic variables</i>			
Sex	Male	16,328	53.62
	Female	14,120	46.37
	Not stated	<5	–
Age	20–29	500	1.64
	30–39	1,363	4.48
	40–49	3,169	10.41
	50–59	6,553	21.52
	60–69	10,140	33.30
	70–79	8,728	28.66
Patient rurality	Major cities	18,954	62.26
	Inner regional	7,943	26.08
	Outer regional	3,015	9.90
	Remote	358	1.18
	Very remote	79	0.26
	Missing	104	0.34
State	New South Wales	21,783	71.53
	Western Australia	8,670	28.47
Indigenous stats	Aboriginal / TSI ¹	1,176	3.86
	Neither	24,978	82.02
	Not stated	4,299	14.12
Smoking status	Smoker	3,828	12.57
	Ex-smoker	10,645	34.96
	Non-smoker	14,387	47.24
	Not stated	1,593	5.23
<i>Health service use during exposure period⁵</i>			
Frequency	0–4	11,154	36.63
	5–9	10,827	35.55
	10–14	4,690	15.40
	15 plus	3,782	12.42
Practice –specific UPC ² index	0–0.39	8,191	26.90
	0.4–0.59	6,489	21.31
	0.6–0.99	4,442	14.59
	1	11,331	37.21
CDM ³ item	No	11,164	36.66
	Yes	19,289	63.34
Rx-Risk comorbidity conditions ⁶	0	1,367	4.49
	1–2	5,404	17.75
	3–4	7,354	24.15
	5–6	6,956	22.84
	7 plus	9,372	30.78
<i>Outcome variables⁷</i>			
HbA1c overuse (two tests within 80 days)	No	26,181	85.97
	Yes	4,272	14.03
HbA1c underuse (8 months without test)	No	11,917	39.13
	Yes	18,536	60.87

Variable		N	%
eGFR ⁴ underuse (14 months without test)	No	22,030	72.34
	Yes	8,423	27.66
HbA1c within target on first test in follow-up	No	16,739	54.97
	Yes	7,391	24.27
	No test	6,323	20.76
Total		30,453	100

¹ Torres Strait Islander

² Usual Provider of Care

³ Chronic Disease Management, representing a reimbursement to a GP providing care for the patient for certain care coordination activities

⁴ Estimated Glomerular Filtration Rate

⁵ March 2015 – Feb 2016

⁶ 5 years ending Feb 2016

⁷ March 2016 – June 2017

* Where a cell has value <5, other values on variable altered to protect confidentiality

Table E-6: Univariate analysis, relationships between the two exposures and each outcome. For the overuse / underuse outcomes n=30,395, for the HbA1c level outcome n=24,093

Exposure	Process of care outcomes						Clinical outcomes		
	HbA1c ¹ underuse		HbA1c ¹ overuse		eGFR ² underuse		HbA1c within target on first test in f/up		
	No	Yes	No	Yes	No	Yes	No	Yes	
Regularity	Least	32.94	67.06	87.98	12.02	67.49	32.51	70.58	29.42
	2	39.50	60.50	85.98	14.02	73.27	26.73	69.50	30.50
	3	41.67	58.33	85.40	14.60	73.76	26.24	68.38	31.62
	4	40.85	59.15	85.11	14.89	75.01	24.99	69.77	30.23
	Most	40.70	59.30	85.39	14.61	72.17	27.83	68.70	31.30
Significance	Chi2(4)=128.7, p<0.001		Chi2(4)=27.5, p<0.001		Chi2(4)=102.3, p<0.001		Chi2(4)=6.8, p=0.144		
Practice-specific UPC ³	0–0.39	43.27	56.73	82.58	17.42	74.20	25.80	68.52	31.48
	0.4–0.59	40.98	59.02	84.20	15.80	72.83	27.17	69.20	30.80
	0.6–0.99	36.92	63.08	87.21	12.79	69.54	30.45	69.15	30.85
	1	35.95	64.05	88.95	11.05	71.81	28.19	70.22	29.78
Significance	Chi2(3)=125.2, p<0.001		Chi2(3)=184.1, p<0.001		Chi2(3)=34.0, p<0.001		Chi2(3)=5.4, p=0.144		
CDM ⁴	No	27.79	72.21	90.08	9.92	68.96	31.04	70.57	29.43
	Yes	45.70	54.30	83.60	16.40	80.94	19.06	68.78	31.22
Significance	Chi2(1)=952.7, p<0.001		Chi2(1)=246.1, p<0.001		Chi2(1)=442.2, p<0.001		Chi2(1)=8.1, p=0.004		

¹ Glycosylated Haemoglobin

² Estimated Glycosylated Haemoglobin Rate

³ Usual Provider of Care

⁴ Chronic Disease Management, representing a reimbursement to a GP providing care for the patient for certain care coordination activities

Table E-7: Intraclass correlation coefficients derived from null models

Outcome variable	ICC ¹
HbA1c underuse ²	0.124
HbA1c overuse	0.151
eGFR underuse ³	0.231
HbA1c result	0.006

¹ Intraclass Correlation Coefficient² Glycosylated Haemoglobin³ Estimated Glomerular Filtration Rate**Table E-8: Outputs of multilevel logistic regression models for all outcomes, displaying results for exposure variables only***

Process outcome: HbA1c ¹ underuse (n=30,395)						
Variable		Odds Ratio	Std Err	Lower CI	Upper CI	p
Regularity	Least regular	Reference				
	2	0.81	0.03	0.75	0.88	<0.001
	3	0.75	0.03	0.70	0.82	<0.001
	4	0.79	0.03	0.73	0.86	<0.001
	Most regular	0.73	0.03	0.67	0.79	<0.001
Practice – specific	0–0.39	Reference				
	0.4–0.59	0.98	0.04	0.91	1.06	0.605
UPC ²	0.6–0.99	1.02	0.05	0.93	1.12	0.693
	1	1.16	0.11	0.97	1.39	0.101
CDM ³ item in exp period		0.53	0.02	0.50	0.57	<0.001
Process outcome: eGFR underuse (n=30,395)						
Variable		Odds Ratio	Std Err	Lower CI	Upper CI	p
Regularity	Least regular	Reference				
	2	0.81	0.04	0.74	0.88	<0.001
	3	0.82	0.04	0.75	0.90	<0.001
	4	0.76	0.03	0.69	0.83	<0.001
	Most regular	0.78	0.04	0.72	0.86	<0.001
Practice – specific	0–0.39	Reference				
	0.40–0.59	0.97	0.04	0.89	1.06	0.488
UPC ²	0.60–0.99	1.03	0.05	0.93	1.15	0.529
	1	1.16	0.11	0.96	1.41	0.126
CDM ³ within exp period		0.63	0.02	0.59	0.67	<0.001
Process outcome: HbA1c ¹ overuse (n=30,395)						
Variable		Odds Ratio	Std Err	Lower CI	Upper CI	p
Regularity	Least regular	Reference				
	2	1.14	0.07	1.01	1.28	0.031
	3	1.12	0.07	1.00	1.26	0.049
	4	1.18	0.07	1.05	1.32	0.006
	Most regular	1.24	0.07	1.10	1.39	<0.001
Practice – specific	0–0.39	Reference				
	0.40–0.59	1.06	0.06	0.95	1.18	0.278
UPC ²	0.60–0.99	1.05	0.07	0.91	1.20	0.527
	1	0.84	0.11	0.64	1.09	0.186
CDM ³ in exp period		1.34	0.06	1.22	1.46	<0.001
Clinical outcome: HbA1c ¹ within target on first test in follow-up (n=24,093)						

Variable		Odds Ratio	Std Err	Lower CI	Upper CI	p
Regularity	Least regular	Reference				
	2	1.06	0.05	0.97	1.17	0.194
	3	1.09	0.05	0.99	1.19	0.080
	4	1.02	0.05	0.93	1.12	0.687
	Most regular	1.07	0.05	0.97	1.17	0.175
Practice – specific UPC ²	0–0.39	Reference				
	0.40–0.59	0.92	0.04	0.84	1.00	0.044
	0.60–0.99	0.94	0.05	0.85	1.03	0.196
	1	0.99	0.07	0.86	1.13	0.841
CDM ³ in exposure period		1.07	0.03	1.00	1.14	0.038

¹ Glycosylated Haemoglobin

² Usual Provider of Care

³ Chronic Disease Management

* Patient-level covariates were the count of GP visits in exposure period, count of comorbid conditions (derived from the RxRisk index), HbA1c level on final test in pre-exposure period, sex, age, rurality (based on the Accessibility / Remoteness Index of Australia), smoking status and indigenous status. Practice-level covariates were area socioeconomic status (based on the Socio-Economic Index for Areas – Index of Relative Social Disadvantage), practice size (number of doctors providing service) and rurality.

Appendix F Supplementary content from Chapter 9 (manuscript 5 and additional analyses)

F.1 Manuscript 5 supplement 1: Detailed cohort entry criteria

Table F-1: Codes used to identify cohort members of secondary prevention group using administrative data

Secondary prevention group	MBS / PBS / ICD10 / ACHI Codes
Hospitalisation with diagnosis code (principal or additional) of	
Ischaemic Heart Disease	I20.x – I25.x
Transient ischaemic attack	G45.x, I65.x, I66.x
Other CVD	I67.2
Ischemic stroke	I63.x-I64.x
Atrial fibrillation	I48.x
Hospitalisation with a procedure indicating	
Transluminal coronary angioplasty	35304.x, 35305.x, 38300.x, 38303.x
Transluminal coronary angioplasty with stenting	35310.x, 38306.x
Coronary artery bypass graft	38497.x, 38503.x, 38500.x
Re-operation for reconstruction of occluded coronary artery graft	38637.x
Percutaneous transluminal rotational atherectomy	38309.00, 38312.x, 38315.00, 38318.x
Open coronary endarterectomy	38505.00
Coronary artery bypass, using other material graft, not elsewhere classified	90201.x
Direct intracoronary artery injection or infusion of a thrombolytic agent	90221.00
Avid imaging study for myocardial infarct	61310.00
Ischemic stroke	31400.00, 33500.00, 33800.00
MBS items indicating:	
Transluminal coronary angioplasty	38300, 38303
Transluminal coronary angioplasty with stenting	38306

Secondary prevention group	MBS / PBS / ICD10 /ACHI Codes
Percutaneous transluminal rotational atherectomy of coronary artery	38309, 38312, 38315, 38318
Coronary artery bypass	38496, 38497, 38498, 38500, 38500, 38501, 38503, 38504
Re-operation for reconstruction of occluded coronary artery graft	38637
Percutaneous transluminal rotational atherectomy	38309, 38312, 38315, 38318
Open coronary endarterectomy	38505
Myocardial infarct study	61310
Exploration of the carotid artery	34100
Carotid endarterectomy	33500
Embolus removal from artery of neck	33800
PBS dispensings of:	
Glyceryl trinitrate	1459T, 8171C, 8027L, 1515R, 8010N, 8028M, 1516T, 8011P, 8119H, 8026K, 3475K
Isosorbide dinitrate	2587E, 2588F
Isosorbide mononitrate	1558B, 8273K
Nicorandil	8228C, 8229D
Perhexeline Maleate	1822X
Self-reported diagnosis of heart attack, angina or stroke	
Self-reported operation for heart disease of transient ischaemic attack	

