School of Physiotherapy and Exercise Science

REHABILITATION PRACTICES FOR ADULTS HOSPITALISED FOR A RESPIRATORY CONDITION.

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DECLARATION

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

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

Signature: Date: 14/08/2020

STATEMENT OF ORIGINALITY

This thesis is presented for the degree of Master of Philosophy (Physiotherapy) at Curtin University, Western Australia. Studies were undertaken between July 2016 and July 2020, through the School of Physiotherapy and Exercise Science at Curtin University, in association with the Department of Respiratory Medicine and the Physiotherapy Department at Royal Perth Hospital, Western Australia.

This research project was developed in association with my supervisors, who have been involved in editing both the thesis and all associated publications.

All material presented in this thesis is original.

ABSTRACT

This thesis comprises two studies: a scoping review and a prospective observational study. Broadly, this body of work aimed to evaluate what is known regarding exercise training for adults hospitalised with an acute or an acute on chronic respiratory condition. Then, specifically in adults hospitalised with community-acquired pneumonia (CAP), what is usual care practice in terms of medical and physiotherapy practice, and healthcare utilisation. Further, in this clinical population, total walking time and non-walking time, as well as the way in which they were accumulated during the period of hospitalisation were also explored.

STUDY 1: SCOPING REVIEW

Background: In the last decade there has been a growing interest in the role of exercise training initiated during the period of hospitalisation, for adults hospitalised with an acute or an acute on chronic respiratory condition. In clinical practice, the implementation of exercise training programs is inconsistent, which may be a reflection of dissimilar training approaches described in earlier work.

Objective: To determine, in adults hospitalised with an acute or an acute on chronic respiratory condition, what has been reported regarding exercise programs in terms of content, tolerability, evaluation and adverse events.

Data sources: A systematic search was conducted of electronic databases (PubMed, EMBASE, CINAHL, PEDro, The Cochrane Library), trial registries and conference abstracts (Thoracic Society of Australia and New Zealand Annual Scientific Meeting, the European Respiratory Society Congress, the American Thoracic Society International Conference).

Review methods: Studies were included if they: (i) recruited adults hospitalised with an acute or an acute on chronic respiratory condition, (ii) described an exercise program that targeted peripheral muscles and (iii) reported that ≥ 80% of the sample had initiated training within 72 hours of hospitalisation.

Results: The last search was conducted on 02/06/2019. Of the 6,282 records identified, 20 met the study criteria. These comprised 18 separate studies (2,018 participants). Studies were conducted in adults hospitalised with an exacerbation of chronic obstructive pulmonary disease (COPD) (n = 1,100 participants) or with CAP (n = 918 participants). The content of exercise programs included aerobic and/or resistance training, neuromuscular electrical stimulation, whole-body vibration, or movement out of bed. In eight studies (44%), the intensity of the initial session was prescribed using objective measures of physical function such as exercise capacity or peripheral muscle force. Across 7,420 training sessions, seven adverse events were reported.

Conclusion: Methods used to prescribe and titrate exercise programs in adults hospitalised with an acute or an acute on chronic respiratory condition were disparate. When reported, programs were well tolerated, and adverse events were infrequent. The majority of studies were those conducted in adults hospitalised with an exacerbation of COPD with only a small number of studies conducted in adults hospitalised with CAP.

STUDY 2: OBSERVATIONAL STUDY IN COMMUNITY-ACQUIRED PNEUMONIA

Background: To date, there are a paucity of data in adults hospitalised with CAP specifically pertaining to baseline physiotherapy practice patterns and participation in walking-based activity during the period of hospitalisation. This is perhaps surprising as earlier work has

suggested that in adults hospitalised with CAP, increasing ward-based walking may reduce hospital length of stay (LOS).

Objectives: In adults hospitalised with CAP, this study sought to report on:

i. usual care in terms of medical and physiotherapy management,
ii. healthcare utilisation, expressed as hospital LOS, the number of readmissions or presentations to any emergency department (ED) and the number of presentations to a general practitioner in the first 30 days following discharge from hospital,
iii. the amount of walking-based activity accumulated during the inpatient stay and,
iv. the influence of average daily step count on healthcare utilisation.

Methods: Observational study with prospective data collection. Following admission, daily step count and variables related to walking and non-walking time were quantified using the StepWatch™ Activity Monitor (SAM). Details regarding demographics, clinical characteristics, clinical care and LOS were extracted from the medical records and hospital electronic data systems. Frailty was calculated via the 7-point Clinical Frailty Scale (higher numbers represent greater frailty). Disease severity was measured via the CURB-65 score. Healthcare utilisation at 30 days following discharge was measured via phone interview.

Results: A total of 200 participants (129 male, mean ± standard deviation [SD] age 67 ± 18 years, CURB-65 score median [interquartile range] 1 [1 to 2]) completed the study. Regarding usual care in terms of medical management, 197 (98%) participants received intravenous antibiotic therapy during the period of hospitalisation. Of the 163 participants who presented directly to the Royal Perth Hospital (RPH), antibiotic therapy was commenced in the ED in 139 (85%) cases. Of the 195 participants who were not using domiciliary oxygen at the time of hospital admission, 109 (56%) received supplemental oxygen therapy during the period of hospitalisation. Regarding usual care in terms of physiotherapy management, a

physiotherapist interacted with 161 (81%) participants for the purpose of assessment and/or treatment of any kind. Ninety (45%) participants received at least one physiotherapy interaction which involved assessment and/or treatment of a respiratory problem. The most commonly used intervention was supervised ambulation, which was undertaken at least once during hospitalisation in 131 (66%) cases. Predictors of an increased number of interactions with a physiotherapist were greater disease severity (incidence rate ratio [IRR] 1.63; 95% confidence interval [CI] 1.12 to 2.38, $p = 0.01$) and higher clinical frailty (IRR 1.67; 95% CI 1.13 to 2.49, $p = 0.01$).

Regarding healthcare utilisation, the median [IQR] LOS was 4 [2 to 4] days. Of the 144 participants who participated in the telephone interview, 112 (78%) participants presented to a general practitioner in the first 30 days following discharge and 21 (14%) participants required readmission to hospital. Hospital LOS was median [IQR] 4 [3 to 8] versus 3 [2 to 5] days in those with more severe disease versus those with less severe disease ($p < 0.001$). Hospital LOS was median [IQR] 5 [3 to 8] versus 3 [2 to 5] days in those who were more frail versus those who were less frail ($p < 0.001$). Increased age and frailty were demonstrated as predictors of referral to rehabilitation (age odds ratio [OR] 1.07; 95% CI 1.00 to 1.12, $p < 0.01$; frailty OR 4.42; 95% CI 1.30 to 15.00, $p = 0.02$). Increased frailty was also a predictor of 30-day readmissions whereby those with a frailty score ≥ 4 had a 2.9 fold increase in odds of being readmitted over the first 30 days following discharge (OR 2.9; 95% CI 1.11 to 7.50, $p = 0.03$).

Regarding the amount of walking-based activity accumulated during the inpatient stay, 121 (61%) participants contributed ≥ 24 hours of SAM data per participant. The median [IQR] number of daily steps was 926 [457 to 1,706]. These were accumulated over median [IQR] 66 [41 to 121] minutes/day, with a usual bout duration of median [IQR] 3 [2 to 4] minutes

and one-minute peak cadence of median [IQR] 56 [43 to 74] steps/minute. An average of median [IQR] 93 [89 to 96] % of waking hours was spent in non-walking time. In the multivariable model, increased frailty was retained as a predictor of lower step count (IRR 0.59; 95% CI 0.41 to 0.85). Specifically, compared to those with a frailty score < 4, those with a frailty score of ≥ 4 took 41% fewer steps per day. For every increase in 500 steps/day, LOS reduced by 11% (IRR 0.89; 95% CI 0.80 to 0.99).

Conclusions: The data in this observational study of adults hospitalised with CAP demonstrated that antibiotic therapy was delivered to almost all participants and was usually initiated in the ED. Physiotherapists interacted with the majority of participants for the purpose of assessment or treatment of any kind. Physiotherapy treatment most often included supervised ambulation. In regard to LOS, those participants with more severe disease had a longer LOS in comparison to those with less severe disease. The data revealed that clinical frailty was an independent predictor of multiple unfavourable outcomes such as referral to rehabilitation on discharge and readmission to hospital within 30 days of discharge. Overall, whilst hospitalised, participants did very little walking which was accumulated in short bouts at a low intensity. Compared with those with a frailty score < 4, those with a frailty score of ≥ 4 took 41% fewer steps per day. Those with a higher daily step count had a shorter LOS. These results suggest that in adults with CAP, the presence of clinical frailty impacts walking-based activity during hospitalisation, and walking-based activity influences hospital LOS.

OVERALL CONCLUSION

The body of research within this thesis identified a growing body of data exploring the role of exercise training for adults hospitalised with an acute or an acute on chronic respiratory condition. The majority of studies were conducted in adults hospitalised with COPD, with a

small number of studies conducted in adults hospitalised with CAP. This disparity in the volume of data is likely a reflection of the previous work regarding the description of exercise training in COPD. Future studies exploring the role of exercise training in adults hospitalised with a respiratory condition require greater transparency to optimise the implementation of exercise training interventions in clinical practice. Further, this body of research identified a paucity of data describing usual care practices and participation in walking-based activity in adults hospitalised with CAP. Adults hospitalised with CAP accumulated low levels of walking-based activity, which was accumulated in short bursts with prolonged bouts of non-walking time. Clinical frailty was identified as a valuable and informative measure in predicting patient outcomes in adults hospitalised with CAP. The importance of clinical frailty can be applied in clinical work and in future research pertaining to adults hospitalised with CAP. Specifically for clinicians, the assessment of frailty on initial patient presentation can provide valuable information regarding clinical trajectory and patient outcomes. In regard to research, future studies that explore the effectiveness of interventions that are targeted at increasing walking-based activity in adults hospitalised with CAP should consider focussing recruitment on adults who are frail. By recruiting adults who are frail, it will increase the opportunity to demonstrate the effect of a walking-based intervention on measures of physical function and health-related quality of life (HRQOL).

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PUBLICATIONS ARISING AS PART OF THIS THESIS

Rice H, Hill K, Fowler R, Watson C, Waterer G, Harrold M. Reduced step count and clinical frailty in hospitalized adults with community-acquired pneumonia. *Respir Care* 2019; 65: 455-463.

Rice H, Harrold M, Fowler R, Watson C, Waterer G, Hill K. Exercise training for adults hospitalized with an acute respiratory condition: a systematic scoping review. *Clin Rehabil* 2020; 34(1): 45-55.

AWARDS

Thoracic Society of Australia and New Zealand and the Australian Annual Scientific Meeting 2018, Adelaide, South Australia: best poster.

LIST OF ABBREVIATIONS

ACPRC: Association of Chartered Physiotherapists in Respiratory Care

ATS: American Thoracic Society

ATSI: Aboriginal and Torres Strait Islander

BMI: Body mass index

CAP: Community-acquired pneumonia

CI: Confidence interval

COPD: Chronic obstructive pulmonary disease

CT: Computed tomography

CURB-65: Confusion, urea, respiratory rate, blood pressure, age 65

CXR: Chest x-ray

ED: Emergency Department

GP: General practitioner

HAP: Hospital-acquired pneumonia

HR: Hazard ratio

HREC: Human Research Ethics Committees

HRQOL: Health-related quality of life

ICC: Intercostal catheter

ICU: Intensive care unit

IQR: Interquartile range

IRR: Incidence rate ratio

ISWD: Incremental shuttle walk distance

kg: Kilogram

kgf: Kilogram force

LOS: Length of stay

m: metres

min: minutes

n: number

N: Newton

NHANES: National Health and Nutrition Examination Survey (United States)

NIV: Non-invasive ventilation

NMES: Neuromuscular electrical stimulation

OR: Odds ratio

PA: Physical activity

PEEP: Positive end expiratory pressure

PSI: Pneumonia severity index

RCT: Randomised controlled trial

RPH: Royal Perth Hospital

RM: Repetition maximum

ROM: Range of motion

SAM: StepWatch^{TM} Activity Monitor

SD: Standard deviation

SPSS: Statistical Package for the Social Sciences

TSANZ: Thoracic Society of Australia and New Zealand

UBD: Usual bout duration

UBD$_{WT}$: Usual bout duration walking time

UBD$_{NWT}$: Usual bout duration non-walking time

USA: United States of America

yr: years

6MWD: Six-minute walk distance

6MWT: Six-minute walk test

1. CHAPTER 1: INTRODUCTION

This chapter describes the background, research questions and significance of this body of research. Components of this chapter have been published previously.[1, 2]

1.1. Background and research questions

Previous work has shown that an episode of hospitalisation for an acute or an acute on chronic respiratory condition is associated with impairments in exercise capacity, peripheral muscle strength and the ability to undertake activities of daily living.[3-7] Much of these data have been demonstrated in adults hospitalised with an exacerbation of chronic obstructive pulmonary disease (COPD),[5-7] with a small amount of data from adults hospitalised with community-acquired pneumonia (CAP).[3, 4] These appear to be the most common and well-studied respiratory conditions in adults requiring hospitalisation. Given the impairment in physical function associated with a period of hospitalisation for a respiratory condition, there is a case to initiate exercise training during these events to ameliorate these sequelae.

Hospitalisation for a respiratory condition places a considerable financial burden on the Australian healthcare system.[8, 9] The cost related to the management of COPD has been estimated as $8.8 billion per year,[8] with approximately one third of these costs being attributed to hospital care.[9] Further, the cost related to adults hospitalised with CAP has been estimated to be between $300 and $350 million per year.[10] Given this economic burden, there is an interest in the effect of interventions to reduce healthcare costs, via reductions in measures such as hospital LOS and hospital readmissions.

