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

Running head: Measuring regularity of General Practitioner contact

Article category: Research methods

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Key messages

- Regularity of General Practitioner (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

Abstract

Background: Studies examine longitudinal continuity of General Practitioner (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 hospitalisation.

Methods: A cohort at risk of diabetes-related hospitalisation in Western Australia from 1990-2004 was identified using linked administrative data. For each regularity index, relationships with number of GP contacts were assessed. Hospitalisation 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 to existing indices. Associations with hospitalisation differed between measures; for previously published indices there were no significant associations between regularity and hospitalisation whereas on the new index most regular GP contact was associated with reduced hospitalisation (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 hospitalisation

Keywords: Continuity of Patient Care, Diabetes Mellitus, General Practice, Health Policy, Health Services Research, Research Design

Background

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 (5, 6). Most of these measures aim simply to summarise whether patients consistently receive care through the same provider(s), contrasting with the breadth of definitions of continuity of care (4, 5). 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 1(a) displays the difference between regularity and frequency of contacts.

One Australian study has assessed the impact of regular GP contacts on hospitalisation 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 hypothesised that regular GP visits would allow early recognition of changes in condition and treatment adjustment, while the American research hypothesised 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 two-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 (11), 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 hospitalised, hence associations between regularity and hospital use may be confounded by frequency. This confounding is displayed in Figure 1(b). 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 hospitalisation.

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 (14)) 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 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 (15) 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 (16). 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 (17).

Cohort at risk of diabetes hospitalisation

A cohort at risk of diabetes hospitalisation was identified as described previously (16). 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: (a) diagnosis in hospital; (b) diabetes cycle of care consultation in MBS data; or (c) quantitation of HbA1c in MBS data twice within six months. Likely diabetes was identified by: (a) diagnosis of impaired glucose function in hospital; (b) an oral glucose tolerance test outside of pregnancy in MBS data; or (c) HbA1c quantitation once within six months. Codes are detailed in Supplementary table S1.

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, 18). 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 (11) (hence should not differ between those with a high mean number of days between GP contacts compared to 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.

Hospitalisation outcomes

Outcomes were diabetes-related hospitalisations, including potentially preventable hospitalisations (19) and other hospitalisations where diabetes increases risk (20). Codes are listed in Supplementary table S1. A hospitalisation 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 one year.

Covariates

The administrative data listed sex, age and Indigenous status. Socioeconomic status and residential remoteness were obtained from national indices based on postcodes (21, 22). 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 hospitalisation records, and compared to the Charlson index resulted in improved correction of mortality and hospitalisation outcomes (23). Comorbidity was recorded as the count of MACSS conditions in each patient's hospitalisation records in the preceding 5 years (24), updated annually. Diabetes risk level was a covariate in models. Further details are provided in Supplementary table S2.

Descriptive statistics

Analyses were performed using Stata SE version 14.2 (25).

Sex, age, Indigenous status, socio-economic status, remoteness, diabetes risk level, annual hospital use and primary care contacts were summarised. 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 1(b)). 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 was compared to 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 to 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 hospitalisation was assessed by regressing the number of diabetes-related hospitalisations on each regularity index.

Diabetes-related hospitalisation 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 Figure 1(b)) 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 hospitalisations), 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 enrolees, 88.1% had no diabetes hospitalisation 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 >=2 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 ten 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 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 (Figure 2(a-c)). For the variance index and the interval index these associations were positive (Figure 2(a) and 2(c) respectively), i.e. frequency increased with greater regularity, while the relative variance index showed the reverse. Coefficients were smallest for the relative variance score indicating the weakest association between regularity and frequency (Figure 2(b)). 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 to 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 to 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 2(d-f). For the variance index (Figure 2(d)) being in the most regular group was associated with a small, non-significant reduction in the hospitalisation rate in the following year compared to 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 to 0.96) though the middle two categories remained non-significant. For the relative variance index (Figure 2(e)) being in the most regular group was associated with a significant reduction in hospitalisation compared to baseline (IRR 0.90, CI 0.88 to 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 (Figure 2(f)), there were no significant differences observed between any level of regularity and hospitalisation. 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 to 1.08) to 0.99 (CI 0.95 to 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 hospitalisation rate were assessed, as hospitalisation is important to patients and funders and analysed often (26-28). For the relative variance index, most regular GP contact was associated with reduced hospitalisation in the following year compared to 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 hospitalisation, 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 hospitalisation. 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 hospitalisation 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 (29) 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 (30) and use of health services may have also changed. Associations reported here between regularity of GP contact and hospitalisation 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 hospitalisation, the major assumption was that sicker people are more likely to visit the GP and to be hospitalised. 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.

Ethical approval

Approval granted by University of Western Australia and Curtin University Human Research Ethics Committees which exempted the study from requiring patient consent.

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Conflicts of Interest

None to declare.