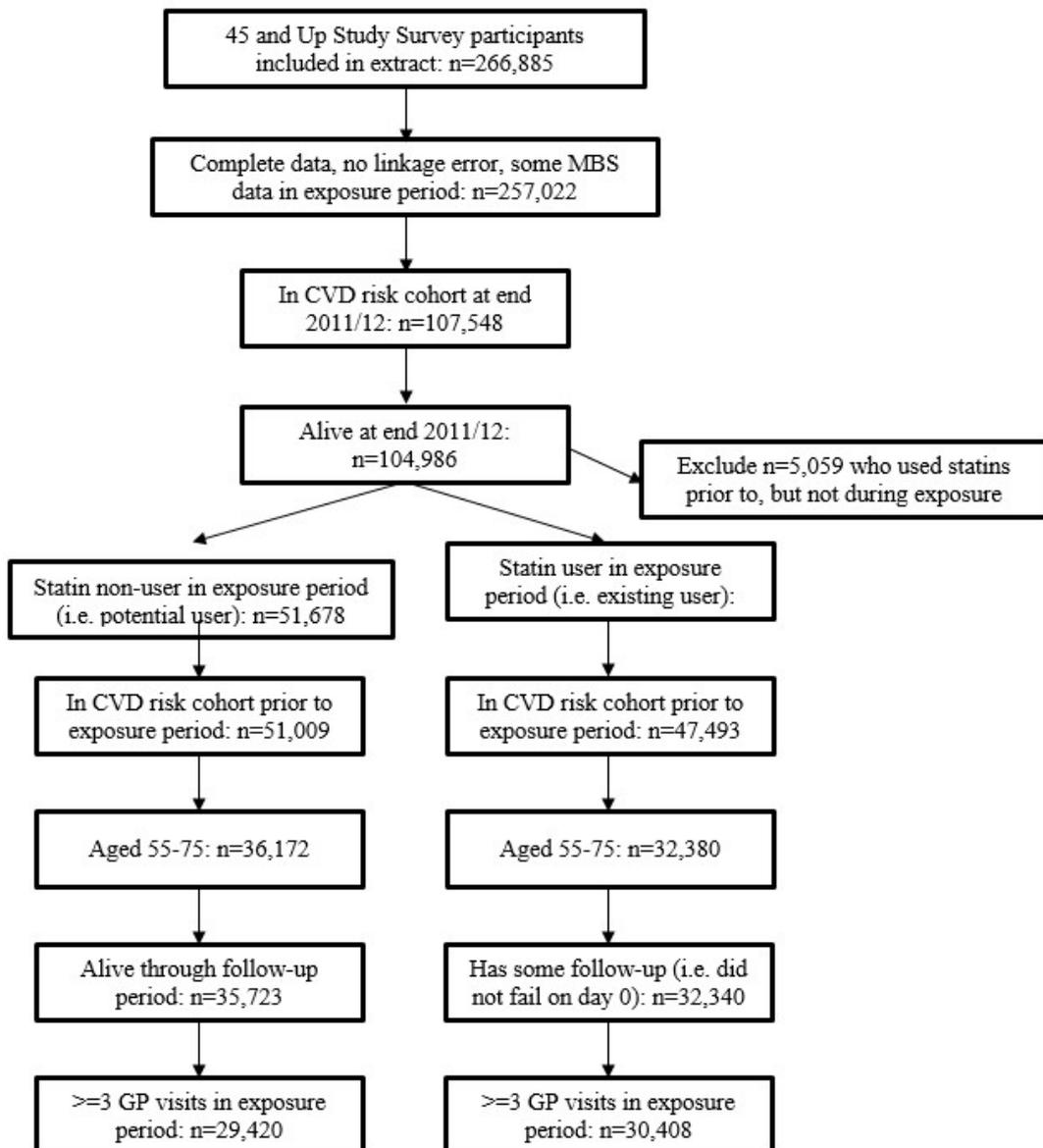
Table F-2: Combinations of self-report data resulting in entry to primary prevention group. Participants meeting all criteria on a row enter the study cohort in the primary prevention group.

Diabetes	Sex	Age	Smoker (ever)	High BP	High cholesterol
Y	—	≥60	—	—	—
Y	—	55 - 59	N	Y	Y
Y	—	55 - 59	Y	—	Y
Y	—	55 - 59	Y	Y	—
N	F	≥55	Y	Y	—
N	F	≥55	Y	—	Y
N	F	≥65	N	Y	Y

N	M	≥ 65	Y	—	—
N	M	≤ 64	Y	—	—
N	M	≥ 55	N	Y	—

— Indicates that any value applies. Table adapted from Liu et al. 2016 (296).

F.2 Manuscript 5 supplement 2: Cohort identification flow chart



F.3 Manuscript 5 supplement 3: Model assumptions and sensitivity analyses

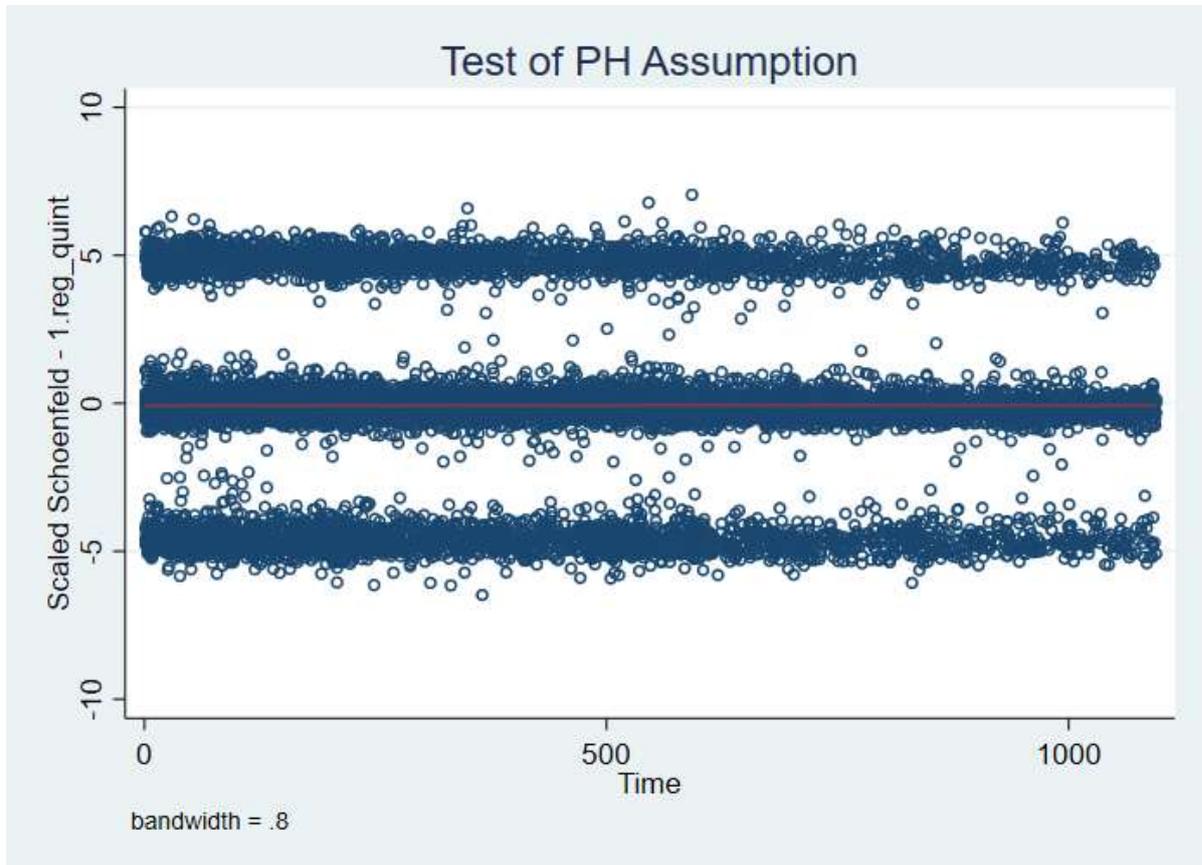


Figure F-1: Plot of scaled Schoenfeld residuals for level 2 of regularity, a zero slope indicates proportionality

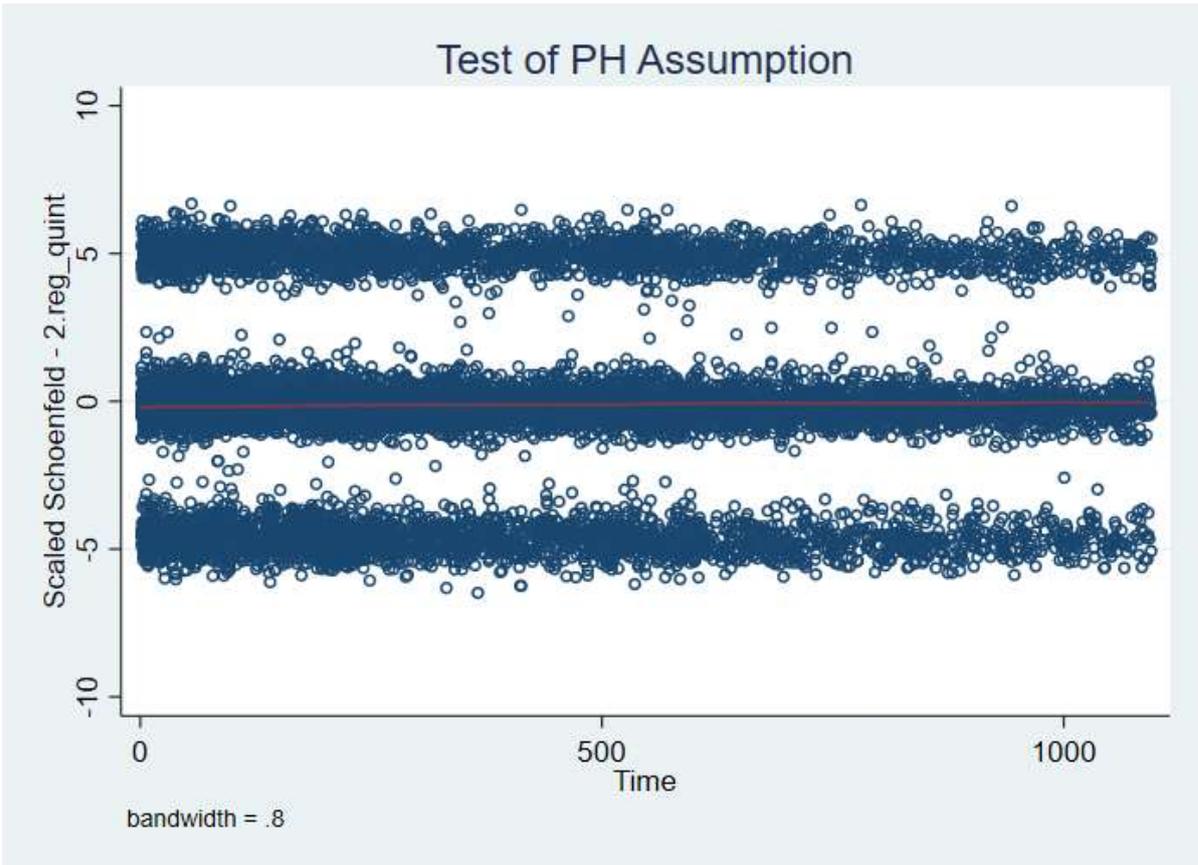


Figure F-2: Plot of scaled Schoenfeld residuals for level 3 of regularity, a zero slope indicates proportionality