A Cochrane review published in 2016[11] included 20 randomised controlled trials (RCTs) which compared the effect of exercise training with usual care (i.e. no exercise training) in

people who were hospitalised, or who had been recently discharged from hospital, with an exacerbation of COPD. Of the 20 RCTs, 12 studies commenced exercise training during the period of hospitalisation. Exercise training programs included aerobic training, resistance training, a combination of aerobic and resistance training, and other training modalities such as neuromuscular electrical stimulation (NMES). The Cochrane review demonstrated that exercise training was effective at improving several outcomes, including exercise capacity, health-related quality of life (HRQOL) and reduced the odds of readmission in adults hospitalised with an exacerbation of COPD.

There are three RCTs that have explored the effect of initiating an exercise training program during the period of hospitalisation in adults with CAP.[12-14] Of these, one described a combination of aerobic and resistance training,[13] and two studies described movement out of bed within 24 hours of hospitalisation with progressive daily movement.[12, 14] Data from these studies revealed that, in adults hospitalised with CAP, when compared to a usual care group that did not receive any exercise training, initiating exercise training during hospitalisation increased exercise capacity measured at the time of discharge[13] and decreased hospital length of stay (LOS) by one day.[12, 14]

Although there is a Cochrane review[11] and multiple RCTs[12-14] to support the role of exercise training in adults hospitalised with a respiratory condition, there appears to be a gap in the implementation of this evidence.[15] In clinical practice, exercise training during the period of hospitalisation for a respiratory condition is not consistently prioritised. Practice patterns at some sites suggest regular implementation of exercise training while other sites give greater attention to airway clearance techniques.[16] Inconsistencies in the implementation of exercise training in adults hospitalised with an acute respiratory condition may reflect the disparate approaches described by earlier work regarding; (i) initial prescription of exercise intensity,

(ii) titration of exercise intensity and, (iii) methods used to objectively evaluate the effect of the program. Further, there have been some concerns raised regarding the safety of initiating an exercise training program in a population of adults who are acutely unwell.[17] To address these issues, the aim of the current scoping review was, in adults hospitalised with an acute or an acute on chronic respiratory condition, to determine the prescription and titration of exercise training, together with the tolerability, evaluation and occurrence of any observed adverse events during inpatient exercise training. This study originally sought to explore effectiveness of initiating an exercise training program in adults hospitalised for an acute or acute on chronic respiratory condition. However, the vast majority of RCTs in this area have been done in people with COPD. As these studies have been meta-analysed in the past (and suggest a positive effect),[11] this study aimed to focus on a different gap; namely the (practical) implementation of such programs. To ensure all data pertaining to the implementation of these programs were captured (not just data contained in RCTs), a scoping review was undertaken.

To address this implementation gap and the inconsistencies in clinical practice, further structure and clarity is required to guide clinicians in how to safely and successfully implement an exercise training program in adults who are hospitalised with a respiratory condition. Therefore, the first study presented in this thesis was a scoping review, designed to answer the following research question:

In adults hospitalised with an acute or an acute on chronic respiratory condition, what research has been reported on exercise training in terms of prescription, titration, tolerability, evaluation and occurrence of any observed adverse events during inpatient exercise training?

The second study presented in this thesis focuses exclusively on adults hospitalised with CAP. That is, whilst there are data describing physiotherapy practices and participation in walking-based activity in adults hospitalised with an exacerbation of COPD,[16, 18-21] there are a paucity of data in adults hospitalised with CAP. This is surprising given that the incidence of CAP in Australia has been reported as 24.5 cases per 10,000 adults.[22] Without data describing usual physiotherapy practices and participation in walking-based activity, it is not clear how much walking-based activity is undertaken during the period of hospitalisation for CAP and what variables influence walking-based activity on the ward. This means that there are less data to inform clinical decisions. Specifically, the lack of data describing walking-based activity makes it difficult for health professionals to identify who is at greatest risk of an adverse outcome during the period of hospitalisation and shortly following discharge.

Based on data in other populations, the variables that are likely to influence walking-based activity on the ward include age,[23] disease severity,[24, 25] and frailty.[26-28] Physical activity is known to decrease with advancing age, which is a result of age-related decline of body systems.[23] It would therefore seem reasonable that adults of older age are likely to participate in lower levels of physical activity on the ward. Regarding disease severity, increased disease severity has been associated with lower levels of physical activity in adults admitted to the intensive care unit (ICU),[24] and in adults with stable COPD.[25] Frailty has been emerging in the literature as a variable that influences patient outcomes in other hospitalised populations, specifically hospital readmissions and inpatient mortality.[26, 27] It would seem reasonable that frailty, which has been described as an increased vulnerability and decreased physical reserve,[28] would also influence walking-based activity on the ward. Barriers to mobilisation, such as symptoms and physical attachments, are also likely to impact on walking-based activity.[29-34] To date, the variables that specifically influence walking-based activity in adults hospitalised with CAP are unknown.

Therefore, the second study presented in this thesis was a prospective observational study that aimed to answer the following research questions:

In adults hospitalised with CAP,

i. *What is usual care in terms of medical and physiotherapy management?*
ii. *What is the healthcare utilisation, expressed as hospital LOS, the number of readmissions or presentations to any emergency department (ED) and the number of presentations to a general practitioner in the first 30 days following discharge?*
iii. *How much walking time and non-walking time is accumulated during the inpatient stay?*
iv. *Does average daily step count influence healthcare utilisation?*

1.2. Significance and novelty

Hospitalisation for a respiratory condition is common and costly.[8, 9] Specifically, episodes of hospitalisation for COPD and CAP place a huge economic burden on the Australian healthcare system each year.[8-10] Therefore, interventions that may reduce healthcare costs are of great interest. There are systematic reviews in adults hospitalised with COPD[11] and RCTs in adults hospitalised with CAP[12-14] that have shown that exercise training is effective in improving several outcomes, including decreasing hospital LOS[12, 14] and reducing the odds of readmission.[11] However, the uptake of exercise training programs is limited by barriers such as patient symptoms, space and time constraints, physical attachments,[29-33, 35] as well as ongoing safety concerns.[17] Regarding Study 1, the scoping review presented in this thesis will be the first to systematically map what has been reported regarding exercise training initiated within 72 hours of admission for an acute or an acute on chronic respiratory condition. Specific detail regarding content, prescription, titration, tolerability, evaluation and adverse

events will provide clinicians with practical guidance regarding how to successfully and safely implement an exercise training program in adults who are hospitalised with a respiratory condition.

Regarding Study 2, this will be the first study to report current practice patterns for adults hospitalised for CAP, using data that were collected prospectively. Understanding current practice patterns regarding medical and physiotherapy management will provide data that can be used to benchmark against other comparable facilities and also to serve as baseline data to examine the impact of any change in usual care. A focus of this study was to explore walking-based activity (and non-walking based activity) in adults hospitalised with CAP, using objective measures of daily step count, one-minute peak cadence and measures of walking and non-walking time. Detailed analyses of the impact that walking-based activity, age, the presence of a chronic respiratory condition, disease severity and clinical frailty, have on outcomes of hospital LOS, the need for further rehabilitation on discharge, and hospital readmissions has not been explored.

In contrast to earlier work that has explored the impact of age on patient outcomes in adults with CAP,[36-39] data showing that walking-based activity may influence patient outcomes is important as this variable has the capacity to be influenced by physiotherapists during an inpatient admission. In other populations, physical activity during the period of hospitalisation has been shown to influence LOS[40] and hospital readmissions within 30 days of initial discharge.[41] Data highlighting which patients are at greatest risk of low levels of walking-based activity offers physiotherapists an evidence-based method for triaging care. That is, those individuals at risk of low levels of walking-based activity on the ward can be prioritised for physiotherapy interventions targeted at increasing walking-based activity. By

prioritising the most vulnerable cohort, it will increase the opportunity for physiotherapists to influence patient outcomes, such as reductions in hospital LOS and hospital readmissions.

2. CHAPTER 2: LITERATURE REVIEW

This narrative literature review comprises three parts. Part 1 defines community-acquired pneumonia (CAP); the pathophysiology, diagnostic and clinical features, and the associated mortality and morbidity. Part 2 discusses the impact of hospitalisation specifically for CAP on measures of physical function and describes the factors that are likely to contribute to the decline in physical function that is seen. Part 3 explores the role of exercise training in adults hospitalised with CAP, as an intervention to minimise physical deterioration. Where there was a paucity of literature pertaining specifically to adults hospitalised specifically with CAP, studies that recruited populations who were hospitalised with an acute or an acute on chronic respiratory condition other than CAP were discussed.

2.1. Part 1: Community-acquired pneumonia

Part 1 of this chapter defines CAP, its risk factors and the associated pathophysiology and microbiology. It then describes the incidence of CAP in adults, the diagnostic and clinical features, morbidity and mortality, and medical management.

2.1.1. Definition, pathophysiology, risk factors and microbiology

A formal definition of CAP is:

> An acute infection of the pulmonary parenchyma that is associated with at least some symptoms of acute infection, accompanied by the presence of an acute infiltrate on a chest radiograph or auscultatory findings consistent with pneumonia (such as altered breath sounds and/ or localised rales), in a patient not hospitalised or residing in a long-term-care facility for ≥ 14 days before onset of symptoms.[42(p348-349)]

An opportunity for infection arises when defence mechanisms are bypassed or fail, and microbial pathogens move into the lower respiratory tract.[43, 44] The pathogen is able to invade the lung parenchyma to stimulate an inflammatory process whereby exudate fills the alveoli, impairing alveolar ventilation and gas exchange.[45, 46] This results in pulmonary consolidation.[45, 46] This pathological process involving the lung parenchyma is unique to CAP and does not occur in any other acute respiratory condition.[46]

Risk factors for CAP include comorbid disease, those on extremes of the age continuum, alcoholism, smoking, malnutrition and an immunocompromised state (e.g. diabetes mellitus, acquired immune deficiencies).[45, 47-49] When compared with individuals with mild chronic obstructive pulmonary disease (COPD), those with severe COPD have an increased odds of developing CAP (odds ratio [OR] 1.35; 95% confidence interval [CI] 1.11 to 1.63).[50] This is thought to be due to compromised mucociliary mechanisms which can allow the transfer of pathogens from the larger airways to the lung parenchyma.[49]

The driving pathogen for the development of CAP can be bacterial, viral, fungal or secondary to mycoplasma pneumoniae.[46] Viral pneumonias contribute to approximately half of all cases of CAP with bacterial pneumonias (30%), mycoplasma (20%) and fungal (< 1%) pneumonias contributing less frequently.[46] Depending whether the pathogen elicits a typical or atypical set of symptoms, these pathogens are further classified into 'typical' or 'atypical'.[47] Pathogens labelled as 'typical' evoke an acute onset of symptoms such as fever, pleuritic chest pain and productive cough.[47] The 'typical' pathogens include streptococcus pneumonia, which is the most common pathogen worldwide,[47, 48, 51-55] staphylococcus aureus, group A streptococci, moraxella catarrhalis, anaerobes, and aerobic gram-negative bacteria.[55] 'Atypical' pathogens cause a gradual onset of symptoms such as dyspnoea, a non-productive cough, fatigue and headache.[47] The specific 'atypical' pathogens include mycoplasma

pneumoniae, legionella pneumophila and chlamydial organisms.[55] While the driving pathogen is of interest it is only identified in less than one in five of cases of CAP.[54]

2.1.2. Incidence, diagnostic and clinical features

2.1.2.1. Incidence, cost and need for hospitalisation

Worldwide the incidence of CAP has been reported to be between 9 and 248 cases per 10,000 adults.[22, 56-60] In Australia the incidence of CAP has been reported as 24.5 cases per 10,000 adults.[22] The associated length of stay (LOS) in hospital is between 5 and 7 days (5 days in New Zealand[61] and 7 days in Australia[22]). Periods of hospitalisation are costly.[62] The annual cost associated with CAP has been estimated as NZ$63 million,[63] AU$350 million,[10] US$17 billion,[64] and €10 billion[65]. These data highlight that CAP is a common and costly condition worldwide.

It has been reported that between 20 and 60% of adults with CAP require hospitalisation (20% in the United Kingdom [UK],[66] 40% in the United States of America [USA][67] and 60% in Spain[68]). Adults hospitalised with an episode of CAP are more likely to be older in age, have multiple comorbidities, cognitive impairment and poor oral intake, be unable to perform activities of daily living or reside in a nursing home.[39, 69, 70] The decision for hospitalisation is influenced by multiple factors which include symptoms and disease severity, plus other variables such as healthcare structure and accessibility, patient characteristics and clinician opinion. Of those hospitalised with CAP, between 1% and 19% require escalation of care which includes an admission to an intensive care unit (ICU) (1 to 10% in Europe,[71] 5% in the UK,[38] 9% in Japan,[72] 10% in Australia[22] and 19% in the USA[73]). It is generally accepted that those adults who are hospitalised with CAP and require admission to the ICU have severe CAP,[69] which has been formally defined by the American Thoracic Society (ATS) as:

> The presence of either one of two major criteria, or the presence of two of three minor criteria. The major criteria include the need for mechanical ventilation and septic shock; the minor criteria include systolic blood pressure (BP) ≤ 90 mm Hg, multilobar disease, and $PaO_2/FiO_2 < 250$.[69(p1731)]

2.1.2.2. Diagnostic features

Several studies have used computed tomography (CT) as the 'gold standard' for identifying pulmonary consolidation as an accurate diagnostic marker for CAP.[74, 75] Although a CT scan has demonstrated better accuracy in diagnosing CAP when compared to other imaging modalities,[74] there are impracticalities associated with CT that limit its feasibility in routine clinical practice. These include radiation exposure, cost and potential access issues in less developed countries.[74] Given these issues, a chest x-ray (CXR) is the primary modality used in clinical practice to diagnose CAP. The limitations associated with the use of CXR however include a lag between clinical presentation and visible consolidation,[74, 76] poor agreement between clinician interpretation independent of clinician qualification and experience,[74, 76 74, 77] and lower diagnostic accuracy when compared to other imaging modalities.[74, 77]

Given the known limitations associated with CXR, clinical criteria are usually used in partnership with CXR findings to assist in the diagnosis of CAP. These comprise one major criteria (i.e. cough, sputum production, or temperature > 37.8°C) or two minor criteria (i.e. pleuritic chest pain, dyspnoea, altered mental status, pulmonary consolidation on physical examination, or leukocyte count >12,000/μL)".[12] A study by Claessens et al[74] demonstrated that the combination of clinical features plus CXR was better at diagnosing CAP than CXR alone, using CT as the gold standard. Of 150 confirmed cases, CXR alone diagnosed 80 (53%) cases while CXR plus clinical features diagnosed 143 (95%) cases. Therefore,

combined clinical and radiographic assessment is used in routine clinical practice to identify CAP.