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Figure legends

Figure 1: Diagram A presents 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. Diagram B displays the hypothesised relationships between regularity of GP contacts, frequency of GP contacts and hospitalisation. Associations between regularity of GP contacts and hospitalisation may be confounded by frequency of GP contacts.

Figure 2: Outputs of regression models displating relationships between regularity of GP contact, frequency of GP contact and diabetes-related hospitalisation 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 hospitalisation 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 Austalian adults at risk of diabetes-related hospitalisation from 1990-2004. Covariates in all models 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 5-year comorbid condition count.

Figure 1

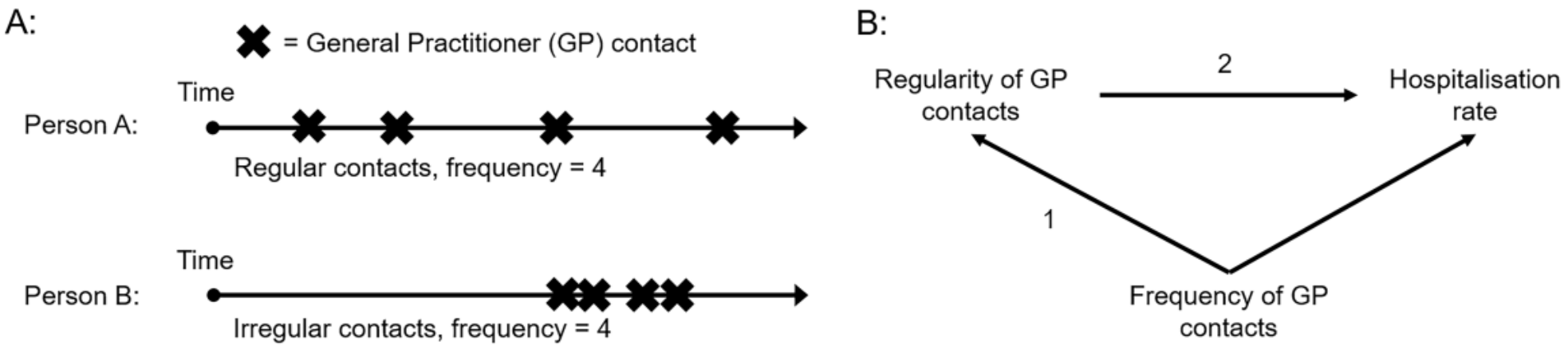

A:
= General Practitioner (GP) contact
Time
Person A:
Regular contacts, frequency = 4
Time
Person B:
Irregular contacts, frequency = 4
B:
Regularity of GP contacts
2
Hospitalisation rate
1
Frequency of GP contacts

Figure 2

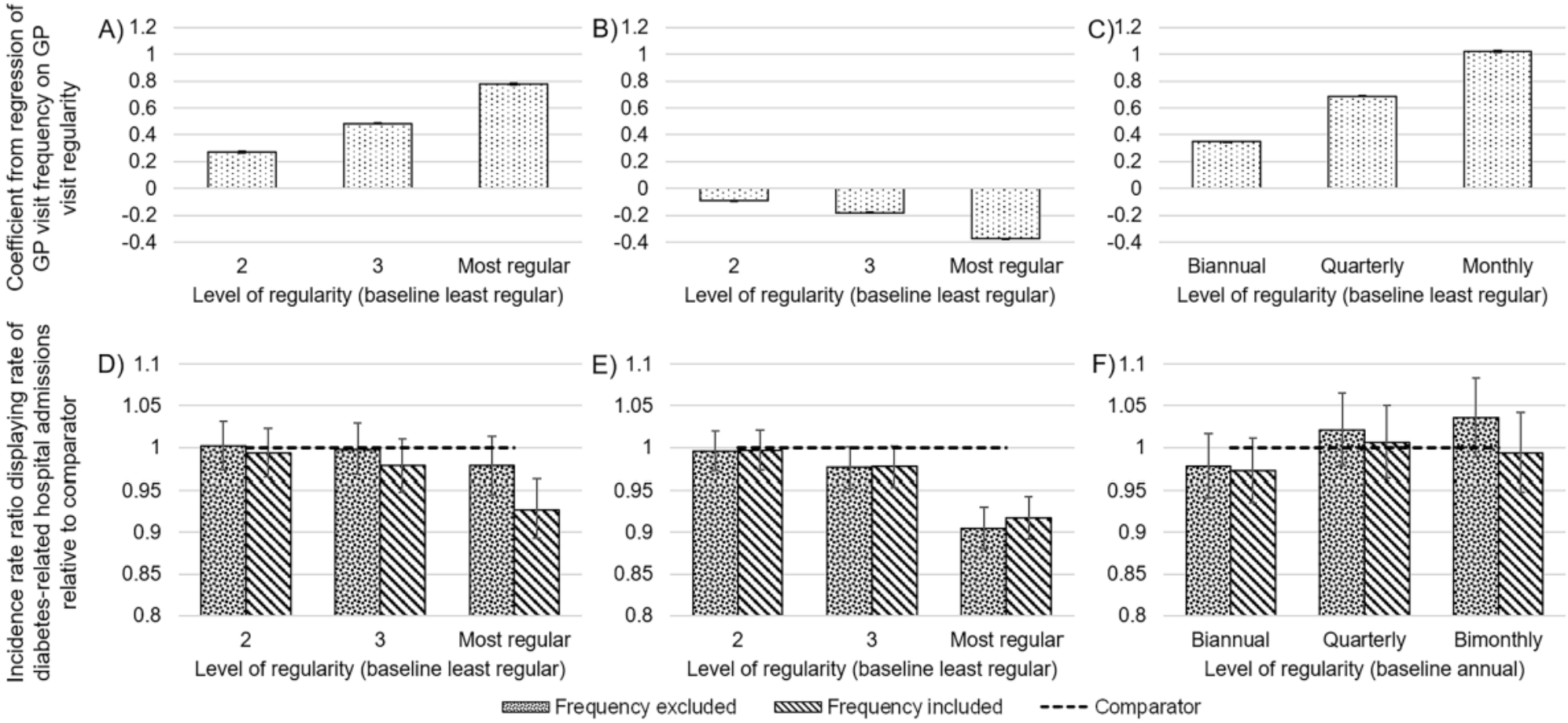
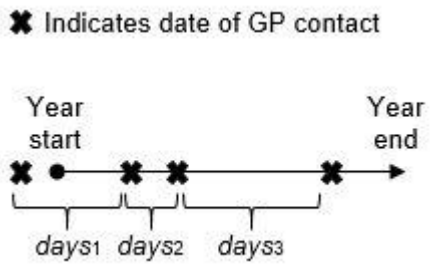