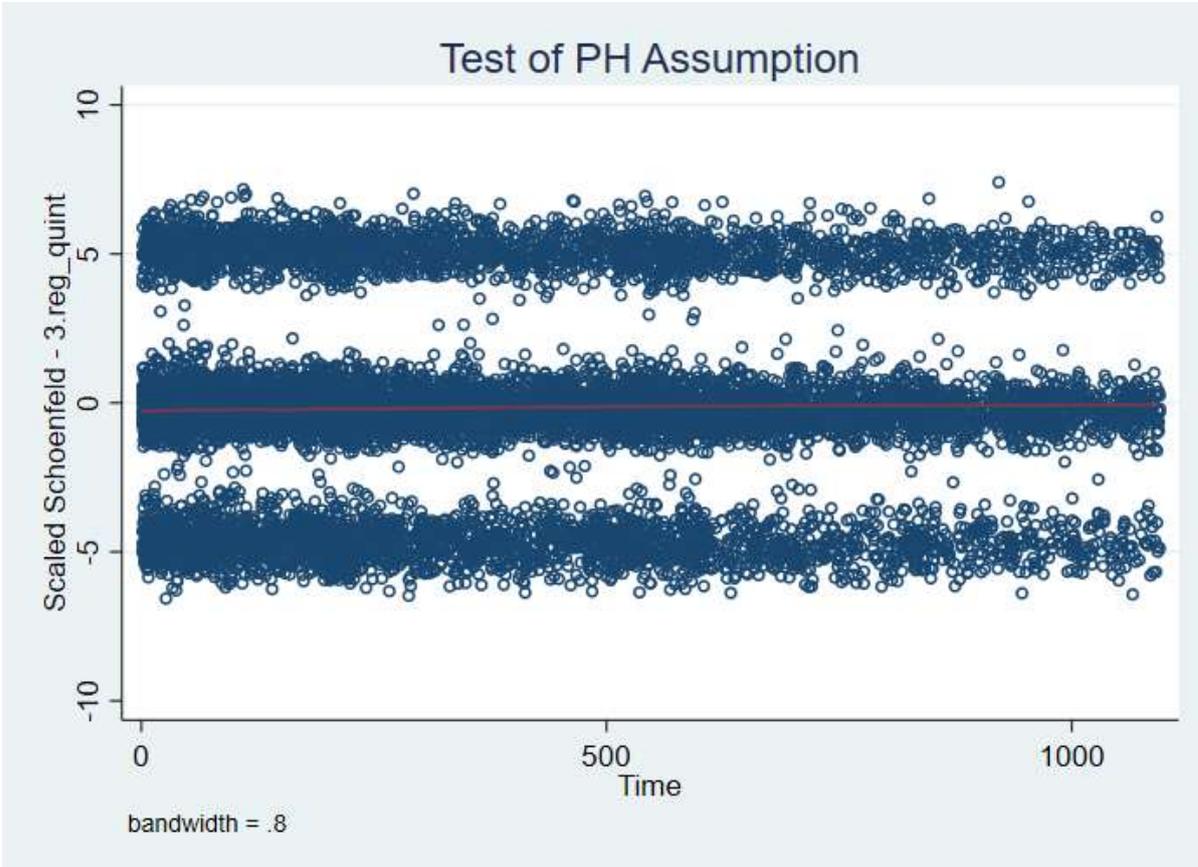


Figure F-3: Plot of scaled Schoenfeld residuals for level 4 of regularity, a zero slope indicates proportionality

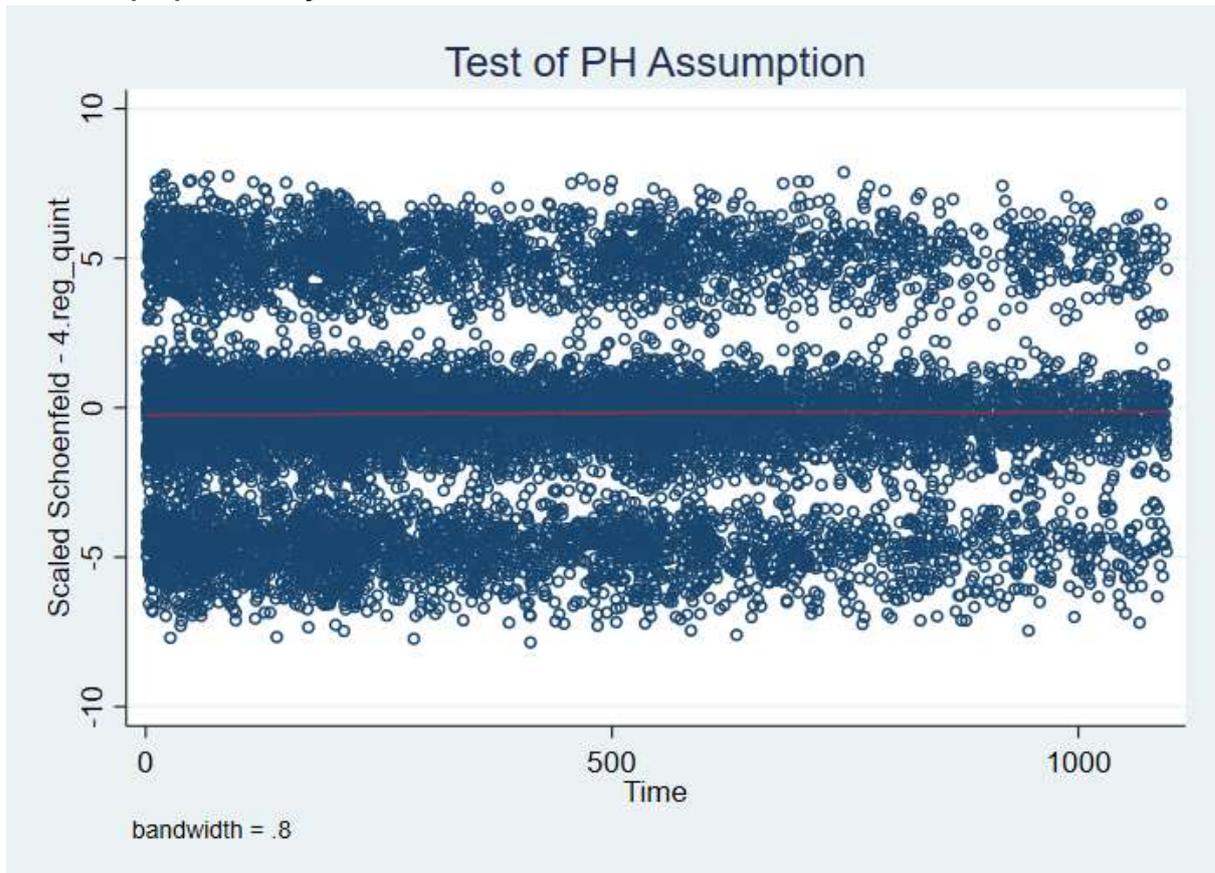


Figure F-4: Plot of scaled Schoenfeld residuals for level 5 of regularity, a zero slope indicates proportionality

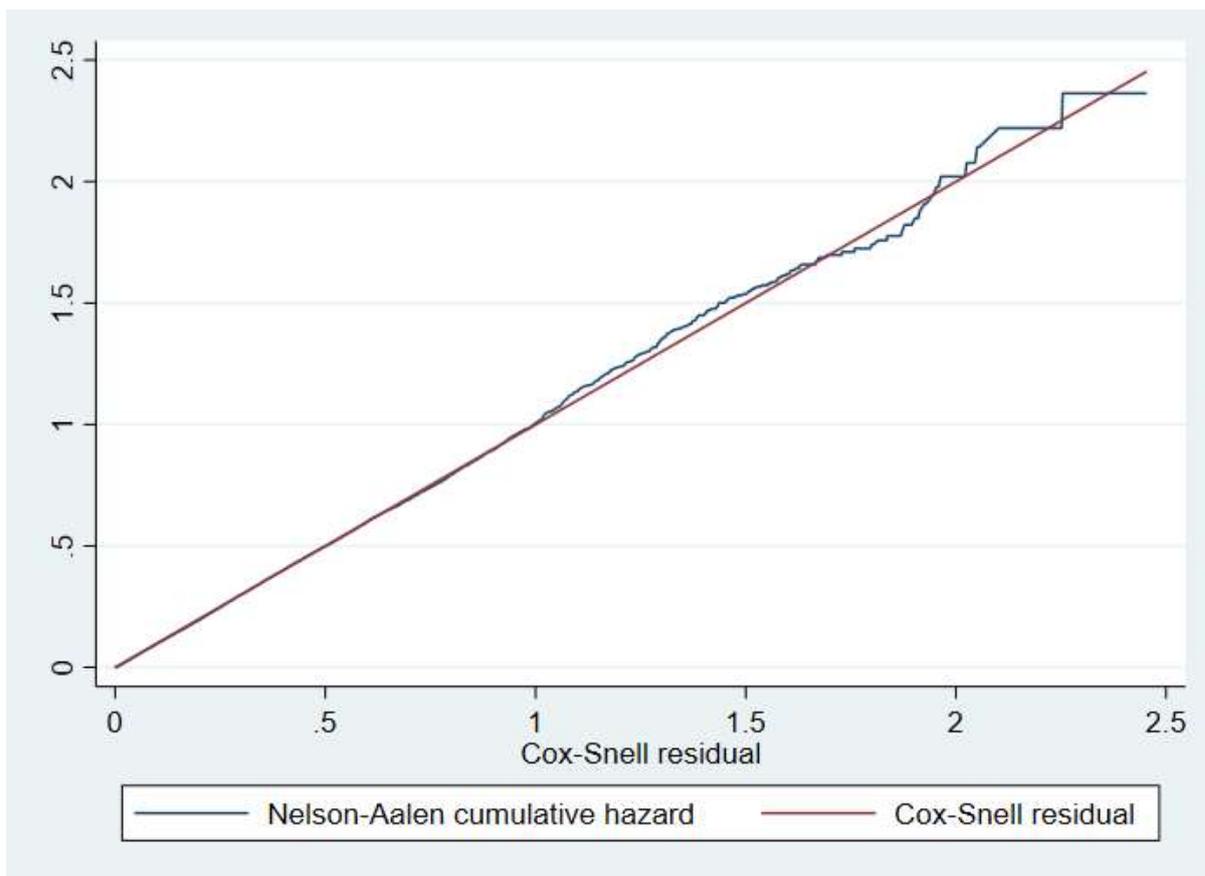


Figure F-5: Cox-Snell residuals assessing model fit

Table F-3: Results of logistic regression reporting associations between continuity of primary care during July 2011 to June 2012 exposure period and odds of statin initiation in the following two years, among sub-group of potential users