In regard to clinical assessment, clinical features may vary with advancing age. Previous work has shown that in comparison to younger adults, elderly adults with CAP present with fewer symptoms and often these symptoms are atypical.[69, 78] Reasons for this may include altered cognition, communication difficulties or the presence of comorbid disease that produces overlapping clinical features of CAP.

The severity of CAP is most often graded by using either the Pneumonia Severity Index (PSI)[37] or the CURB-65 Index.[38] The process of scoring is shown in Figures 2.1 and Figure 2.2, respectively. There is evidence to show that severity of CAP graded using the PSI and/or CURB-65 Index scores is associated with survival at 30 days following diagnosis.[79-81] These tools were designed to identify predictors of worse morbidity and mortality in adults with CAP.[48] As the score or class increases the risk of 30-day mortality increases (shown in Figure 2.3).[37, 38] The PSI or the CURB-65 Index are widely used to grade the severity of illness in clinical trials conducted in adults with CAP.[12-14, 56, 60, 82-84] However, they are not consistently used in clinical practice, even though they provide valuable information regarding the risk of mortality.[85]

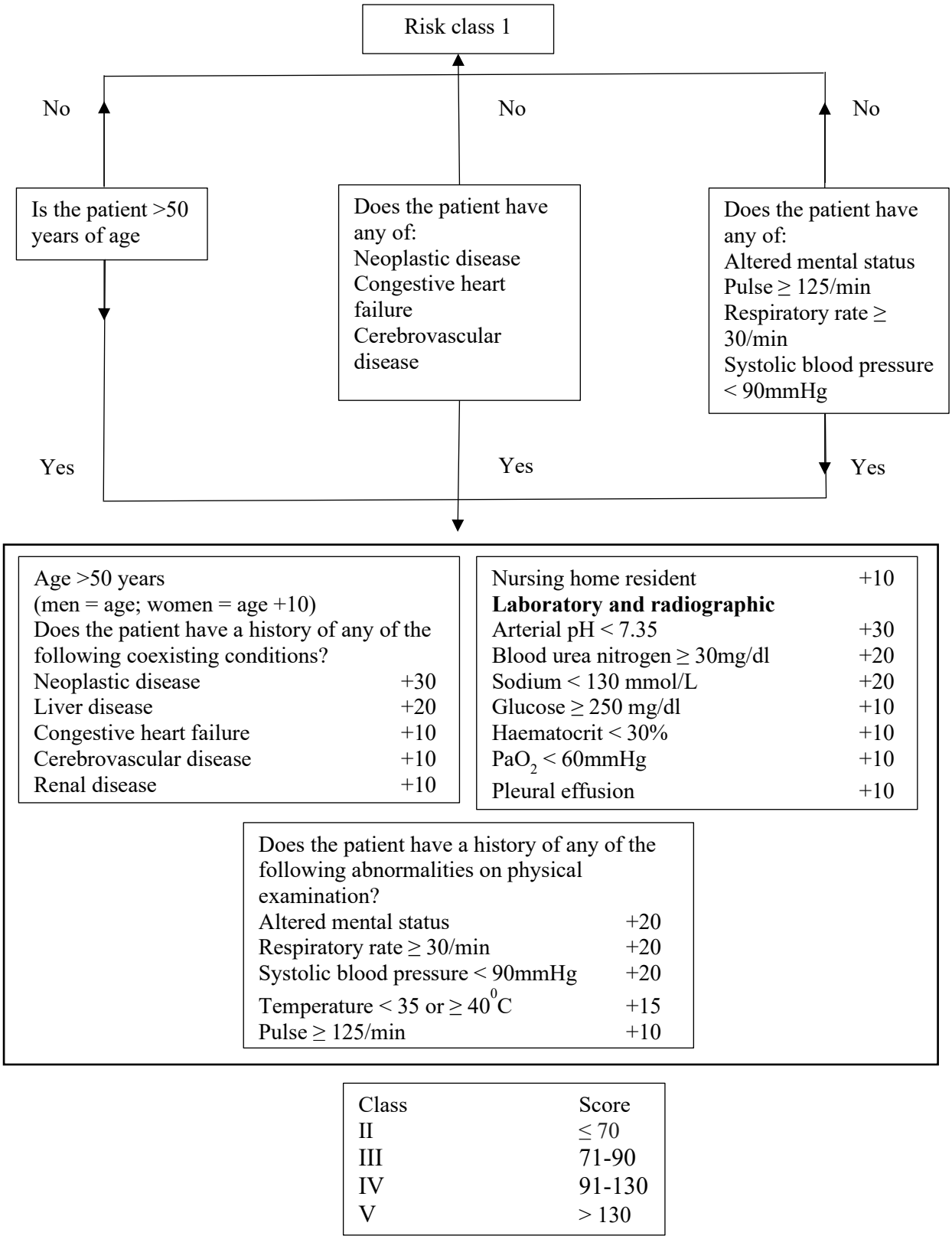

Figure 2.1 Pneumonia Severity Index

Figure taken from Fine et al.[37]

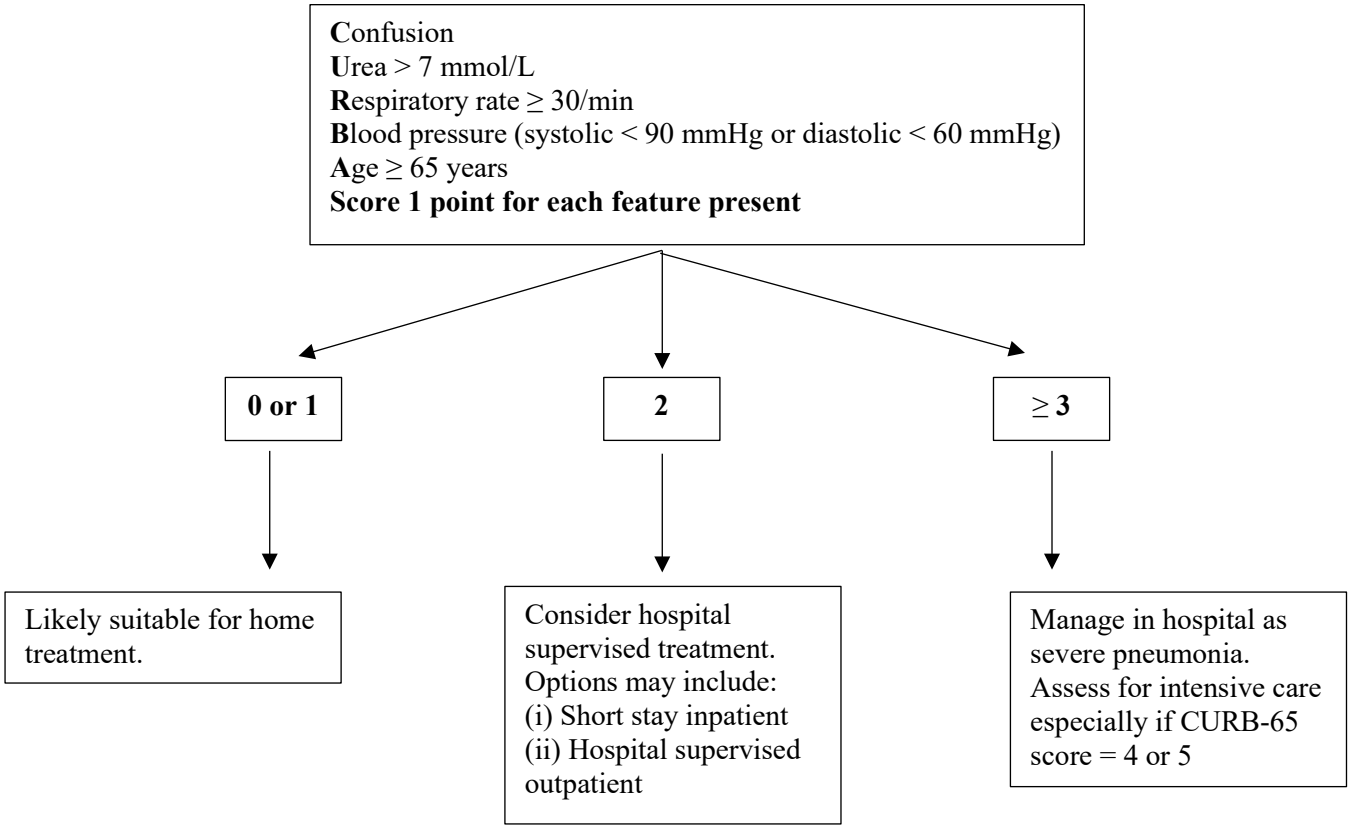

Figure 2.2 CURB-65 Score

Figure taken from Capelastegui et al.[81]

Pneumonia Severity Index		CURB-65	
Score	30-day mortality	Score	30-day mortality
I	0.1%	0	0.6%
II	0.6%	1	2.7%
III	0.9%	2	6.8%
IV	9.3%	3	14.0%
V	27.0%	4	27.8%
		5	27.8%

Figure 2.3 30-day mortality prediction as per the PSI and CURB-65 Index

2.1.2.3. Clinical frailty

Given that individuals hospitalised with CAP are often of increased age with multiple comorbidities,[22, 59, 61] it is likely that this population is characterised by clinical frailty. Frailty has been defined as:

> A physiologic state of increased vulnerability to stressors that results from decreased physiologic reserves, and even dysregulation, of multiple physiologic systems.[28(p256)]

Given the influence of frailty in other hospitalised populations,[86-90] there is an interest in the impact of clinical frailty on patient outcomes in adults hospitalised with CAP. Specifically in adults hospitalised with COPD, clinical frailty has been associated with a higher risk of readmission within 90 days following discharge,[86, 87] and an unfavourable discharge destination following hospitalisation.[88] In older adults hospitalised with a general medical condition, clinical frailty is associated with a longer LOS and increased mortality at 12 months following hospitalisation.[89, 90] Clinical frailty is often measured using either the Clinical Frailty Scale[91] or the Frailty Index.[92] These tools are commonly used in clinical practice and research conducted in hospitalised older adults and other respiratory populations.[26, 89, 93] There is evidence that Clinical Frailty Scale[91] and Frailty Index[92] scores are associated with higher mortality in community dwelling older adults.[94, 95] Data on the prevalence of frailty in adults hospitalised with CAP are scarce. However, one cohort study with short term follow up analysed the effect of frailty on the incidence of hospitalisation in older adults with CAP.[96] Frailty was defined using a combination of items from the Frailty Index[92] plus additional items selected by the authors such as living alone, anxiety and depression, pressure injuries and visual impairment. In this study, visual impairment was the only frailty item associated with increased odds of being hospitalised within 28 days of diagnosis of CAP (OR 1.10; 95% CI 1.02 to 1.18).

2.1.3. Mortality and morbidity

2.1.3.1. Mortality

Inpatient mortality for adults hospitalised with CAP is between 7 and 13%.[22, 37, 97, 98] This mortality risk remains relatively stable for one month following hospital discharge (5 to 19%)[37, 38, 82, 99] but increases to 33% at 12 months.[97] Mortality at 24 months following discharge is 34%.[100] Inpatient mortality for adults hospitalised with CAP is comparable to other respiratory conditions such as exacerbations of COPD (7 to 8%)[101-103] and other acute respiratory viruses such as influenza that do not involve CAP (9% to 17%).[104, 105] The reason for this may be due to common risks such as older age, admission to ICU, complications during hospitalisation, confusion and prolonged LOS, which, while independent of a specific illness, are associated with a higher mortality.[103, 106-108]

2.1.3.2. Morbidity

The common complications associated with CAP are either respiratory or cardiac. Respiratory complications associated with CAP include parapneumonic effusion and empyema.[46, 55] The incidence of parapneumonic effusion in adults hospitalised with CAP has been reported to be between 20 and 40% and increases to 60% in severe CAP.[109, 110] Variables associated with the development of respiratory complications include low serum albumin, elevated C-reactive protein, increased platelet count, low serum sodium, prior history of intravenous drug use and chronic alcoholism.[84] The presence of a respiratory complication has been shown to increase LOS, the need for an ICU admission and mortality.[84, 109, 111]

An episode of CAP is associated with an increased risk of a cardiac complications such as decompensated heart failure,[112-116] myocardial infarction,[113-118] and new arrhythmias.[113-117] In adults hospitalised with CAP the incidence of decompensated heart failure within 30 days of

diagnosis of CAP is almost three times that of myocardial infarction and new arrythmias (14.1%, 95% CI 9.3 to 20.6 versus 5.3%, 95% CI 3.2 to 8.6 versus 4.7%, 95% CI 2.4 to 8.9 respectively).[116] The incidence of cardiac complications in adults hospitalised with CAP may be explained by the multiple inflammatory and infective drivers resulting from the CAP that cause an increased demand on the myocardium.[116, 119-121] Cardiac complications in adults with CAP is important given their presence is associated with a higher mortality at 30 days following discharge.[84, 122]

With respect to readmission to hospital, the proportion of adults readmitted to hospital within 30 days following discharge for CAP has been reported to be between 7 and 18%.[14, 36, 123-125] Variables associated with a higher risk of readmission include the presence of coronary artery disease,[123] decompensated heart failure,[36, 124] COPD,[123, 124] age 65 years or more[36] and multiple comorbidities (with a Charlson Comorbidity Index score > two).[36]

It has not yet been explored whether levels of physical activity or sedentary time accumulated during the period of hospitalisation for CAP are associated with the rate of readmission. Variables of physical activity are of interest given the relationship demonstrated between physical activity and the incidence of hospitalisation or readmission in other populations.[41, 126, 127] Further, participation in physical activity is a *modifiable* risk factor that can be influenced by physiotherapists and other team members on the ward. Previous work conducted in older adults hospitalised with a medical condition has shown that those who were readmitted within 30 days of discharge had a lower daily step count during the initial period of hospitalisation than those who were not readmitted (median [interquartile range (IQR)] 323 steps [71 to 652] versus 674 steps [324 to 1604]; $p < 0.01$).[41] Similarly, studies conducted in adults recently discharged following an exacerbation of COPD have shown that those individuals with higher levels of physical activity immediately following discharge had

a lower risk of readmission in comparison to those with very low levels of physical activity.[126, 127] It is currently unknown if levels of physical activity during the period of hospitalisation are associated with outcomes such as readmissions in adults hospitalised with CAP. This is an existing gap in the literature which will be explored in this body of work.