Coefficient from regression of GP visit frequency on GP visit regularity
A)
B)
C)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
2
3
Most regular
Biannual
Quarterly
Monthly
Level of regularity (baseline least regular)
Incidence rate ratio displaying rate of diabetes-related hospital admissions relative to comparator
D)
E)
F)
1.1
1.05
1
0.95
0.9
0.85
0.8
Bimonthly
Level of regularity (baseline annual)
Frequency excluded
Frequency included
Comparator

Table 1: Details on the three indices used to measure regularity of general practitioner contact.

Index	Method	Notes
Variance index	$r = \frac{1}{1 + var(days)}$	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, 18).
Relative variance index	$r = 1/(1 + \frac{sd(days)}{mean(days)} * 100)$	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.
Interval index	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.	Produces an ordinal 4-level variable. Person-years with fewer than two years are dropped to reflect the variance and relative variance indices and ensure identical cohorts for comparison. Similar approach to previously published index, with different intervals (9).



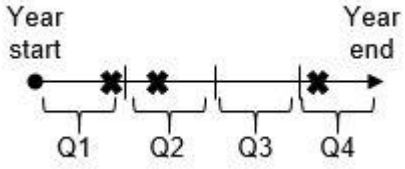


Table 2: Characteristics of the cohort at risk of diabetes-related hospitalisation identified via administrative data in Western Australia from 1990 to 2004. Characteristics separately described for individuals' first years in the study cohort and for all records.

	Variable	All records n(%)[1]
Sex	Female	354,797 (51.75)
	Male	330,826 (48.25)
SEIFA quintile[2]	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[2]	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[2]	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)[3]
	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**

[1] Number and percentage of all person-years in category

[2] Missing data accounting for 0.7% of records for Socio Economic 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.

[3] Mean and standard deviation values for all person-years

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.

	A: Crosstab of relative variance index and variance index				
Relative variance index	**Variance index**				
	Least regular	**2**	**3**	**Most regular**	**Total**
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**
	B: Crosstab of relative variance index and interval index				
	Variance index				
Interval index	**Least regular**	**2**	**3**	**Most regular**	**Total**
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**

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[1] and hospitalisations where diabetes is known to increase risk are those reported by Davis *et al*.[2]

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

[1] National Health Performance Authority. Healthy Communities: Potentially preventable hospitalisations in 2013-14, Technical Supplement. Sydney, 2015.

[2] Davis W, Hendrie D, Knuiman M, Davis T. Determinants of Diabetes-attributable Non-Blood Glucose-Lowering Medication Costs in Type 2 Diabetes. Diabetes Care. 2005; 28(2):329-36.

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)[1] and characterised as the count of MACSS conditions, excluding 'endocrine, metabolic or immune

[1] Holman CDJ, Preen DB, Baynham NJ, Finn JC, Semmens JB. A multipurpose comorbidity scoring system performed better than the Charlson index. J Clin Epidemiol. 2005; 558:1006-14

		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 [2]
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

[2] Mundlak Y. On the Pooling of Time Series and Cross Section Data. Econometrica. 1978;46(1):69-85.

Supplementary table S3: 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 5-year comorbid condition count.