Dispensation in follow-up period		OR (95% CI)	Std. Err.	z	P>z
Regularity	Least regular	Reference			
	2	1.082 (0.991–1.182)	0.049	1.75	0.080
	3	1.092 (1.000–1.192)	0.049	1.97	0.049
	4	1.106 (1.013–1.208)	0.050	2.24	0.025
	Most regular	1.150 (0.051–1.257)	0.052	3.06	0.002
COC index	<0.5	Reference			
	0.5–0.74	1.095 (1.019–1.177)	0.040	2.47	0.014
	0.75–0.99	1.100 (1.000–1.210)	0.053	1.97	0.049
	1	1.099 (1.026–1.178)	0.039	2.69	0.007
Frequency	3–5	Reference			
	6–9	1.244 (1.156–1.340)	0.047	5.81	<0.001
	10–14	1.309 (1.202–1.424)	0.057	6.23	<0.001
	15–19	1.248 (1.121–1.390)	0.068	4.04	<0.001
	20 plus	1.163 (1.038–1.304)	0.068	2.59	0.009
RxRisk ^a	0	Reference			
	1–2	0.925 (0.846–1.011)	0.042	-1.73	0.085

Dispensation in follow-up period		OR (95% CI)	Std. Err.	z	P>z
	3–5	1.661 (1.531–1.800)	0.069	12.29	<0.001
	6 plus	3.178 (2.902–3.480)	0.147	24.94	<0.001
CVD status	High CVD risk	Reference			
	History of CVD	2.046 (1.881–2.227)	0.088	16.64	<0.001
Heart disease ^b	Yes	1.144 (1.042–1.257)	0.055	2.81	0.005
Diabetes ^b	Yes	2.627 (2.430–2.839)	0.104	24.32	<0.001
High blood pressure ^b	Yes	1.299 (1.228–1.374)	0.037	9.12	<0.001
Language other than English ^b	Yes	1.166 (1.059–1.284)	0.057	3.14	0.002
Stroke ^b	Yes	0.738 (0.641–0.849)	0.053	-4.24	<0.001
Non-melanoma skin cancer ^b	Yes	0.857 (0.807–0.911)	0.026	-4.99	<0.001
Depression ^b	No	Reference			
	Yes	0.823 (0.758–0.893)	0.034	-4.67	<0.001
	Missing	0.998 (0.919–1.085)	0.042	-0.04	0.969
	cons	0.126 (0.112–0.140)	0.007	-36.57	<0.001

^a Number of 46 RxRisk conditions present in individual based on prior five years medication records

^b Based on self-report

Table F-4: Association between primary care continuity during July 2011 to June 2012 exposure period and statin adherence among the cohort of existing users; non-adherence defined as a 60-day period without statin supply

	Variable*	Haz. Ratio (95% CI)	Std. Err.	z	P>z
Regularity	Least regular	Reference			
	2	0.914 (0.860–0.971)	0.028	-2.93	0.003
	3	0.862 (0.811–0.917)	0.027	-4.72	<0.001
	4	0.833 (0.783–0.887)	0.027	-5.72	<0.001
	Most regular	0.832 (0.781–0.887)	0.027	-5.66	<0.001
COC index	<0.5	Reference			
	0.5–0.74	0.913 (0.867–0.963)	0.024	-3.38	0.001
	0.75–0.99	0.903 (0.843–0.966)	0.031	-2.95	0.003
	1	0.905 (0.861–0.953)	0.023	-3.84	<0.001
Frequency	3–4	Reference			
	6–9	0.894 (0.846–0.945)	0.025	-3.96	<0.001
	10–14	0.894 (0.840–0.953)	0.029	-3.46	0.001
	15–19	0.908 (0.840–0.981)	0.036	-2.43	0.015
	20 plus	0.861 (0.792–0.935)	0.036	-3.56	<0.001
RxRisk ^a	0	Reference			
	1–2	1.502 (1.387–1.626)	0.061	10.04	<0.001
	3–5	1.084 (1.012–1.162)	0.038	2.28	0.022
	6 plus	0.875 (0.815–0.938)	0.031	-3.74	<0.001
Current Work Status ^b	Other	Reference			
	Fully retired	0.788 (0.751–0.826)	0.019	-9.89	<0.001
Highest Qualification ^b	No school certificate or other qualification	Reference			
	School or intermediate certificate	0.975 (0.910–1.044)	0.034	-0.73	0.465
	Higher school or leaving certificate	1.114 (1.024–1.211)	0.048	2.51	0.012
	Trade or apprenticeship	1.054 (0.977–1.138)	0.041	1.37	0.172
	Certificate or diploma	1.136 (1.058–1.220)	0.041	3.5	<0.001
University degree or higher	1.380 (1.286–1.482)	0.050	8.88	<0.001	
High blood pressure ^b	No	Reference			
	Yes	0.898 (0.862–0.935)	0.019	-5.14	<0.001
CVD status	High CVD risk	Reference			
	History of CVD	1.024 (0.971–1.079)	0.028	0.87	0.386
Heart disease ^b	No	Reference			
	Yes	0.833 (0.785–0.883)	0.025	-6.09	<0.001

Stratifying variables include age, language other than English at home, prescriber, and SEIFA.

^a Number of 46 RxRisk conditions based on prior five years medication dispensing records

^b Based on self-report

F.4 Distribution of regularity scores among potential statin users

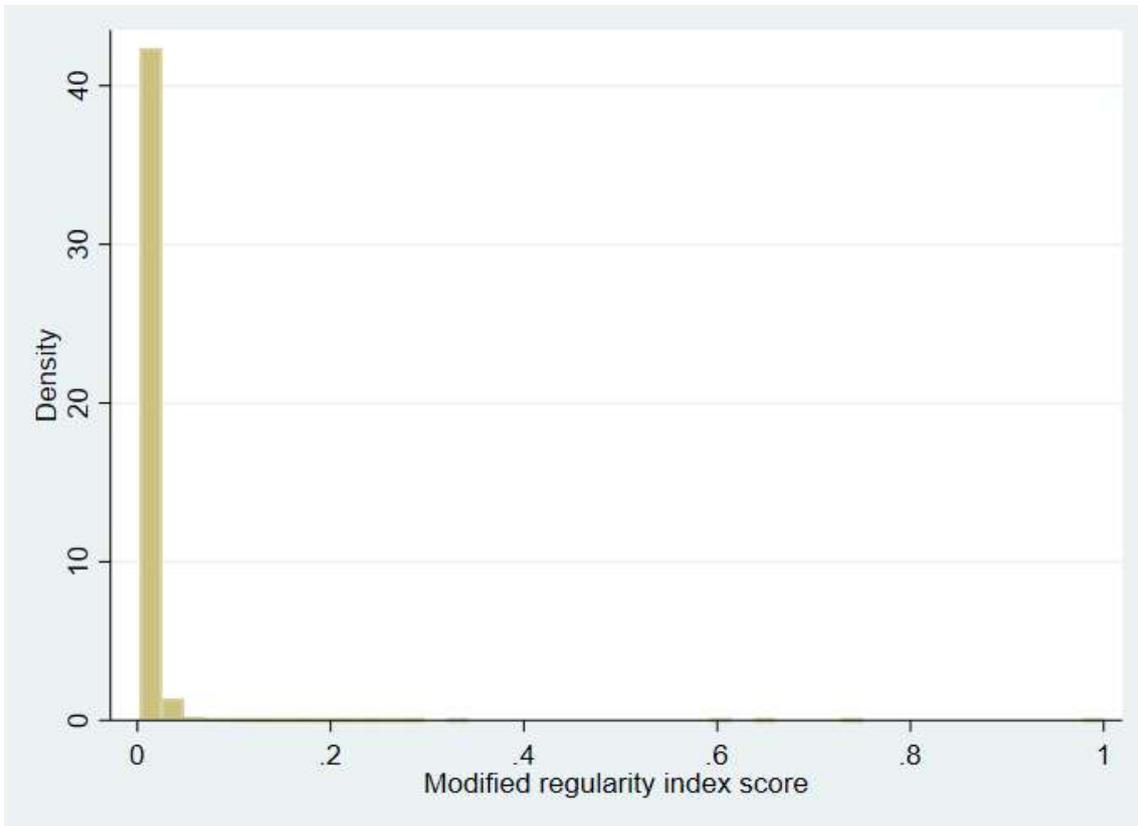


Figure F-6: Histogram of regularity score values, cohort of potential statin users

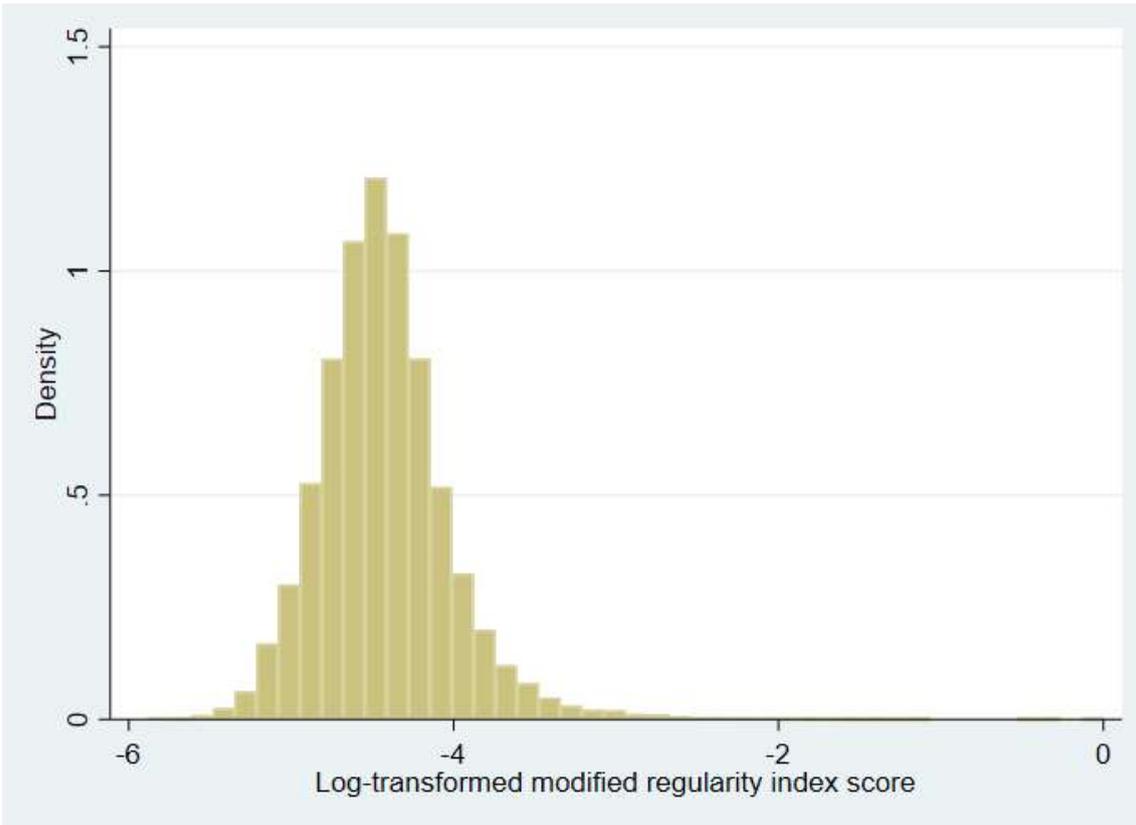


Figure F-7: Histogram of log-transformed regularity score values, cohort of potential statin users