2.1.4. Medical management

2.1.4.1. Antibiotic therapy

The primary medical treatment for CAP is antibiotic therapy.[46] In clinical practice the majority of cases of CAP are treated with empirical antibiotic therapy.[55, 74, 128] In the minority of cases when the specific pathogen has been identified, targeted antibiotic therapy is initiated.[128] Second line medical therapy includes supportive fluid resuscitation, oxygen therapy and the management of electrolyte imbalances.[46, 129] The addition of a corticosteroid, either intravenous or oral, may shorten the time to clinical stability and reduce hospital LOS.[130-133] However the study results are mixed, with some studies demonstrating that the addition of corticosteroid treatment provides treatment benefit,[132] and while other studies have not found this.[130, 133] Specifically, one randomised controlled trial (RCT) demonstrated an increase in survival (100% versus 70%; p = 0.01; 95% CI not provided)[132] while two RCTs demonstrated no difference.[130, 133] Given that the RCT by Confalonieri et al[132] did not use a pneumonia-specific disease severity tool, it is possible that their cohort was more medically well when compared to the other studies,[130, 133] which could explain the more favourable survival. At present, the addition of a corticosteroid is not included in current clinical practice guidelines.[69, 134]

2.1.4.2. Oxygen therapy and non-invasive ventilation

There are limited data regarding the proportion of adults hospitalised with CAP who require supplemental oxygen and non-invasive ventilation (NIV) therapy. Specifically, regarding

oxygen therapy, there are no data demonstrating an improvement in outcome with supplemental oxygen in CAP. However, American and British treatment guidelines recommend that hypoxaemia diagnosed using either percutaneous oxygen saturation or arterial blood gases, should be managed with supplemental oxygen.[69, 135] Therefore it would seem reasonable that in current practice, oxygen therapy would be routinely utilised in a subset of adults with CAP who present with reduced oxygenation. To our knowledge, data regarding the proportion of adults hospitalised with CAP who require supplemental oxygen have not yet been reported.

Regarding NIV therapy, there may be a role for NIV therapy in the management of acute respiratory failure in adults with CAP.[136] Pulmonary consolidation can drive an intrapulmonary shunt and ventilation/perfusion mismatch, resulting in hypoxemia.[137, 138] The positive expiratory end pressure (PEEP) delivered by NIV can assist in correcting blood gas abnormalities by facilitating the recruitment of nonaerated alveoli and redistributing ventilation to newly recruited areas.[138] By treating the hypoxaemia via NIV it would seem reasonable that more aggressive measures such as intubation and invasive mechanical ventilation may be prevented.

Despite the physiological rationale, there are few studies that explore the benefit of NIV in CAP. To date, the existing literature includes a Cochrane review[139] and an earlier RCT (which was not included in the Cochrane review).[140] The Cochrane review exclusively investigated the role of NIV therapy in comparison to supplemental oxygen in adults with CAP or hospital acquired pneumonia (HAP).[139] The results of the Cochrane review showed that NIV reduced the risk of mortality in the ICU, rates of invasive intubation and complications and decreased ICU LOS.[139] By comparison, the earlier RCT by Ferrer et al[140] included adults with acute hypoxic respiratory failure, independent of its aetiology. Of the

105 participants recruited to this study, 65 (62%) participants had CAP. They found that in comparison to oxygen therapy, NIV reduced the need for invasive intubation, mortality in the ICU, incidence of septic shock and improved survival at 90 days from randomisation.[140] The findings from these studies show that the implementation of NIV may have a survival benefit and reduce the need for invasive intubation in adults hospitalised with CAP.[139, 140] In comparison to oxygen therapy, adults with CAP who received NIV had a lower ICU mortality (OR 0.28; 95% CI 0.09 to 0.88[139] and subgroup with CAP 16% versus 53%; p = 0.03)[140] and a lower odds of requiring intubation and mechanical ventilation (OR 0.26; 95% CI 0.11 to 0.61[139] and subgroup with CAP 26% versus 73%; p = 0.02).[140] However, the samples of these studies were small (n = 151[139] and n = 65).[140] Although it is accepted that the implementation of NIV may have a clinical benefit in adults hospitalised with CAP, the uptake of these therapies in adults hospitalised with CAP is currently not known.

2.2. Part 2: The impact of hospitalisation

Part 2 of this chapter describes the impact of hospitalisation for an episode of CAP on measures of physical function. It explores the reductions in exercise capacity, peripheral muscle strength, the ability to undertake activities of daily living and patterns of physical activity and sedentary time. Part 2 also explores the impact of hospitalisation on health-related quality of life (HRQOL). Factors likely to contribute to these changes in physical function are investigated.

2.2.1. The impact of hospitalisation

In adults hospitalised with CAP, there are a scarcity of data reporting the magnitude of decrements in exercise capacity, peripheral muscle strength and ability to undertake activities of daily living.[3, 4, 141] Given that CAP is an acute illness, it is not feasible to quantify the

magnitude of impairments observed during the period of hospitalisation relative to objective measures of function collected prior to hospitalisation. Changes in function have therefore been explored by comparing measures collected in adults with CAP relative to those collected in age matched controls, or changes over a period of recovery.

2.2.1.1. Exercise capacity

In comparison to healthy age matched controls, adults who are hospitalised with CAP appear to have impaired exercise capacity early in the disease course. An observational study by Jose et al[3] measured exercise capacity in 45 adults hospitalised for CAP (mean ± standard deviation [SD] age 49 ± 16 years). In comparison to healthy controls, adults who presented to hospital with CAP had reduced six-minute walk distance on day two of hospitalisation (mean ± SD 381 ± 108 versus 587 ± 87 m; $p < 0.001$). In a different cohort, an interventional study by Jose et al[13] demonstrated that natural recovery in exercise capacity may occur during the period of hospitalisation. That is, data collected in the control group of this interventional study, who received usual physiotherapy care which comprised airway clearance, breathing exercises and walking, demonstrated an increased incremental shuttle walk distance from day 1 to day 10 of hospitalisation (mean ± SD 313 ± 91 versus 346 ± 94 m; p value or 95% CI not provided). Given that the average LOS for CAP is 7 days in Australia,[22] these discharge measures taken on day 10 of hospitalisation may have less relevance to clinical practice in Australian hospitals.[13] This is because adults who are hospitalised in Australia have experienced less natural recovery during hospitalisation and may have a greater impairment in exercise capacity on discharge.

There is a scarcity of work in adults with CAP reporting the time course of natural recovery following hospital discharge. However, in other respiratory populations such as those with COPD, studies demonstrate that exercise capacity continues to improve beyond discharge.

An observational study of 17 adults hospitalised for an exacerbation of COPD (median [IQR] age 69 [60 to 78] years) noted that in comparison to day eight of hospitalisation, exercise capacity had improved at one month following discharge (median [IQR] increase 73 [27 to 149] m; p = 0.01; 95% CI not provided).[5] Although exercise capacity had increased at this time, it was still below measures taken during periods of clinical stability.[142, 143] These data suggest that only partial recovery had occurred at one month following discharge. Thus, the data available in adults hospitalised with CAP suggest that at the time of the acute illness exercise capacity is reduced. However, further work is needed to determine if and when exercise capacity improves as the respiratory condition improves.

2.2.1.2. Peripheral muscle strength

Relative to healthy controls, adults hospitalised with CAP have lower peripheral muscle strength early in the disease course. This reduction has been noted in one study by Jose et al[3] that collected measures of peripheral muscle strength using a hand held dynamometer on the second day of hospitalisation, when compared to measures taken in age matched controls (biceps mean ± SD 12.4 ± 4.9 versus 15.9 ± 5.6 kilogram-force [kgf] [equivalent to 122 ± 48 versus 156 ± 55 N]; p = 0.03, and quadriceps mean ± SD 19 ± 7.2 versus 29 ± 6.4 kgf [equivalent to 186 ± 71 versus 284 ± 63 N]; p < 0.001).[3] An observational study by Martin-Salvador et al[141] collected admission measures of quadricep femoris force in 116 adults hospitalised with CAP. Measures of quadricep femoris force reported in this study by Martin-Salvador et al[141] were 50% less than measures reported by Jose et al[3] (mean ± SD 97 ± 28 N[141] versus 186 ± 71 N).[3] Overall, these data suggest that adults hospitalised with CAP have impaired peripheral muscle strength on admission relative to healthy age matched controls. It is difficult to comment on the reason for difference in values between the two studies because the study by Martin-Salvador et al[141] did not report specific details of the population, such as measures of age. The study by Martin-Salvador et al[141] was able to demonstrate that

peripheral muscle strength declined during the period of hospitalisation for CAP (quadriceps femoris force fell from mean ± SD 97 ± 28 to 92 ± 36 N; p = 0.04).[141] More studies are required to confirm the presence, rate and mechanisms of decline in peripheral muscle strength in individuals hospitalised with CAP.

Currently there are no data reporting the trajectory of recovery of peripheral muscle strength beyond hospital discharge in adults hospitalised for CAP. Data from other populations such as adults hospitalised with an exacerbation of COPD have suggested that an episode of hospitalisation is associated with a prolonged impairment in peripheral muscle strength. For COPD, persistent reductions in muscle strength have been demonstrated one month following discharge (mean ± SD decline discharge to one month 1.23 ± 3.35kg; 95% CI 4.3 to 1.8).[6] It is unclear if similar trends exist in adults who have been hospitalised with CAP.

2.2.1.3. Ability to undertake activities of daily living

In addition to reductions in exercise capacity and peripheral muscle strength following an episode of hospitalisation for CAP relative to age matched controls or changes over recovery, adults may experience increased difficulty undertaking activities of daily living at the time of discharge.[4] In an observational study of 301 adults (mean ± SD age 49 ± 16 years) hospitalised with CAP, over one third of the participants self-reported a functional decline at discharge when compared to pre-admission.[4] In this study, pre-admission measures were collected via a questionnaire through self-report or via the participant's next of kin. They found that disease severity was weakly associated with greater functional decline during hospitalisation (R = 0.26; 95% CI 0.15 to 0.36).[4] At three months following discharge, 34 (12%) participants had not returned to pre-admission measures. At 12 months following discharge in a regression analysis, the lack of recovery in functional status at three months post discharge increased the 'hazard' of hospital readmission or death (hazard ratio [HR]

6.16; 95% CI 3.42 to 11.07). Other variables associated with poor outcomes were a low Mini Mental State Exam score (HR 0.91; 95% CI 0.84 to 0.98) and higher Charlson Comorbidity Index score (HR 1.24; 95% CI 1.03 to 1.51).[4] These data are interpreted with caution given the known limitations of self-reported measures, which include cultural and social biases, difficulty with recall and participant comprehension.[144, 145]

2.2.1.4. Physical activity

In populations such as adults hospitalised with a medical condition or an exacerbation of COPD, participation in physical activity during the period of hospitalisation has been shown to influence important outcomes such as hospital readmissions and mortality.[41, 126] Specifically, in a study of adults with stable COPD followed over 20 years, those people who engaged in low, moderate and high levels of physical activity had lower risk of hospitalisation and better survival than those with very low physical activity levels.[146] Similar data have been published in people hospitalised with a general medical condition[41] or recently discharged following an exacerbation of COPD, over shorter time periods.[126, 127] Although earlier work has explored the effect of initiating exercise rehabilitation for adults hospitalised with CAP, to date, these studies have not quantified participation in physical activity during the hospital stay. Therefore, the following section reviews data published in other populations such as those hospitalised with an exacerbation of COPD, as these populations are broadly similar in terms of age and LOS.

2.2.1.4.1. Daily step count

Earlier work has shown that adults hospitalised with an exacerbation of COPD (mean ± SD age 69 ± 10 years) have reduced daily step count when compared to step counts in healthy age matched controls (mean ± SD 602 ± 610 steps per day[20] versus range 3,302 to 5,269 steps per day).[147] Older adults hospitalised with a general medical condition (mean ± SD age 77 ±

7 years) have also demonstrated reduced daily step count in comparison to healthy age matched controls (mean ± SD 764 ± 706 steps per day[40] versus range 3,302 to 5,269 steps per day).[147] Factors likely to contribute to the reduction in step count include symptoms such as dyspnoea and lethargy,[47] and environmental factors such as lack of space and attachments like continuous oxygen therapy.[29] Given that these factors may also be relevant for adults hospitalised with CAP, it would be reasonable to expect that adults hospitalised with CAP will also have a reduced daily step count when compared to step counts in healthy controls.

One RCT was identified that explored the use an educational booklet in 68 adults hospitalised with a medical condition.[29] Of this mixed cohort, 29 (43%) participants were hospitalised for CAP (mean ± SD age 69 ± 7 years). The average daily step count in this population was lower when compared to healthy age matched controls (mean ± SD 3,971 ± 1,706 steps per day[29] versus range 4,761 to 6,127 steps per day).[147] However, when compared to other studies where adults were hospitalised with an exacerbation of COPD[20] or older adults hospitalised with a general medical condition,[40] the average daily step count in this mixed cohort population was considerably higher (mixed cohort mean ± SD 3,971 ± 1,706[29] versus COPD mean ± SD 602 ± 610[20] versus older adults hospitalised with a general medical condition mean ± SD 764 ± 706 steps per day).[40] The disparity in average daily step counts may be explained by differences in age or in disease severity. Using hospital LOS as a surrogate measure of disease severity, the participants of the mixed cohort required a shorter LOS (mean ± SD LOS 5 ± 3 days)[29] when compared to adults hospitalised with an exacerbation of COPD (mean ± SD LOS 9 ± 3 days)[20] or a general medical condition (mean ± SD LOS 8 ± 5 days).[40] This suggests that the mixed cohort[29] had a lower severity of illness than those hospitalised with an exacerbation of COPD[20] or a general medical condition.[40]

While measuring time spent in physical activity, data collected using accelerometers or inclinometers in adults hospitalised with an exacerbation of COPD or a general medical condition have demonstrated that very small proportions of time are spent in standing or walking.[5, 148] Given the generic hospital environment and broad similarities in age and symptoms such as dyspnoea and fatigue, it is likely that adults hospitalised with CAP are also likely to spend small proportions of their time standing and walking during the period of hospitalisation.

2.2.1.5. Sedentary time

To date there are a lack of data quantifying the proportion of time spent in sedentary behaviour in adults hospitalised with CAP. Earlier work conducted in older adults hospitalised with a general medical condition has shown that a large proportion of time during hospitalisation is spent in lying (mean ± SD 83.3 ± 12.2%[148] and median [interquartile range] 70.8 [60 to 80]%),[149] and sitting (mean ± SD 13 ± 10%[148] and median [interquartile range] 21.2 [12 to 30%]),[149] even though at least one quarter of overall hours is accounted by sleep. One observational study in older adults (mean ± SD age 74.0 ± 6.5 years) hospitalised with a general medical condition demonstrated that one third of the sample spent more than 90% of their hospitalisation in bed, including the time spent in sleep.[148] Given the similar symptoms and hospital specific barriers to physical activity, it would seem reasonable to expect that adults hospitalised with CAP are likely to spend a large proportion of their time in hospital in sedentary behaviour.

2.2.1.6. Patterns of accumulation

There is growing recognition that the way in which physical activity or sedentary behaviour are accumulated over time may also influence health outcomes.[150-153] Studies in general populations have demonstrated that prolonged periods of uninterrupted sedentary time is

associated with cardiovascular risk factors such as a higher body mass index (BMI), waist circumference, triglyceride levels, and plasma glucose.[154] One metric that has been used to describe patterns of accumulation in community dwelling adults[154-156] and officer workers[157] is usual bout duration (UBD). The measure of UBD is similar to the half-life in pharmaceutical studies. Physical activity UBD is calculated by taking all bouts of accumulated physical activity for an individual and calculating the midpoint, whereby half of all bouts of activity will be shorter than the UBD and half of all bouts will be longer than the UBD.[156] This methodology can also be used for sedentary time UBD. Measures of UBD extend beyond measures of the magnitude of physical activity or sedentary time by describing how physical activity or sedentary time are accumulated. Given that the UBD of sedentary time can influence health outcomes independent of total sedentary time,[154] it is possible that UBD will become a useful measure to describe physical activity and inactivity in adults who are hospitalised with acute respiratory or medical conditions, including CAP.

2.2.1.7. Health-related quality of life

Previous work has shown that adults who are treated for CAP, either in hospital or the community, present with reduced HRQOL within the first week of diagnosis.[3, 158] Reduction in HRQOL has been demonstrated in comparison to pre-illness measures,[158] and to age and sex matched controls.[3] Although there are currently no data reporting how long any worsening of HRQOL lasts following hospitalisation for an episode of CAP, earlier work in similar populations, including COPD, suggests that HRQOL may improve after hospital discharge.[159] One observational study in adults who were discharged from hospital following an exacerbation of COPD demonstrated a clinically and statistically significant improvement in health status, a construct which is similar to HRQOL, at 3 months following discharge (mean change in the COPD Assessment Test score -3; 95% CI -4.4 to -1.6).[159] Improvement in HRQOL after discharge is important given that better HRQOL has been shown to be

associated with increased exercise capacity, peripheral muscle strength and physical activity in healthy populations[160, 161] and those who have been recently hospitalised with an acute medical condition.[162]

2.2.2. Factors contributing to the decline in physical function in adults hospitalised with community-acquired pneumonia

The main factors that are likely to result in functional decline during hospitalisation can be broadly grouped as: (i) an acute illness, (ii) generalised deconditioning and, (iii) side-effects of pharmacological treatments**.**

2.2.2.1. Acute illness

The disease process of CAP can drive a deterioration in physical function. The inflammatory process within the lung parenchyma, associated with CAP, has the capacity to impair gas exchange and result in hypoxaemia.[45, 46] Oxidative stress initiates the release of inflammatory products such as interleukin (IL)-8 and tumour necrosis factor (TNF) α, which attract inflammatory cells.[163] A study conducted in adults hospitalised with CAP noted a relationship between inflammatory markers and functional decline.[4] Specifically, increased levels of TNF-α were associated with an increased odds of functional decline, measured as the ability to undertake activities of daily living at the time of discharge (OR 1.12; 95% CI 1.08 to 1.15). Increased levels of inflammatory products like insulin-like growth factor I (IGF-1) have been associated with reductions in peripheral muscle strength in adults with stable respiratory disease[164] and those hospitalised with an exacerbation of COPD.[7] This association may also exist in adults hospitalised with CAP. Collectively these data suggest that oxidative stress and systemic inflammation adversely influence physical function and may contribute to the physical decline that is experienced by adults hospitalised with CAP.

2.2.2.2. Generalised deconditioning

Prolonged periods of mechanical unloading of weight bearing tissue are known to have deleterious effects on several body systems, especially the musculoskeletal and cardiovascular systems. These deleterious changes are known from literature exploring the effects of being in space (reduced gravity environments),[165-167] limb immobilisation studies[168, 169] and, more recently, work conducted in ICU.[170, 171] A prolonged period of bed rest and physical inactivity results in reductions in muscle protein synthesis, muscle length, muscle strength and muscle mass, particularly in anti-gravity muscle groups.[168-170] Impaired muscle structure and function is associated with impaired exercise capacity and a reduced ability to undertake activities of daily living that rely on muscle strength and endurance.[172, 173] The reduction in muscle protein synthesis may be amplified by suboptimal nutrition and inadequate protein intake, further fuelling muscle atrophy.[174, 175] Reduced weight bearing causes bone resorption to exceed bone formation which reduces bone integrity.[168-170] Cardiovascular changes associated with physical inactivity include decreased venous return and stroke volume, increased resting heart rate and orthostatic intolerance.[176] These changes impact on functional exercise capacity and exercise tolerance.

To our knowledge, there are no studies to date that specifically explore the reasons why adults hospitalised with CAP are likely to experience periods of physical inactivity. However, previous work in adults hospitalised with other conditions suggest that there are multiple factors influencing physical activity levels in hospitalised adults.[29-34] Studies conducted in adults hospitalised with a general medical condition, exacerbation of COPD and those in ICU have identified common barriers to physical activity. Disease specific barriers include symptoms of dyspnoea, pain, weakness and fatigue.[29-34] Hospital specific barriers include a lack of space, physical attachments such as continuous oxygen therapy, time constraints, and limited staff to provide assistance to those who cannot mobilise independently.[29-34]

Collectively these barriers drive prolonged periods of bed rest in adults who are hospitalised with a variety of conditions, likely including CAP.

2.2.2.3. Adverse effects of corticosteroid therapy

Although the addition of a corticosteroid is not recommended in clinical practice guidelines, a small proportion of patients with CAP do receive a corticosteroid, and therefore some of the following data may apply.[69, 134] Changes in muscle function are well established as a side-effects of corticosteroid use.[177-179] However, data that have demonstrated that corticosteroids use is associated with myopathy were collected in studies that delivered prolonged doses of corticosteroid therapy to adults with COPD.[177-179] A study which explored a shorter course of corticosteroids (2 weeks) did not demonstrate any association with myopathy.[179] Given that courses of corticosteroid therapy in adults hospitalised with CAP are likely to be short or absent,[134] it may be that changes in muscle strength in adults hospitalised with CAP are less likely to be a result of corticosteroid therapy.

2.3. Part 3: Physiotherapy management

Part 3 of this chapter describes the physiotherapy management for adults with CAP, which has been divided into three parts: airway clearance, exercise training and other strategies. Other strategies include behaviour change techniques, the prescription of walking aids and the use of neuromuscular electrical stimulation (NMES). Although there has been a Delphi study and consensus statement pertaining to physiotherapy for adults who are mechanically ventilated with a severe CAP,[180, 181] the scope of this thesis does not extend to adults who are mechanically ventilated. To date, there is a lack of clinical guidelines or consensus statements specifically pertaining to the physiotherapy management of adults hospitalised with CAP,

who are not mechanically ventilated. This is likely reflective of the lack of robust clinical trials to guide clinical practice in this area.

2.3.1. Airway clearance

There is no evidence supporting the benefit of formal airway clearance strategies in adults hospitalised with CAP.[182-184] Even in populations such as adults hospitalised with an exacerbation of COPD who are known to be chronic sputum producers, the evidence regarding the efficacy of airway clearance techniques is unclear.[18, 185] Guidelines from the Association of Chartered Physiotherapists in Respiratory Care (ACPRC) in the UK recommend that:

> Patients admitted with primary uncomplicated pneumonia should not be treated with traditional airway clearance techniques routinely.[186(pi5)]

However, some institutions recommend that variables such as a pre-existing respiratory condition, the presence of a neuromuscular condition or 'important bronchial secretions' may provide a clinical indication for using formal airway clearance techniques.[187] To our knowledge, there are no data to describe how frequently airway clearance techniques are used in adults hospitalised with CAP.

2.3.2. Exercise training and participation in physical activity on the ward

Adults hospitalised with CAP experience impairments in exercise capacity, peripheral muscle strength and the ability to undertake activities of daily living when compared to age matched controls or pre-admission measures.[3, 4] Given these impairments are likely to result, at least in part from a period of prolonged convalescence during hospitalisation, they are likely to be ameliorated with exercise training. Three RCTs were identified that have explored the effect of initiating an exercise training program during the period of hospitalisation in adults with

CAP.[12-14] Of these, one described a combination of aerobic and resistance training,[13] and two studies described movement out of bed within 24 hours of hospitalisation with progressive daily movement.[12, 14] Data from these studies revealed that, in adults hospitalised with CAP, when compared to a usual care group that did not receive any exercise training, initiating exercise training during hospitalisation resulted in increased exercise capacity measured at the time of discharge[13] and reductions in hospital LOS by one day.[12, 14]

In regard to the evidence that has been reported for exercise training in adults hospitalised with any respiratory condition, this will be described in Chapter 3 of this thesis. Specifically, Chapter 3 will elaborate on what has been reported regarding exercise programs in adults hospitalised with an acute or an acute on chronic respiratory condition in terms of content, tolerability, evaluation and adverse events.

There is a paucity of data regarding the safety of initiating exercise training during the period of hospitalisation for CAP. There are three RCTs that have exclusively explored the role of exercise training during hospitalisation for CAP.[12-14] In each of these studies, there were no adverse events associated with exercise training. A stepped-wedge cluster RCT by Lloyd et al[188] explored the role of a bundle of care in adults hospitalised with CAP. Those participants who were admitted to an intervention ward received four interventions which included the prescription of prednisolone, an early transition to oral antibiotic therapy, early mobilisation, and malnutrition screening. In comparison to those participants who received 'usual care' (which was not defined), those participants randomised to the intervention arm had a higher number of gastrointestinal bleeds (9 versus 3 events; 95% CI 0.005 to 0.01). However, it is difficult to ascribe this difference in events solely to early mobilisation given that there were four components of the intervention arm. Further, there was no difference in the number of adverse events during physiotherapy between the intervention and control groups.

Regarding the safety of initiating exercise training in adults hospitalised with respiratory conditions other than CAP, the study by Greening et al[17] is controversial. In this study of people hospitalised with an exacerbation of COPD, when compared with a control group who received 'usual care' (airway clearance, supervised mobilisation, education and nutritional screening), those who participated in exercise training had higher odds for mortality at 12 months following randomisation (OR 1.74; 95% CI 1.05 to 2.88). It is difficult to attribute this mortality difference to the exercise training program as; (i) the difference in mortality was only seen more than five months after hospital discharge, (ii) the per protocol analysis, which included those who completed the intervention period, did not show a difference in mortality and, (iii) those in the intervention group had lower FEV_1 at baseline and FEV_1 is a strong predictor of mortality in people with COPD.[189] These data suggest that further data are needed in this area and some caution may be required regarding exercise training in adults hospitalised with COPD.