F.5 Residuals following regression of regularity on continuity index, cohort of potential statin users

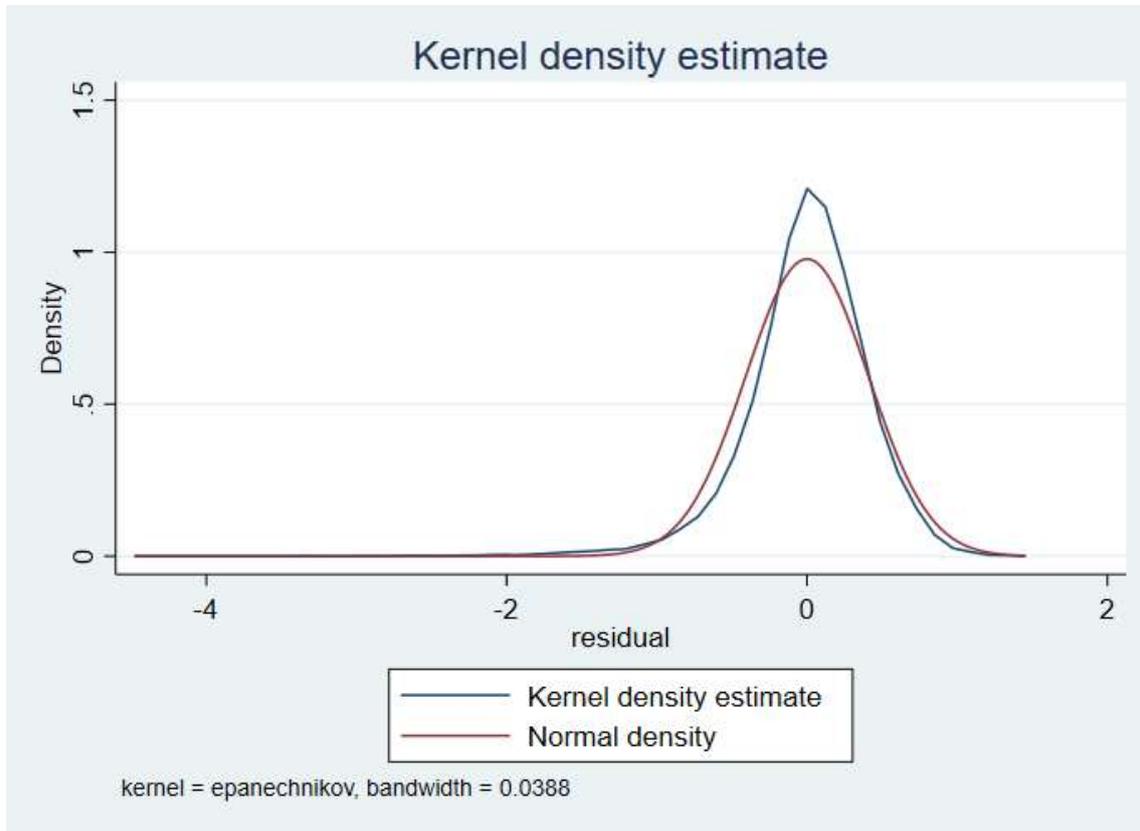


Figure F-8: Distribution of residuals against normal distribution, cohort of existing statin users

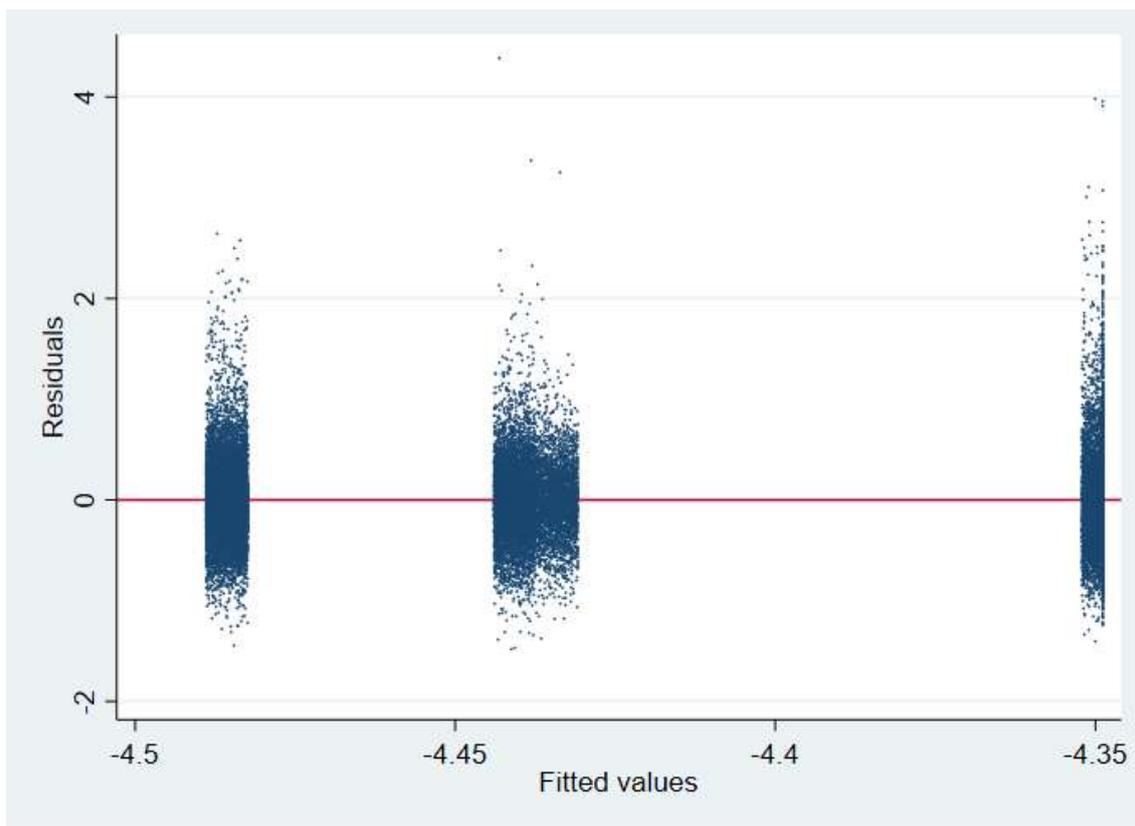


Figure F-9: Plot of residuals against fitted values, cohort of potential statin users.

F.6 Full outputs of all mediation models, cohort of existing statin users

Table F-5: Full output of mediation model 1 among existing statin users; regularity as exposure, cardiovascular hospitalisation as outcome, exposure and mediator measured concurrently (reproduction of Table 9-11)

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	-0.037	0.015	-2.49	0.013	-0.067	-0.008
MPR	-0.389	0.082	-4.77	<0.001	-0.549	-0.229
COC	0.082	0.076	1.08	0.281	-0.067	0.231
Frequency	0.022	0.003	8.94	<0.001	0.017	0.027
RxRisk comorbs in previous five years	0.089	0.008	11.74	<0.001	0.074	0.104
Age	0.014	0.005	3.03	0.002	0.005	0.023
Retired	-0.107	0.048	-2.22	0.026	-0.201	-0.012
High blood pressure	0.080	0.044	1.81	0.071	-0.007	0.166
Lang. other than English at home	-0.155	0.075	-2.07	0.038	-0.302	-0.008
Statins for secondary prevention	0.595	0.056	10.53	<0.001	0.484	0.705
Heart disease diagnosis	0.207	0.052	3.95	<0.001	0.104	0.310
Vigorous exercise at least once weekly	-0.078	0.042	-1.89	0.059	-0.160	0.003
Current smoker	0.063	0.079	0.79	0.427	-0.092	0.217
Constant	-4.120	0.293	-14.04	<0.001	-4.696	-3.545

Part 2: Mediator on exposure and covariates

	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	0.010	0.001	10.35	<0.001	0.008	0.012
COC	0.023	0.005	4.74	<0.001	0.014	0.033
Frequency	-0.001	0.000	-4.72	<0.001	-0.001	-0.001
RxRisk comorbs in previous five years	0.004	0.001	8.36	<0.001	0.003	0.006
Age	0.003	0.000	10.23	<0.001	0.002	0.004
Retired	0.032	0.003	9.98	<0.001	0.026	0.038
High blood pressure	0.027	0.003	9.29	<0.001	0.021	0.033
Lang. other than English at home	-0.040	0.005	-8.33	<0.001	-0.049	-0.031
Statins for secondary prevention	0.007	0.004	1.99	0.046	0.000	0.015
Heart disease diagnosis	0.017	0.004	4.32	<0.001	0.009	0.025
Vigorous exercise at least once weekly	-0.002	0.003	-0.89	0.371	-0.008	0.003
Current smoker	-0.031	0.005	-5.78	<0.001	-0.041	-0.020
Constant	0.554	0.019	29.32	<0.001	0.517	0.591

Part 3: Effects summary

	Estimate	Bias	Bstrap SE	Lower	Upper
CDE	0.861	0.004	0.050	0.778	0.972
NIE	0.984	0.000	0.004	0.976	0.991
TE	0.847	0.004	0.049	0.761	0.953

*CDE = controlled direct effect; NIE = natural indirect effect; TE = total effect

Table F-6: Full output of mediation model 2 among existing statin users; COC as exposure, cardiovascular hospitalisation as outcome, exposure and mediator measured concurrently