To date, there are no clinical practice guidelines pertaining to physical activity and sedentary behaviour during the period of hospitalisation for adults who are hospitalised with any condition. However, a recent Delphi study has generated 12 expert recommendations regarding participation in physical activity and sedentary behaviour in older adults hospitalised with a general medical condition.[190] The key principles of these recommendations are: (i) adults who are hospitalised should engage in physical activity as their abilities and medical condition allows, (ii) participation in physical activity and reductions in sedentary behaviour during hospitalisation should be prioritised as per any other activity of daily living and (iii) patients and all healthcare professionals should share the responsibility of facilitating physical activity on the ward.[190]

2.3.3. Other approaches

In adults hospitalised with CAP there are a lack of data exploring the benefit of other strategies to manage the deterioration in physical function associated with an episode of hospitalisation. Other approaches have been utilised in adults hospitalised with an exacerbation of COPD, a general medical condition and critical illness, some of which may be useful and relevant in adults hospitalised with CAP. These include behaviour change techniques, the use of walking aids such as rollators and NMES.

2.3.3.1. Behaviour change

Behaviour change techniques have been defined in the literature as:

> Coordinated sets of activities designed to change specified behaviour patterns.[191(p1)]

The principles of behaviour change could play an important role in adults hospitalised with CAP. Behaviour change principles embedded in other interventions such as exercise training or mobilisation programs could be a powerful way to improve adherence. Increasing adherence outside of supervised interventions may be an effective way to maintain short-term gains. The work relating to behaviour change techniques in adults with chronic respiratory disease and adults who are hospitalised is in its infancy.[192-195] Therefore, the feasibility and potential benefit of behaviour change techniques is yet to be determined.

Data investigating the use of behaviour change techniques in hospitalised populations are scarce. One RCT explored the use of an educational booklet in 68 adults hospitalised with a medical condition, of which 29 (43%) participants were hospitalised for CAP.[29] This booklet explained the importance of physical activity during the period of hospitalisation. In comparison to usual care, those in the intervention group had a higher daily step count (mean ± SD 3,971 ± 1,706 versus 4,945 ± 2,117 steps; 95% CI 28 to 1,919) and spent less time in

sedentary behaviour during the hospitalisation (between-group difference -6%; 95% CI 0 to -11).[29] This study is one of the first to explore behaviour change techniques in adults who are hospitalised with a respiratory or medical condition. These preliminary data suggest this is an area worth investigating in adults hospitalised with a variety of conditions, including CAP.

2.3.3.2. Walking aids

In selected people, the provision of a walking aid may increase the capacity to ambulate during a period of hospitalisation. Although this has not been explored in CAP, a previous RCT on adults hospitalised with an exacerbation of COPD explored the use of a gutter frame during supervised ambulation.[196] Those adults who walked with a gutter frame during the period of hospitalisation had a greater improvement in the ability to undertake activities of daily living at the time of discharge when compared to those who walked with a rollator (gutter frame mean increase Barthel Index score 1.22 ± 1.77 versus rollator 0.55 ± 0.91; p = 0.003; 95% CI not given). There was a weak association between an increased Barthel Index score and a decline in dyspnoea (R = -0.27; p < 0.005).[196] The use of a walking aid in adults hospitalised with CAP, such as a gutter frame, may be a useful tool when targeted at those who are limited by dyspnoea.

2.3.3.3. Neuromuscular electric stimulation

Acknowledging that there are no studies that have explored the role of NMES in adults hospitalised with CAP, data from other populations suggests that NMES may be useful in selected people.[197-202] Earlier work in adults with COPD or critical illness suggests that NMES is best targeted at those who are unable to engage in weight bearing activity due to critical illness, severe dyspnoea or other comorbid conditions that limit weight bearing activity.[197-202] Similar to these populations, in adults hospitalised with CAP, NMES may be useful for those who unable to engage in active mobilisation and formal exercise training.

2.3.4. Conclusion

Part 3 of this chapter describes the interventions that may have a role in the physiotherapy management of adults hospitalised with CAP. In comparison to adults hospitalised with COPD, there is a dearth of literature regarding the physiotherapy management of adults hospitalised with CAP, who are not admitted to the ICU. Further, prior to interventional studies in this population, it would be useful to identify current physiotherapy practice patterns in adults hospitalised with CAP. This gap in the literature is addressed in Chapter 5 of this thesis.

2.4. Conclusion

Community-acquired pneumonia is a common and costly condition worldwide.[10, 22, 56-60] Between 20 and 60% of adults presenting with CAP require hospitalisation.[66-68] People with CAP who are older in age, have multiple comorbidities, cognitive impairment, poor oral intake, are unable to perform activities of daily living or reside in a nursing home are more likely to require hospitalisation.[39, 69, 70] It is likely that those adults who are hospitalised with CAP are also characterised by frailty, however this is yet to be explored.

Adults hospitalised with CAP have demonstrated impairments in exercise capacity, peripheral muscle strength, and the ability to undertake activities of daily living when compared to healthy age matched controls or to their pre-admission status.[3, 4, 141] These impairments in measures of physical function are likely to be related to the impact of the acute illness and periods of convalescence.[4, 46, 168] Currently there are a paucity of data exploring patterns of physical activity and sedentary time in adults hospitalised with CAP. However, data from comparable populations such as adults hospitalised with an exacerbation

of COPD[20] or a general medical condition[29, 40] suggest that adults hospitalised with CAP may participate in little physical activity during hospitalisation.

To date there are a scarcity of data specific to the physiotherapy management of adults hospitalised with CAP, who are not mechanically ventilated. Current clinical practice is guided by the small amount of data available in CAP plus data from other comparable populations such as adults hospitalised with an exacerbation of COPD or a general medical condition. Before investigating the role of interventions such as exercise training, there is a need to first understand baseline physiotherapy practice patterns in adults hospitalised with CAP.

3. CHAPTER 3: SCOPING REVIEW

This chapter relates to a scoping review which was published in *Clinical Rehabilitation* in February 2020 (Appendix 1).[1] The purpose of this scoping review was to determine what has been reported regarding exercise programs in terms of content, tolerability, evaluation and adverse events in adults hospitalised with an acute or an acute on chronic respiratory condition.

3.1. Objective

The objective of the current scoping review was, in adults hospitalised with an acute or an acute on chronic respiratory condition, to determine the prescription and titration of exercise training, together with the tolerability, evaluation and occurrence of any observed adverse events during inpatient exercise training. Further, where possible, the quality of reporting of the exercise intervention and risk of bias were assessed.

3.2. Methods

This scoping review was undertaken in accordance with established methodological frameworks[203] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[204] A protocol was developed *a priori* and published online at Open Science Framework.[205] Studies of any design were eligible for inclusion if: (i) they recruited adults who were hospitalised with an acute or an acute on chronic respiratory condition, (ii) they described implementing an exercise training program that targeted the peripheral muscles and, (iii) at least 80% of the sample had initiated training within 72 hours of hospitalisation. Exclusion criteria were studies that: (i) performed all exercise training in an outpatient or home-based setting, (ii) recruited a sample in which > 20% had hospital-acquired pneumonia, aspiration pneumonia, lung cancer or were admitted to an intensive care

unit (ICU), (iii) had prescribed either stretching, inspiratory or expiratory muscle training as the only forms of exercise or (iv) were written in a language other than English or Portuguese.

A systematic search of electronic databases, clinical trial registries and conference abstracts was undertaken. An example of the search string is presented in Appendix 2. The last search was conducted on 02/06/2019. The records retrieved during the search were entered into an EndNote library and duplicates were removed. The full text of any record was obtained if, based on title and abstract, it seemed eligible or could not be excluded.

A data dictionary was developed to ensure consistency in data extraction. Data were extracted on the four domains shown in Table 3.1. Regarding the exercise sessions, information was sought on the following variables:

- Content of the exercise training sessions; such as mode of exercise, the method used for initial prescription and to titrate exercise intensity, and level of supervision.
- Tolerability of, and adherence to, the program; such as the number of exercise training sessions completed by the participants as well as the number of exercise training sessions not completed, symptoms during exercise training, and modifications made to the prescribed exercise training protocol.
- Objective methods used to assess exercise capacity, peripheral muscle force, mobility, physical activity, balance and/or frailty.
- Adverse events experienced during exercise training, which were categorised as minor or major. Minor adverse events were defined as any incident that did not require medical attention, such as transient percutaneous oxygen desaturation. Major adverse events were defined as any incident that required medical attention such as myocardial infarction.

- The quality of reporting of the exercise intervention and risk of bias, where possible.

Table 3.1 Domains for data extraction

1.	Study and sample characteristics.
2.	Quality of reporting using the Consensus on Exercise Reporting Template (higher scores indicating detailed reporting, maximum score 16)[206] and the Template for Intervention Description and Replication (higher scores indicating detailed reporting, maximum score 12).[207]
3.	Risk of bias using the Cochrane Risk of Bias Assessment.[208]
4.	Variables related to exercise programs in terms of content, tolerability, evaluation and adverse events.

3.3. Results

A total of 6,282 records were identified of which 5,371 (85%) records were excluded based on the title and abstract. Of the 84 records that underwent full text review, 65 (77%) were excluded. Five (6%) were protocols for studies that met the study criteria and were found on clinical trial registries, but data had not yet been published. A total of 20 records for 18 studies met the criteria for inclusion in this review (Figure 3.1).

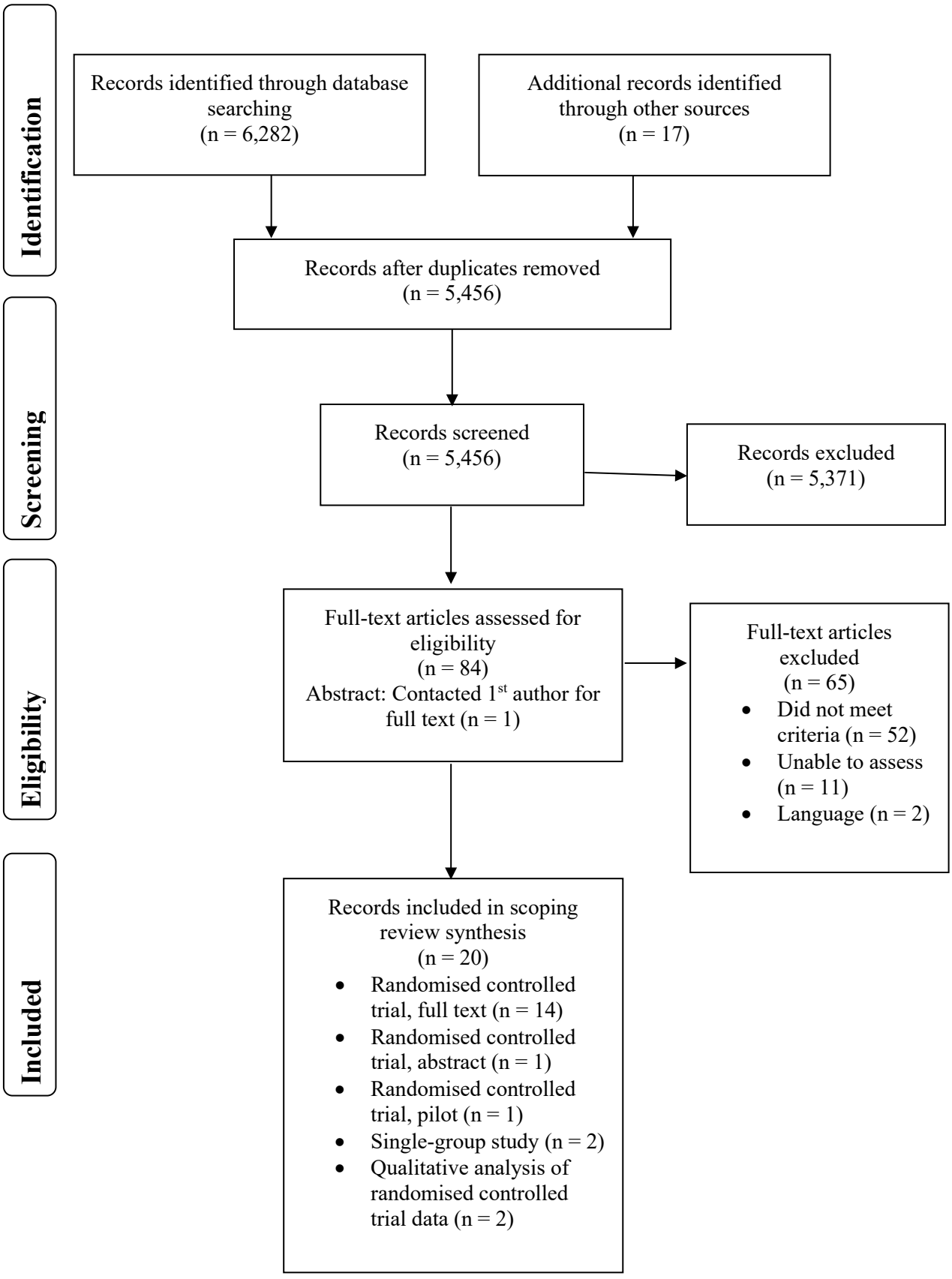

Figure 3.1. Study flow diagram

Figure 3.1 Study flow diagram

It was not possible to assess 11 records against the study criteria for reasons such as the full text not being available, or there was insufficient detail in the manuscript.

Of the studies included in this review, 19 (95%) were published in peer-reviewed journals,[12-14, 17, 209-223] and one (5%) was a published abstract for which further information was obtained from the author.[224] A summary of the included studies is presented in Table 3.2. The most common outcomes reported in the studies were adverse events, exercise capacity, healthcare utilisation and muscle strength. No studies reported on clinical frailty.

Table 3.2 Summary of included studies

Study	Design and sample size	Intervention received by experimental group(s) over and above usual care	Control group	Outcomes	Significant differences in favour of intervention group
Mundy 2003 et al[12]	RCT in 458 participants with CAP. Intervention group: 227 (50%) participants, age ~65 years, pneumonia severity index grade ~3.	Progressive movement.	'Usual care'. No further detail provided.	Adverse events, healthcare utilisation, mortality.	↓ hospital LOS.
Troosters 2010 et al[215]	RCT in 36 participants with exacerbation of COPD. Intervention group: 17 (47%) participants, age 67 ± 8 years, FEV_1 40 ± 12%.	Resistance training of quadriceps.	Standard drug therapy, airway clearance and breathing exercises.	Adverse events, anabolic muscle status, exercise capacity, healthcare utilisation, inflammatory markers, limitation due to dyspnoea, quadriceps strength.	↑ anabolic muscle status, ↑ exercise capacity at discharge, ↑ quadriceps strength at discharge and at 1 month.
Meglic 2011 et al[218]	Single-group study in 19 participants with exacerbation of COPD; age 71 ± 6 years, FEV_1 29 ± 11%.	NMES of quadriceps.	No control group.	Functional assessment of chronic illness therapy questionnaire, limitation due to	N/A (single group study).

				dyspnoea, patient satisfaction, HRQOL.	
Carratala 2012 et al[14]	RCT in 378 participants with CAP. Intervention group: 187 (50%) participants, age 72 ± 14 years and disease severity using pneumonia severity index score 100 ± 32.	Progressive movement.	'Usual care'. No further detail provided.	Adverse events, healthcare utilisation, patient satisfaction, mortality.	↓ hospital LOS.
Giavedoni 2012 et al[211]	RCT in 11 participants with severe exacerbation of COPD; age 72 ± 3 years, FEV_1 41 ± 6%.	NMES of quadriceps.	The other leg was used as the control. Standard drug and oxygen therapy.	Adverse events, quadriceps strength.	↑ quadriceps strength.
Tang 2012 et al[213]	RCT in 32 participants with exacerbation of COPD. Two intervention groups: 11 (34%) participants in the 'low' intensity group, age 68 ± 10 years, FEV_1 45 ± 19% and 10 (31%) participants the 'moderate to high' intensity group, age 74 ± 10 years, FEV_1 46 ± 18%.	Walking and upper and lower limb resistance exercise at either 'low' or 'moderate to high' intensity.	Mobility assessment, functional training for discharge and airway clearance.	Adherence adverse events, Barthel index, exercise capacity, LOS, lung function, muscle strength.	Nil.

Tang 2013 et al[217]	Qualitative analysis of 19 participant responses from study by Tang 2012 et al,[213] age 71 ± 11 years, FEV_1 48 ± 18%.	Walking and upper and lower limb resistance exercise at either 'low' or 'moderate to high' intensity.	Participants of the control group were not invited to participate.	Experience of exercise training during hospitalisation for an exacerbation.	N/A.
Borges 2014 et al[210]	RCT in 29 participants with exacerbation of COPD. Intervention group: 15 (52%), age 64 ± 12 years, FEV_1 42 ± 14%.	Upper and lower limb resistance training.	Usual care, including airway clearance.	Adverse events, exercise capacity, inflammatory markers, LOS, lung function, muscle strength, physical activity, HRQOL.	↑ 'impact' domain of HRQOL, ↑ exercise capacity, ↑ muscle strength.
Greening 2014 et al[17]	RCT in 389 participants with exacerbation of COPD. Intervention group: 196 (50%), age 71 ± 9 years and FEV_1 52 ± 25%.	Walking, resistance training of upper and lower limbs and NMES of quadriceps.	Airway clearance, mobilisation, education, nutritional screening.	Exercise capacity, healthcare utilisation, mortality, quadriceps strength, HRQOL, spirometry.	↑ exercise capacity at 6 weeks, ↓ survival at 12 months.

Greulich 2014 et al[212]	RCT in 40 participants with exacerbation of COPD. Intervention group: 20 (50%) age 66 ± 10 years, FEV_1 33 ± 13%.	Whole body vibration.	5 min mobilisation, 5 min of passive movement, and 10 min of respiratory exercises.	Anabolic muscle status, adverse events, chair rising test, exercise capacity, health status, inflammatory markers, muscle area, LOS, lung function, HRQOL.	↑ chair rising test, ↑ exercise capacity, ↓ inflammatory markers.
He 2015 et al[209]	RCT in 94 participants with exacerbation of COPD. Intervention group: 66 (70%), age 74 ± 2 years, FEV_1 38 ± 3%.	Walking, upper limb endurance and strength training, breathing retraining, education, stretches.	'Usual care'. No further detail provided.	Activities of daily living dyspnoea scale, adverse events, exercise capacity, health status, limitation due to dyspnoea, HRQOL.	Unclear.
Liao 2015 et al[216]	RCT in 61 participants with exacerbation of COPD. Intervention group: 30 (49%), age 68 [range 44 to 89] years, peak expiratory flow 140 [range 50 to 240] L/s.	Rehabilitation package, which included airway clearance techniques, pursed lip breathing, walking and upper limb endurance training.	Usual care.	Cough severity, dyspnoea on completion of 6-miute walk test, ease of expectoration, exercise capacity.	↓ cough severity, ↓ dyspnoea, ↑ ease of expectoration, ↑ exercise capacity.

Tahirah 2015 et al[224]	RCT in 38 participants with exacerbation of COPD. Intervention group: 20 (53%) age 62 ± 7 years, FEV_1 34 ± 14%.	Walking and functional resistance exercises.	Airway clearance, advice to mobilise.	Exercise capacity, physical activity, quadriceps strength, sit to stand test, Timed Up and Go.	↑ exercise capacity, ↑ physical activity, ↑ quadriceps strength.
Jose 2016 et al[13]	RCT in 49 participants with CAP. Intervention group 32 (63%), age 51 ± 21 years, CURB-65 score median [IQR] 1 [0].	Stretching, resistance training of upper and lower limbs and walking.	Airway clearance, breathing exercises and walking.	Adverse events, exercise capacity, Glittre test, inflammatory markers, LOS, limitation due to dyspnoea, muscle strength, HRQOL.	↑ exercise capacity, ↑ Glittre test, ↓ limitation due to dyspnoea, ↑ muscle strength, ↑ 'physical functioning' domain of HRQOL.
Torres-Sanchez 2016 et al[219]	RCT in 49 obese participants with exacerbation of COPD. Intervention group: 24 (49%), age 72 ± 9 years, FEV_1 39% (SD not reported).	Deep breathing exercises, active range of motion of the upper and lower limbs, single leg stance and sit to stand.	Usual care.	Adverse events, dyspnoea, exercise capacity, feelings of anxiety, depression, muscle strength, HRQOL, spirometry.	↓ feelings of depression ↑ exercise capacity, ↑ muscle strength, ↑ 'self-care, usual activities, mood' domains of HRQOL.
Torres-	RCT in 58 participants with	Seated lower limb	'Usual care' with	Adverse events, balance,	↑ balance,

Sanchez 2017 et al[214]	exacerbation of COPD. Intervention group: 29 (50%), age 76 ± 6 years, FEV_1 42 ± 11%.	pedalling exercise.	standard drug therapy.	exercise capacity, LOS, physical activity, quadriceps strength.	↑ physical activity, ↑ quadriceps strength.
Vincent 2017 et al[222]	Qualitative analysis and sub-study of the trial by Greening 2014.[17] Data reported on 100 participants from intervention group, age 71 ± 9 years, FEV_1 1.14 ± 0.6 L.	Walking, resistance training of upper and lower limbs and NMES of quadriceps.	Those in the control group in trial were not invited to participate.	Benefit of exercise healthcare use, family influence, participant confidence, perceptions of recovery.	N/A (intervention group only).
Cox 2018 et al[221]	Randomised trial in 57 participants with exacerbation of COPD (sample age 68 (11) years). Three intervention groups: inpatient exercise 13 (23%), FEV_1 44 ± 15%; home exercise 15 (25%), FEV_1 36 ± 15%; inpatient + home exercise and 14 (24%), FEV_1 49 ± 18%.	Inpatient exercise: upper and lower limb cycling. Home exercise: walking, marching on spot, sit-to-stand, wall push ups, step exercise, squats, bicep curls, arm lifts, shoulder punches with weights, education.	Usual care.	Adverse events, exercise capacity, healthcare utilisation, health status, limitation due to dyspnoea, London Chest Activity scale, HRQOL, physical activity.	Nil.
Torres-Sanchez	RCT in 90 participants with exacerbation of COPD. Two	Breathing and ROM group: deep breathing,	Usual care.	Health status.	In favour of breathing and ROM group (vs

2018 et al[220]	intervention groups: 30 (33%) in 'breathing and ROM' group, age 75 ± 9 years, FEV_1 31 ± 5% and 30 (33%) in resistance training group, age 70 ± 11 years, FEV_1 30 ± 8%.	active range of motion exercises. Resistance training group: upper and lower limb resistance training using elastic bands.			control):↑ 'mobility, self-care, usual activities' domains of health status. In favour of resistance training group (vs control): ↑ domains (except pain) of health status.
Clausen 2019 et al[223]	Single-group in 10 participants with CAP. Age 74 years (SD not reported), CURB-65 score 2 (SD not reported).	'Fast-track pneumonia pathway' which included mobilisation within the first 24 hours of admission.	N/A.	Barthel Index, physical activity, HRQOL, sedentary time.	Nil.

Data are reported as mean ± SD unless otherwise stated. COPD: chronic obstructive pulmonary disease; CAP: community-acquired pneumonia; CURB-65: Confusion Urea, Respiratory rate, Blood pressure, Age ≥ 65 score; FEV_1: forced expiratory volume in one second; HRQOL: health-related quality of life; IQR: interquartile range; LOS: length of stay; N/A: not applicable; NMES: neuromuscular electrical stimulation; RCT: randomised controlled trial; ROM: range of movement; SD: standard deviation.

These 20 studies described 16 unique randomised controlled trials (RCTs),[12-14, 17, 209-216, 219-221, 224] and two were single-group studies.[218, 223] Two studies were qualitative analyses which utilised responses from participants recruited to two of the RCTs[217, 222] The 16 RCTs and two single-group studies were conducted across 13 countries and reported data on 1,146 participants who were prescribed an exercise training program and 872 participants who did not participate in any exercise training. Consistent with previous reviews,[225, 226] study characteristics have been presented as a Harvest plot (Figure 3.2). The mean age of the participants who were prescribed exercise training ranged from 51 to 76 years, and 600 (52%) participants were male. Studies were conducted in adults hospitalised with an exacerbation of chronic obstructive pulmonary disease (COPD) (n = 1,100 participants)[17, 209-216, 218-222, 224] or with community-acquired pneumonia (CAP) (n = 918 participants).[12-14, 223]

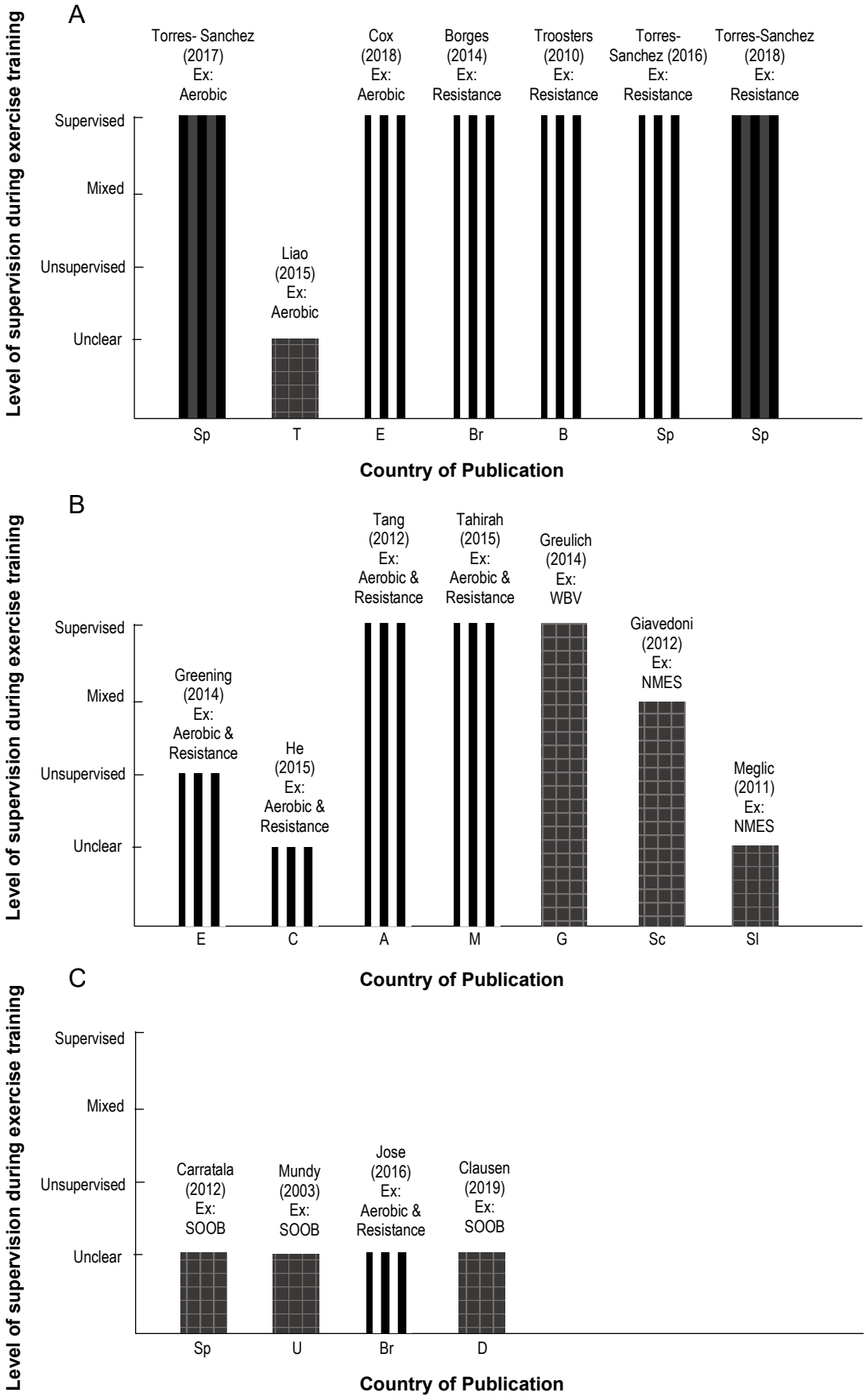

Figure 3.2 Harvest plot summarising methodological design

Figure 3.2 Harvest plot summarising methodological design

Panels A and B pertain to studies conducted in adults hospitalised with exacerbation of COPD. Panel C pertains to studies conducted in adults hospitalised with CAP.