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	0.082	0.076	1.08	0.281	-0.067	0.231
MPR	-0.389	0.082	-4.77	<0.001	-0.549	-0.229
Regularity	-0.037	0.015	-2.49	0.013	-0.067	-0.008
Frequency	0.022	0.003	8.94	<0.001	0.017	0.027
RxRisk comorbs in previous five years	0.089	0.008	11.74	<0.001	0.074	0.104
Age	0.014	0.005	3.03	0.002	0.005	0.023
Retired	-0.107	0.048	-2.22	0.026	-0.201	-0.012
High blood pressure	0.080	0.044	1.81	0.071	-0.007	0.166
Lang. other than English at home	-0.155	0.075	-2.07	0.038	-0.302	-0.008
Statins for secondary prevention	0.595	0.056	10.53	<0.001	0.484	0.705
Heart disease diagnosis	0.207	0.052	3.95	<0.001	0.104	0.310
Vigorous exercise at least once weekly	-0.078	0.042	-1.89	0.059	-0.160	0.003
Current smoker	0.063	0.079	0.79	0.427	-0.092	0.217
Constant	-4.120	0.293	-14.04	<0.001	-4.696	-3.545

Part 2: Mediator on exposure and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	0.023	0.005	4.74	<0.001	0.014	0.033
Regularity	0.010	0.001	10.35	<0.001	0.008	0.012
Frequency	-0.001	0.000	-4.72	<0.001	-0.001	-0.001
RxRisk comorbs in previous five years	0.004	0.001	8.36	<0.001	0.003	0.006
Age	0.003	0.000	10.23	<0.001	0.002	0.004
Retired	0.032	0.003	9.98	<0.001	0.026	0.038
High blood pressure	0.027	0.003	9.29	<0.001	0.021	0.033
Lang. other than English at home	-0.040	0.005	-8.33	<0.001	-0.049	-0.031
Statins for secondary prevention	0.007	0.004	1.99	0.046	0.000	0.015
Heart disease diagnosis	0.017	0.004	4.32	<0.001	0.009	0.025

Vigorous exercise at least once weekly	-0.002	0.003	-0.89	0.371	-0.008	0.003
Current smoker	-0.031	0.005	-5.78	<0.001	-0.041	-0.020
Constant	0.554	0.019	29.32	<0.001	0.517	0.591

Part 3: Effects summary

	Estimate	Bias	Bstrap SE	Lower	Upper
CDE	1.085	0.003	0.084	0.953	1.314
NIE	0.991	0.000	0.003	0.984	0.996
TE	1.075	0.003	0.083	0.942	1.307

*CDE = controlled direct effect; NIE = natural indirect effect; TE = total effect

Table F-7: Full output of mediation model 3 among existing statin users; regularity as exposure, cardiovascular ED presentation as outcome, exposure and mediator measured concurrently

Part 1: Outcome on exposure, mediator and covariates

	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	-0.013	0.016	-0.8	0.427	-0.043	0.018
MPR	-0.294	0.073	-4.05	<0.001	-0.436	-0.152
COC	0.004	0.080	0.06	0.956	-0.151	0.160
Frequency	0.015	0.003	5.8	<0.001	0.010	0.021
RxRisk comorbs in previous five years	0.099	0.008	12.45	<0.001	0.084	0.115
Age	0.034	0.005	7.08	<0.001	0.024	0.043
Retired	-0.216	0.050	-4.3	<0.001	-0.314	-0.117
High blood pressure	0.098	0.046	2.13	0.033	0.008	0.189
Lang. other than English at home	-0.245	0.081	-3.02	0.003	-0.404	-0.086
Statins for secondary prevention	0.771	0.059	13.08	<0.001	0.656	0.887
Heart disease diagnosis	0.117	0.053	2.2	0.028	0.013	0.221
Vigorous exercise at least once weekly	-0.014	0.043	-0.32	0.746	-0.099	0.071
Current smoker	0.030	0.085	0.36	0.721	-0.137	0.197
Constant	-5.668	0.0Robins	-18.4	<0.001	-6.272	-5.065

Part 2: Mediator on exposure and covariates

	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	0.010	0.001	8.29	<0.001	0.008	0.013
COC	0.036	0.006	5.99	<0.001	0.024	0.048
Frequency	-0.002	0.000	-6.69	<0.001	-0.002	-0.001
RxRisk comorbs in previous five years	0.013	0.001	19.07	<0.001	0.011	0.014
Age	0.005	0.000	14.1	<0.001	0.005	0.006
Retired	0.044	0.004	11.19	<0.001	0.037	0.052
High blood pressure	0.029	0.004	7.94	<0.001	0.021	0.036
Lang. other than English at home	-0.042	0.006	-7.09	<0.001	-0.054	-0.031
Statins for secondary prevention	0.002	0.005	0.48	0.631	-0.007	0.011
Heart disease diagnosis	0.026	0.005	5.31	<0.001	0.016	0.036
Vigorous exercise at least once weekly	-0.003	0.003	-0.78	0.435	-0.009	0.004
Current smoker	-0.020	0.007	-3.06	0.002	-0.033	-0.007
Constant	0.310	0.023	13.2	<0.001	0.264	0.356

Part 3: Effects summary

	Estimate	Bias	Bstrap SE	Lower	Upper
CDE	0.951	-0.001	0.060	0.835	1.072
NIE	0.988	0.000	0.003	0.981	0.994
TE	0.940	-0.001	0.059	0.828	1.058

*CDE = controlled direct effect; NIE = natural indirect effect; TE = total effect

Table F-8: Full output of mediation model 4 among existing statin users; COC as exposure, cardiovascular ED presentation as outcome, exposure and mediator measured concurrently

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	0.004	0.080	0.06	0.956	-0.151	0.160
MPR	-0.294	0.073	-4.05	<0.001	-0.436	-0.152
Regularity	-0.013	0.016	-0.8	0.427	-0.043	0.018
Frequency	0.015	0.003	5.8	<0.001	0.010	0.021
RxRisk comorbs in previous five years	0.099	0.008	12.45	<0.001	0.084	0.115
Age	0.034	0.005	7.08	<0.001	0.024	0.043
Retired	-0.216	0.050	-4.3	<0.001	-0.314	-0.117
High blood pressure	0.098	0.046	2.13	0.033	0.008	0.189
Lang. other than English at home	-0.245	0.081	-3.02	0.003	-0.404	-0.086
Statins for secondary prevention	0.771	0.059	13.08	<0.001	0.656	0.887
Heart disease diagnosis	0.117	0.053	2.2	0.028	0.013	0.221
Vigorous exercise at least once weekly	-0.014	0.043	-0.32	0.746	-0.099	0.071
Current smoker	0.030	0.085	0.36	0.721	-0.137	0.197
Constant	-5.668	0.0Robins	-18.4	<0.001	-6.272	-5.065
Part 2: Mediator on exposure and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	0.036	0.006	5.99	<0.001	0.024	0.048
Regularity	0.010	0.001	8.29	<0.001	0.008	0.013
Frequency	-0.002	0.000	-6.69	<0.001	-0.002	-0.001
RxRisk comorbs in previous five years	0.013	0.001	19.07	<0.001	0.011	0.014
Age	0.005	0.000	14.1	<0.001	0.005	0.006
Retired	0.044	0.004	11.19	<0.001	0.037	0.052
High blood pressure	0.029	0.004	7.94	<0.001	0.021	0.036
Lang. other than English at home	-0.042	0.006	-7.09	<0.001	-0.054	-0.031
Statins for secondary prevention	0.002	0.005	0.48	0.631	-0.007	0.011
Heart disease diagnosis	0.026	0.005	5.31	<0.001	0.016	0.036
Vigorous exercise at least once weekly	-0.003	0.003	-0.78	0.435	-0.009	0.004
Current smoker	-0.020	0.007	-3.06	0.002	-0.033	-0.007
Constant	0.310	0.023	13.2	<0.001	0.264	0.356
Part 3: Effects summary						
	Estimate	Bias	Bstrap SE	Lower	Upper	
CDE	1.004	0.004	0.077	0.850	1.149	
NIE	0.990	0.000	0.003	0.981	0.995	
TE	0.994	0.004	0.077	0.839	1.141	

*CDE = controlled direct effect; NIE = natural indirect effect; TE = total effect

Table F-9: Full output of mediation model 5 among existing statin users; regularity as exposure, cardiovascular hospitalisation as outcome, exposure and mediator measured consecutively

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	-0.048	0.025	-1.97	0.049	-0.097	0.000
MPR	-0.537	0.125	-4.28	<0.001	-0.782	-0.291
COC	-0.027	0.124	-0.22	0.827	-0.271	0.217
Frequency	0.022	0.004	5.85	<0.001	0.014	0.029
RxRisk comorbs in previous five years	0.113	0.012	9.39	<0.001	0.089	0.137
Age	0.023	0.007	3.08	0.002	0.008	0.037

Retired	-0.180	0.078	-2.31	0.021	-0.332	-0.027
High blood pressure	0.039	0.071	0.55	0.581	-0.101	0.180
Lang. other than English at home	0.111	0.110	1.01	0.315	-0.105	0.326
Statins for secondary prevention	0.620	0.093	6.67	<0.001	0.438	0.802
Heart disease diagnosis	0.187	0.083	2.26	0.024	0.025	0.350
Vigorous exercise at least once weekly	-0.013	0.067	-0.19	0.851	-0.145	0.120
Current smoker	0.059	0.127	0.46	0.644	-0.190	0.307
Constant	-5.811	0.479	-12.13	<0.001	-6.750	-4.872

Part 2: Mediator on exposure and covariates

	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	0.010	0.001	10.35	<0.001	0.008	0.012
COC	0.023	0.005	4.74	<0.001	0.014	0.033
Frequency	-0.001	0.000	-4.72	<0.001	-0.001	-0.001
RxRisk comorbs in previous five years	0.004	0.001	8.36	<0.001	0.003	0.006
Age	0.003	0.000	10.23	<0.001	0.002	0.004
Retired	0.032	0.003	9.98	<0.001	0.026	0.038
High blood pressure	0.027	0.003	9.29	<0.001	0.021	0.033
Lang. other than English at home	-0.040	0.005	-8.33	<0.001	-0.049	-0.031
Statins for secondary prevention	0.007	0.004	1.99	0.046	0.000	0.015
Heart disease diagnosis	0.017	0.004	4.32	<0.001	0.009	0.025
Vigorous exercise at least once weekly	-0.002	0.003	-0.89	0.371	-0.008	0.003
Current smoker	-0.031	0.005	-5.78	<0.001	-0.041	-0.020
Constant	0.554	0.019	29.32	<0.001	0.517	0.591

Part 3: Effects summary

	Estimate	Bias	Bstrap SE	Lower	Upper
CDE	0.824	0.011	0.081	0.671	0.993
NIE	0.978	0.000	0.006	0.967	0.990
TE	0.806	0.011	0.080	0.650	0.968

*CDE = controlled direct effect; NIE = natural indirect effect; TE = total effect

Table F-10: Full output of mediation model 6 among existing statin users; COC as exposure, cardiovascular hospitalisation as outcome, exposure and mediator measured consecutively

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	-0.027	0.124	-0.22	0.827	-0.271	0.217
MPR	-0.537	0.125	-4.28	<0.001	-0.782	-0.291
Regularity	-0.048	0.025	-1.97	0.049	-0.097	0.000
Frequency	0.022	0.004	5.85	<0.001	0.014	0.029
RxRisk comorbs in previous five years	0.113	0.012	9.39	<0.001	0.089	0.137
Age	0.023	0.007	3.08	0.002	0.008	0.037
Retired	-0.180	0.078	-2.31	0.021	-0.332	-0.027
High blood pressure	0.039	0.071	0.55	0.581	-0.101	0.180
Lang. other than English at home	0.111	0.110	1.01	0.315	-0.105	0.326
Statins for secondary prevention	0.620	0.093	6.67	<0.001	0.438	0.802
Heart disease diagnosis	0.187	0.083	2.26	0.024	0.025	0.350
Vigorous exercise at least once weekly	-0.013	0.067	-0.19	0.851	-0.145	0.120
Current smoker	0.059	0.127	0.46	0.644	-0.190	0.307
Constant	-5.811	0.479	-12.13	<0.001	-6.750	-4.872

Part 2: Mediator on exposure and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	0.023	0.005	4.74	<0.001	0.014	0.033

Regularity	0.010	0.001	10.35	<0.001	0.008	0.012
Frequency	-0.001	0.000	-4.72	<0.001	-0.001	-0.001
RxRisk comorbs in previous five years	0.004	0.001	8.36	<0.001	0.003	0.006
Age	0.003	0.000	10.23	<0.001	0.002	0.004
Retired	0.032	0.003	9.98	<0.001	0.026	0.038
High blood pressure	0.027	0.003	9.29	<0.001	0.021	0.033
Lang. other than English at home	-0.040	0.005	-8.33	<0.001	-0.049	-0.031
Statins for secondary prevention	0.007	0.004	1.99	0.046	0.000	0.015
Heart disease diagnosis	0.017	0.004	4.32	<0.001	0.009	0.025
Vigorous exercise at least once weekly	-0.002	0.003	-0.89	0.371	-0.008	0.003
Current smoker	-0.031	0.005	-5.78	<0.001	-0.041	-0.020
Constant	0.554	0.019	29.32	<0.001	0.517	0.591

Part 3: Effects summary

	Estimate	Bias	Bstrap SE	Lower	Upper
CDE	0.973	0.006	0.115	0.790	1.236
NIE	0.988	0.000	0.004	0.980	0.994
TE	0.962	0.006	0.113	0.775	1.218

*CDE = controlled direct effect; NIE = natural indirect effect; TE = total effect

Table F-11: Full output of mediation model 7 among existing statin users; regularity as exposure, cardiovascular ED presentation as outcome, exposure and mediator measured consecutively

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	-0.017	0.025	-0.68	0.497	-0.065	0.032
MPR	-0.274	0.112	-2.45	0.014	-0.494	-0.054
COC	-0.240	0.124	-1.93	0.053	-0.484	0.003
Frequency	0.018	0.004	4.54	<0.001	0.010	0.025
RxRisk comorbs in previous five years	0.112	0.012	9.17	<0.001	0.088	0.136
Age	0.020	0.007	2.69	0.007	0.005	0.035
Retired	-0.019	0.079	-0.24	0.807	-0.174	0.136
High blood pressure	0.166	0.073	2.27	0.023	0.023	0.309
Lang. other than English at home	0.006	0.116	0.05	0.961	-0.222	0.233
Statins for secondary prevention	0.703	0.091	7.77	<0.001	0.526	0.881
Heart disease diagnosis	-0.023	0.082	-0.28	0.779	-0.184	0.138
Vigorous exercise at least once weekly	0.027	0.068	0.4	0.690	-0.106	0.160
Current smoker	0.293	0.120	2.45	0.014	0.059	0.528
Constant	-5.899	0.482	-12.25	<0.001	-6.842	-4.955

Part 2: Mediator on exposure and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	0.010	0.001	8.29	<0.001	0.008	0.013
COC	0.036	0.006	5.99	<0.001	0.024	0.048
Frequency	-0.002	0.000	-6.69	<0.001	-0.002	-0.001
RxRisk comorbs in previous five years	0.013	0.001	19.07	<0.001	0.011	0.014
Age	0.005	0.000	14.1	<0.001	0.005	0.006
Retired	0.044	0.004	11.19	<0.001	0.037	0.052
High blood pressure	0.029	0.004	7.94	<0.001	0.021	0.036
Lang. other than English at home	-0.042	0.006	-7.09	<0.001	-0.054	-0.031
Statins for secondary prevention	0.002	0.005	0.48	0.631	-0.007	0.011
Heart disease diagnosis	0.026	0.005	5.31	<0.001	0.016	0.036
Vigorous exercise at least once weekly	-0.003	0.003	-0.78	0.435	-0.009	0.004
Current smoker	-0.020	0.007	-3.06	0.002	-0.033	-0.007

Constant	0.310	0.023	13.2	<0.001	0.264	0.356
Part 3: Effects summary						
	Estimate	Bias	Bstrap SE	Lower	Upper	
CDE	0.935	0.006	0.096	0.760	1.140	
NIE	0.989	0.000	0.005	0.980	0.997	
TE	0.925	0.006	0.095	0.752	1.127	

Table F-12: Full output of mediation model 8 among existing statin users; COC as exposure, cardiovascular ED presentation as outcome, exposure and mediator measured consecutively

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	-0.240	0.124	-1.93	0.053	-0.484	0.003
MPR	-0.274	0.112	-2.45	0.014	-0.494	-0.054
Regularity	-0.017	0.025	-0.68	0.497	-0.065	0.032
Frequency	0.018	0.004	4.54	<0.001	0.010	0.025
RxRisk comorbs in previous five years	0.112	0.012	9.17	<0.001	0.088	0.136
Age	0.020	0.007	2.69	0.007	0.005	0.035
Retired	-0.019	0.079	-0.24	0.807	-0.174	0.136
High blood pressure	0.166	0.073	2.27	0.023	0.023	0.309
Lang. other than English at home	0.006	0.116	0.05	0.961	-0.222	0.233
Statins for secondary prevention	0.703	0.091	7.77	<0.001	0.526	0.881
Heart disease diagnosis	-0.023	0.082	-0.28	0.779	-0.184	0.138
Vigorous exercise at least once weekly	0.027	0.068	0.4	0.690	-0.106	0.160
Current smoker	0.293	0.120	2.45	0.014	0.059	0.528
Constant	-5.899	0.482	-12.25	<0.001	-6.842	-4.955
Part 2: Mediator on exposure and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	0.036	0.006	5.99	<0.001	0.024	0.048
Regularity	0.010	0.001	8.29	<0.001	0.008	0.013
Frequency	-0.002	0.000	-6.69	<0.001	-0.002	-0.001
RxRisk comorbs in previous five years	0.013	0.001	19.07	<0.001	0.011	0.014
Age	0.005	0.000	14.1	<0.001	0.005	0.006
Retired	0.044	0.004	11.19	<0.001	0.037	0.052
High blood pressure	0.029	0.004	7.94	<0.001	0.021	0.036
Lang. other than English at home	-0.042	0.006	-7.09	<0.001	-0.054	-0.031
Statins for secondary prevention	0.002	0.005	0.48	0.631	-0.007	0.011
Heart disease diagnosis	0.026	0.005	5.31	<0.001	0.016	0.036
Vigorous exercise at least once weekly	-0.003	0.003	-0.78	0.435	-0.009	0.004
Current smoker	-0.020	0.007	-3.06	0.002	-0.033	-0.007
Constant	0.310	0.023	13.2	<0.001	0.264	0.356
Part 3: Effects summary						
	Estimate	Bias	Bstrap SE	Lower	Upper	
CDE	0.788	0.005	0.094	0.626	0.978	
NIE	0.990	0.000	0.004	0.981	0.998	
TE	0.780	0.005	0.094	0.615	0.977	

*CDE = controlled direct effect; NIE = natural indirect effect; TE = total effect

F.7 Full mediation model outputs, cohort of potential statin users

Table F-13: Full output of mediation model 1 among potential statin users; hospitalisation as outcome, regularity as exposure

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	0.001	0.018	0.06	0.949	-0.034	0.037
Initiation	0.055	0.058	0.94	0.348	-0.060	0.169
COC	-0.109	0.086	-1.28	0.202	-0.277	0.058
Frequency	0.022	0.003	7.20	<0.001	0.016	0.028
RxRisk comorbs in previous five years	0.079	0.009	8.29	<0.001	0.060	0.097
Age	0.034	0.005	6.46	<0.001	0.024	0.045
Retired	-0.121	0.058	-2.09	0.036	-0.234	-0.008
High blood pressure	0.029	0.051	0.57	0.570	-0.072	0.130
Lang. other than English at home	-0.084	0.092	-0.92	0.359	-0.026	0.095
Statins for secondary prevention	0.587	0.068	8.70	<0.001	0.045	0.719
Heart disease diagnosis	0.089	0.072	1.22	0.221	-0.053	0.230
Vigorous exercise at least once weekly	0.064	0.050	1.27	0.203	-0.034	0.161
Current smoker	0.106	0.089	1.19	0.233	-0.068	0.280
Constant	-5.716	0.336	-17.00	<0.001	-6.375	-5.057
Part 2: Mediator on exposure and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	0.024	0.011	2.12	0.034	0.002	0.047
CoC	0.175	0.053	3.28	0.001	0.071	0.280
Frequency	-0.026	0.003	-10.24	<0.001	-0.031	-0.021
RxRisk comorbs in previous five years	0.293	0.006	46.39	<0.001	0.281	0.306
Age	-0.010	0.003	-3.04	0.002	-0.017	-0.004
Retired	-0.030	0.037	-0.84	0.399	-0.102	0.041
High blood pressure	0.210	0.033	6.41	<0.001	0.146	0.274
Lang. other than English at home	0.266	0.055	4.81	<0.001	0.157	0.374
Statins for secondary prevention	0.540	0.044	12.26	<0.001	0.454	0.627
Heart disease diagnosis	0.357	0.050	7.19	<0.001	0.259	0.454
Vigorous exercise at least once weekly	0.018	0.031	0.59	0.557	-0.043	0.080
Current smoker	-0.244	0.059	-4.17	<0.001	-0.359	-0.129
Constant	-2.244	0.212	10.60	<0.001	-2.659	-1.829
Part 3: Effects summary						
	Estimate	Bias	Bstrap SE	Lower CI	Upper CI	
CDE	1.005	-0.001	0.074	0.868	1.169	
NDE	1.005	-0.001	0.074	0.868	1.169	
NIE	1.001	0.000	0.001	0.999	1.004	
MTE	1.005	-0.001	0.074	0.868	1.168	

*CDE = Controlled Direct Effect, NDE = Natural Direct Effect, NIE = Natural Indirect Effect, MTE = Marginal Total Effect

Table F-14: Full output of mediation model 2 among potential statin users; hospitalisation as outcome, COC as exposure

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	-0.109	0.086	-1.28	0.202	-0.277	0.058

Initiation	0.055	0.058	0.94	0.348	-0.060	0.169
Regularity	0.001	0.018	0.06	0.949	-0.034	0.037
Frequency	0.022	0.003	7.20	<0.001	0.016	0.028
RxRisk comorbs in previous five years	0.079	0.009	8.29	<0.001	0.060	0.097
Age	0.034	0.005	6.46	<0.001	0.024	0.045
Retired	-0.121	0.058	-2.09	0.036	-0.234	-0.008
High blood pressure	0.029	0.051	0.57	0.570	-0.072	0.130
Lang. other than English at home	-0.084	0.092	-0.92	0.359	-0.026	0.095
Statins for secondary prevention	0.587	0.068	8.70	<0.001	0.045	0.719
Heart disease diagnosis	0.089	0.072	1.22	0.221	-0.053	0.230
Vigorous exercise at least once weekly	0.064	0.050	1.27	0.203	-0.034	0.161
Current smoker	0.106	0.089	1.19	0.233	-0.068	0.280
Constant	-5.716	0.336	-17.00	<0.001	-6.375	-5.057

Part 2: Mediator on exposure and covariates

	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	0.175	0.053	3.28	0.001	0.071	0.280
Regularity	0.024	0.011	2.12	0.034	0.002	0.047
Frequency	-0.026	0.003	-10.24	<0.001	-0.031	-0.021
RxRisk comorbs in previous five years	0.293	0.006	46.39	<0.001	0.281	0.306
Age	-0.010	0.003	-3.04	0.002	-0.017	-0.004
Retired	-0.030	0.037	-0.84	0.399	-0.102	0.041
High blood pressure	0.210	0.033	6.41	<0.001	0.146	0.274
Lang. other than English at home	0.266	0.055	4.81	<0.001	0.157	0.374
Statins for secondary prevention	0.540	0.044	12.26	<0.001	0.454	0.627
Heart disease diagnosis	0.357	0.050	7.19	<0.001	0.259	0.454
Vigorous exercise at least once weekly	0.018	0.031	0.59	0.557	-0.043	0.080
Current smoker	-0.244	0.059	-4.17	<0.001	-0.359	-0.129
Constant	-2.244	0.212	10.60	<0.001	-2.659	-1.829

Part 3: Effects summary

	Estimate	Bias	Bstrap SE	Lower CI	Upper CI
CDE	0.896	0.003	0.077	0.748	1.050
NDE	0.896	0.003	0.077	0.748	1.050
NIE	1.001	0.000	0.002	0.999	1.006
MTE	0.898	0.003	0.077	0.751	1.053

*CDE = Controlled Direct Effect, NDE = Natural Direct Effect, NIE = Natural Indirect Effect, MTE = Marginal Total Effect

Table F-15: Full output of mediation model 3 among potential statin users; emergency department presentations as outcome, regularity as exposure

Part 1: Outcome on exposure, mediator and covariates						
	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	-0.037	0.031	-1.20	0.230	-0.098	0.023
Initiation	-0.178	0.101	-1.77	0.077	-0.375	0.020
COC	-0.108	0.147	-0.73	0.465	-0.397	0.181
Frequency	0.015	0.005	3.16	0.002	0.006	0.026
RxRisk comorbs in previous five years	0.109	0.016	6.97	<0.001	0.079	0.140
Age	0.036	0.009	3.99	<0.001	0.018	0.054
Retired	-0.069	0.098	-0.70	0.482	-0.261	0.123
High blood pressure	0.060	0.088	0.69	0.492	-0.112	0.233
Lang. other than English at home	0.029	0.150	0.19	0.846	-0.265	0.324
Statins for secondary prevention	0.795	0.110	7.21	<0.001	0.579	1.011

Heart disease diagnosis	-0.079	0.116	-0.68	0.496	-0.307	0.149
Vigorous exercise at least once weekly	0.200	0.086	2.33	0.020	0.031	0.368
Current smoker	0.178	0.148	1.20	0.230	-0.113	0.468
Constant	-7.184	0.577	12.45	<0.001	-8.316	-6.053

Part 2: Mediator on exposure and covariates

	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
Regularity	0.024	0.011	2.12	0.034	0.002	0.047
COC	0.175	0.053	3.28	0.001	0.071	0.280
Frequency	-0.026	0.003	-10.24	<0.001	-0.031	-0.021
RxRisk comorbs in previous five years	0.293	0.006	46.39	<0.001	0.281	0.306
Age	-0.010	0.003	-3.04	0.002	-0.017	-0.004
Retired	-0.030	0.037	-0.84	0.399	-0.102	0.041
High blood pressure	0.210	0.033	6.41	<0.001	0.146	0.274
Lang. other than English at home	0.266	0.055	4.81	<0.001	0.157	0.374
Statins for secondary prevention	0.540	0.044	12.26	<0.001	0.454	0.627
Heart disease diagnosis	0.357	0.050	7.19	<0.001	0.259	0.454
Vigorous exercise at least once weekly	0.018	0.031	0.59	0.557	-0.043	0.080
Current smoker	-0.244	0.059	-4.17	<0.001	-0.359	-0.129
Constant	-2.244	0.212	10.60	<0.001	-2.659	-1.829

Part 3: Effects summary

	Estimate	Bias	Bstrap SE	Lower CI	Upper CI
CDE	0.862	0.007	0.105	0.673	1.076
NDE	0.862	0.007	0.105	0.673	1.076
NIE	0.998	0.000	0.002	0.992	0.999
MTE	0.860	0.008	0.104	0.670	1.075

*CDE = Controlled Direct Effect, NDE = Natural Direct Effect, NIE = Natural Indirect Effect, MTE =

Marginal Total Effect

Table F-16: Full output of mediation model 4 among potential statin users; emergency department presentation as outcome, COC as exposure

Part 1: Outcome on exposure, mediator and covariates

	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	-0.108	0.147	-0.73	0.465	-0.397	0.181
Initiation	-0.178	0.101	-1.77	0.077	-0.375	0.020
Regularity	-0.037	0.031	-1.20	0.230	-0.098	0.023
Frequency	0.015	0.005	3.16	0.002	0.006	0.026
RxRisk comorbs in previous five years	0.109	0.016	6.97	<0.001	0.079	0.140
Age	0.036	0.009	3.99	<0.001	0.018	0.054
Retired	-0.069	0.098	-0.70	0.482	-0.261	0.123
High blood pressure	0.060	0.088	0.69	0.492	-0.112	0.233
Lang. other than English at home	0.029	0.150	0.19	0.846	-0.265	0.324
Statins for secondary prevention	0.795	0.110	7.21	<0.001	0.579	1.011
Heart disease diagnosis	-0.079	0.116	-0.68	0.496	-0.307	0.149
Vigorous exercise at least once weekly	0.200	0.086	2.33	0.020	0.031	0.368
Current smoker	0.178	0.148	1.20	0.230	-0.113	0.468
Constant	-7.184	0.577	12.45	<0.001	-8.316	-6.053

Part 2: Mediator on exposure and covariates

	Coef.	Std. Err.	z	P>z	Lower CI	Upper CI
COC	0.175	0.053	3.28	0.001	0.071	0.280
Regularity	0.024	0.011	2.12	0.034	0.002	0.047

Frequency	-0.026	0.003	-10.24	<0.001	-0.031	-0.021
RxRisk comorbs in previous five years	0.293	0.006	46.39	<0.001	0.281	0.306
Age	-0.010	0.003	-3.04	0.002	-0.017	-0.004
Retired	-0.030	0.037	-0.84	0.399	-0.102	0.041
High blood pressure	0.210	0.033	6.41	<0.001	0.146	0.274
Lang. other than English at home	0.266	0.055	4.81	<0.001	0.157	0.374
Statins for secondary prevention	0.540	0.044	12.26	<0.001	0.454	0.627
Heart disease diagnosis	0.357	0.050	7.19	<0.001	0.259	0.454
Vigorous exercise at least once weekly	0.018	0.031	0.59	0.557	-0.043	0.080
Current smoker	-0.244	0.059	-4.17	<0.001	-0.359	-0.129
Constant	-2.244	0.212	10.60	<0.001	-2.659	-1.829

Part 3: Effects summary

	Estimate	Bias	Bstrap SE	Lower CI	Upper CI
CDE	0.898	0.005	0.142	0.665	1.248
NDE	0.898	0.005	0.142	0.665	1.248
NIE	0.996	0.000	0.003	0.988	0.999
MTE	0.894	0.005	0.141	0.664	1.246

*CDE = Controlled Direct Effect, NDE = Natural Direct Effect, NIE = Natural Indirect Effect, MTE =

Marginal Total Effect

Appendix G Attribution statements



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02 Aug 2021

To whom it may concern,

I, David Youens, had a major contribution to the conceptualisation, coordination, and implementation of the research which resulted in the following manuscript:

Youens, D., Robinson, S., Doust, J., Harris, MN., Moorin, R. Associations between regular GP contact, diabetes monitoring and glucose control: an observational study using general practice data. Under review at *BMJ Open*.

I contributed to a significant extent to the conceptualisation, data analysis, drafting, writing and editing of the manuscript under review above which is used for my PhD thesis. Accordingly I am the lead author on this submission.

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Youens, D., Harris, M., Robinson, S., Preen, DB., Moorin, RE., 2019. Regularity of contact with GPs: Measurement approaches to improve valid associations with hospitalization. *Family Practice* 36(5): 650-656. DOI: 10.1093/fampra/cmz002.

I contributed to a significant extent to the conceptualisation, data analysis, drafting, writing and editing of the paper above which is used for my PhD thesis. Accordingly I am the lead author on this publication.

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I, David Youens, had a major contribution to the conceptualisation, coordination, and implementation of the research which resulted in the following paper:

Youens, D., Preen, D B., Harris, M., Wright, C., Moorin, R., 2021. Regularity of contact with general practitioners and diabetes-related hospitalisation through a period of policy change: a retrospective cohort study. *Health Services Management Research*, published online ahead of print. DOI: 10.1177/09514848211020866

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I, as co-author, endorse that this level of contribution by the candidate indicated above is appropriate.

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Youens, D., Doust, J., Robinson, S., Moorin, R., 2021. Regularity and Continuity of GP Contacts and Use of Statins Amongst People at Risk of Cardiovascular Events. *Journal of General Internal Medicine* 36(6): 1656-1665. DOI: 10.1007/s11606-021-06638-3.

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