 Initial exercise training session prescribed based on the results of an initial exercise assessment, with structured titration of exercise training.

 Initial exercise training session prescribed based on the results of an initial exercise with no structured titration of exercise training.

 Initial exercise training session is identical across all participants, with structured titration of exercise training.

 Initial exercise training session is identical across all participants, with no structured titration of exercise training.

A: Australia. Br: Brazil. B: Belgium. C: China. D: Denmark. E: England. Ex: Exercise. G: Germany. M: Malaysia. NMES: Neuromuscular electrical stimulation. Sc: Scotland. Sl: Slovenia. Sp: Spain. SOOB: Sit out of bed. T: Taiwan. U: USA. WBV: Whole body vibration.

Across the 16 RCTs and two single-group studies, participants allocated to the intervention groups completed ~ 7,420 training sessions over a period of 4 to 14 days.[12-14, 17, 209-216, 218-221, 223, 224] The content of the training programs is summarised in Figure 3.2 and Table 3.3. Approaches to exercise training included exclusive aerobic training,[214, 216, 221] exclusive resistance training[210, 215, 219, 220] a combination of aerobic and resistance training,[13, 17, 209, 213, 224] neuromuscular electrical stimulation (NMES),[211, 218] whole-body vibration[212] and movement out of bed within 24 hours of hospitalisation with progressive daily movement.[12, 14, 223] Eight studies individualised the prescription of the initial exercise training session using objective measures of exercise capacity,[13, 17, 209, 213, 224] peripheral muscle force[17, 209, 210, 213, 215, 221] or tasks commonly undertaken during activities of daily living.[224]

Table 3.3 Content of training programs

Study	Initial exercise prescription	Method used to progress exercise	Uptake / adherence
Mundy 2003 et al[12]	Daily 'movement out of bed with change from horizontal to upright position for at least 20 min during the first 24 hr of hospitalisation'.	'Progressive movement each subsequent day'; no other details reported.	166 (73%) participants achieved early mobilisation goal.
Troosters 2010 et al[215]	Seated double leg extension, 3 sets of 8 repetitions at 70% of 1RM, performed daily for 7 days.	'Adjustments in the load were made based on symptoms'.	6 ± 1 sessions completed out of 7 prescribed sessions. 41% of participants performed single leg extension due to dyspnoea.
Meglic 2011 et al[218]	NMES of quadriceps for 25 min, twice daily, 6 days/week (no other details).	Details not reported.	All prescribed sessions were performed.
Carratala 2012 et al[14]	Daily 'movement out of bed with change from horizontal to upright position for at least 20 min during the first 24 hr of hospitalisation'.	'Progressive movement each subsequent day'; no other details reported.	370 (98%) participants achieved early mobilisation goal.
Giavedoni 2012 et al[211]	NMES of quadriceps for 30 min daily for 14 days. Biphasic pulse 50 Hz, pulse duration of 400ms, 8s on: 20s off. Current increased to maximum tolerated.	Intensity ↑ according to tolerance.	All prescribed sessions were performed.

Tang 2012 et al[213]	'Low intensity' group: walking at 40% of average 3-min walk test speed for 7.5 min and 2 sets of 20 to 25 repetitions at 40% of 1RM. 'Moderate to high intensity' group: walking at 70% of average 3-min walk test speed for 7.5 min and 2 sets of 8 to 10 repetitions at 70% of 1RM. Exercise performed for 15 min twice daily.	10% ↑ walking distance once participant achieved distance with a change in Borg score of 1 to 2. ↑ load once 2 sets of the prescribed number of repetitions were completed.	'Low intensity' group completed 78 ± 17% of prescribed sessions, range 59% to 100%. 'Moderate to high intensity' group completed 71 ±19% of prescribed sessions, range 50% to 100%.
Borges 2014 et al[210]	2 sets of 8 repetitions at 80% of 1RM performed daily. Muscle actions targeted were shoulder flexion, abduction, elbow flexion, knee extension, flexion and hip flexion.	↑ load according to tolerance.	Completed 5.6 sessions (adherence 95%, SD not reported).
Greening 2014 et al[17]	Walking at speed equal to 85% of VO_2 peak estimated from ISWD. Resistance exercise using free weights: 3 sets of 8 repetitions 'based on 1RM'. NMES of bilateral quadriceps, 30 min, symmetrical biphasic pulse at 50 Hz, pulse duration of 300ms, 15s on, 5s off. Exercises performed once daily.	Walking time ↑ to maintain Borg dyspnoea score between 3 and 5 and exertion score < 13. Resistance load ↑ to maintain exertion score ≥ 13. Intensity of NMES ↑ according to tolerance.	Walking training: completed 2.7 ± 2.6 sessions. Resistance training: completed 2.5 ± 1.9 sessions. NMES: completed 3.6 ± 3.2 sessions.
Greulich 2014 et al[212]	3 × 2 min on the vibrating platform performed daily.	Details not reported.	Details not reported.

He 2015 et al[209]	Walking for 5 - 10 min at 60% of 'peak work rate achieved in the 6-min walk test'. 2 min of bilateral shoulder flexion and abduction using light free weight. 1 set of 10 repetitions against body weight or free weights (muscle groups not described). Exercises performed daily.	↑ to 20 min of continuous walking as symptoms permitted. ↑ to 3 sets of 10 repetitions when exercises performed 'without any difficulty'.	Completed 9 ± 1 sessions.
Liao 2015 et al[216]	Upper limb exercise (overhead activity) and walking. Exercises performed twice daily, for 10 min each. No other details reported.	Details not reported.	Details not reported.
Tahirah 2015 et al[224]	Walking training set at the distance achieved on 2-min walk test. Resistance training comprised sit-to-stand, step ups, half squats. Number of repetitions was based performance on the Sit to Stand Test. Exercise performed twice daily.	↑ walk distance by 20% every second day, if symptoms permitted. ↑ number of repetitions of each resistance exercise by 1 set, if symptoms permitted.	4 ± 1 supervised sessions and 4 ± 1 unsupervised sessions were completed. Percentage of scheduled supervised and unsupervised sessions performed were 96 ± 9% and 92 ± 13%, respectively.
Jose 2016 et al[13]	Warm up and stretches. Walking at 70% peak speed achieved during incremental shuttle walk test. Resistance exercise for biceps, deltoids, quadriceps and hamstrings for 25 min, 3 sets of 8 repetitions at 70% of 1RM using resistance band. Exercise performed daily for eight days.	Walking speed titrated ↑ to maintain dyspnoea score ≥ 4 and ≤ 6 and heart rate equal to rate established by Karvonen's equation. Resistance training load titrated to maintain fatigue ≥ 4 on Borg scale.	8 sessions prescribed. Number of competed sessions not reported.

Torres-Sanchez 2016 et al[219]	Breathing exercises, active movement of upper and lower limbs, and muscle strengthening (no other details reported). Exercise performed twice daily for 30 - 45 min per session.	Progressed according to time, such that by the fifth day they were also completing sit-to-stands and single leg stance. Number of repetitions based on dyspnoea and fatigue (targets not reported).	Details not reported.
Torres-Sanchez 2017 et al[214]	Daily seated pedalling exercise. No other details provided.	Cycling time, velocity and intensity were titrated to maintain dyspnoea and fatigue at score of 6 on the Borg scale.	Details not reported.
Cox 2018 et al[221]	Inpatient exercise only group: 16 revolutions of upper and lower limb cycling at 80% of maximal resistance to complete two revolutions 3 times a day for 5 days. Home exercise only group: walking and 8 functional exercises (e.g. squats). Sets and repetitions not reported. Completed 4 sessions over 2 weeks. Sessions were 20 to 60 min. Inpatient and home exercise group: received both interventions.	Inpatient group: 'workload could be increased'; no other details reported. Home exercise: details not reported.	Inpatient exercise: of 384 prescribed sessions, 131 (34%) sessions were completed across group. Home exercise: of 92 prescribed sessions, 72 (78%) sessions were completed.
Torres-Sanchez 2018 et al[220]	'Breathing and ROM' group: daily relaxation exercises, pursed lip breathing, active expiration and active range of motion exercises for 30 - 40 min.	'Breathing and ROM' group: details not reported. 'Resistance training' group:	Details not reported.

	'Resistance training' group: daily upper and lower limb training with an elastic band for 30 - 40 min.	progressed according to dyspnoea and fatigue (targets not reported). Load reduced muscle if soreness persisted > a few hours.	
Clausen 2019 et al[223]	Mobilisation for at least 20 min within the first 24 hours of admission. Frequency not described.	Details not reported.	Details not reported.

Data are reported as mean ± SD unless otherwise stated. ISWD: Incremental shuttle walk distance; NMES: neuromuscular electrical stimulation; RM: repetition maximum; ROM: range of movement; SD: standard deviation; VO_2: rate of oxygen uptake.

Regarding exercise prescription, walking-based exercise was prescribed at intensities that ranged from 40% of the average speed achieved during a three-minute walk test[213] to a speed equivalent to 85% of peak oxygen consumption estimated from the distance walked on the incremental shuttle walk test.[13, 17, 209] Upper and lower limb cycling was prescribed at an intensity of 80% of the maximal resistance against which participants were able to complete two pedal revolutions.[221] Resistance training was prescribed at intensities that ranged from 40% of one repetition maximum[213] to 80% of one repetition maximum.[13, 17, 210, 215]

Regarding the titration of the exercise dose, 11 studies described doing this based on symptoms.[13, 17, 209-211, 213-215, 219-221] Generally, when described, exercise intensity was progressed with the goal of participants reporting dyspnoea, fatigue or exertion that was perceived to be 'moderate to severe,'[13, 17, 209-211, 213, 215] with only one study titrating exercise dose to have participants report dyspnoea that was 'above severe to very severe.'[214]

Tolerability, defined as the average number of exercise training sessions that were completed as a percentage of the number of those prescribed, was reported in seven RCTs and one single-group study (n = 549 participants allocated to the intervention group) and ranged from 31% to 100%.[12, 17, 210, 211, 213, 215, 218, 221] The reasons for not completing exercise sessions were feeling unwell or fatigued (n = 38 sessions), interruptions by medical staff or family (n = 15 sessions), the participant being unavailable (n = 17 sessions), the therapist being unavailable (n = 36 sessions), participant declining (n = 42 sessions), muscle soreness (number of sessions not reported), dyspnoea (number of sessions not reported) and increased confusion (number of sessions not reported).[14, 210, 213, 221] In two studies, the intensity of dyspnoea resulted in modifications to the prescribed exercise training protocol, including single leg rather than double leg resistance training (n = 7 participants)[215] and the use of non-invasive ventilation during exercise (used in 35% of sessions, number of participants not reported).[210]

Two studies reported on adherence, defined as the proportion of participants who completed the training prescribed. In the study by Mundy et al, 73% of the sample completed the initial training session, but adherence beyond this was not reported.[12] The study by Cox et al reported that of the training sessions that were started, 100% were completed as prescribed.[221]

During the period of hospitalisation, 15 (83%) studies described collecting objective measures for the purpose of exercise prescription or evaluation. These measures quantified exercise capacity, peripheral muscle force, ability to undertake activities of daily living, physical activity or balance. Specific tests that were used were the six-minute walk test,[209, 210, 212, 215, 216, 221] three-minute walk test,[213] two-minute walk test,[221, 224] two-minute step in place test,[219] incremental shuttle walk test,[13, 17] sit-to-stand tests,[212, 214, 224] one repetition maximum,[13, 17, 210, 211, 213-215, 219, 224] the Glittre Test,[13] Timed Up and Go[224] or one-leg stance balance assessment.[214] Physical activity was measured in three (17%) studies using a physical activity monitor.[214, 223, 224] The Barthel Index was recorded in one study.[220] Data on outcomes that may have been used to evaluate the longer-term effectiveness of an exercise training intervention, such as hospital readmissions, were not extracted.

Across all training sessions completed by those allocated to the intervention group, seven adverse events were reported. The presence or absence of adverse events was not reported in four studies[216, 219, 220, 223] or in the published abstract.[224] Of the remaining 13 studies, 11 reported no adverse events and two reported adverse events in six and five participants, respectively.[210, 213] Minor adverse events were reported in six participants[210, 213] and these comprised transient percutaneous oxygen desaturation and increased dyspnoea during exercise training. Regarding major adverse events, one participant experienced chest pain during ‘low-intensity walking’ and was found to be in atrial fibrillation which resolved spontaneously after one hour.[213]

The qualitative analyses[217, 222] and the study reported in abstract form only[224] were not assessed using the Consensus on Exercise Reporting Template, Template for Intervention Description and Replication or risk of bias assessment. Across the 17 studies that were assessed the (mean ± standard deviation [SD]) Consensus on Exercise Reporting Template scores and Template for Intervention Description and Replication scores were 8.4 ± 4.0 (range 3 to 14) and 6.8 ± 2.7 (range 3 to 11). The scores for each scale and risk of bias results are presented in Table 3.4, Table 3.5 and Figure 3.3.

Table 3.4 Scores for the Consensus on Exercise Reporting Template

		Numbers are as per the reference list																
Item	**Description of:**	**12**	**13**	**14**	**17**	**209**	**210**	**211**	**212**	**213**	**214**	**215**	**216**	**218**	**219**	**220**	**221**	**223**
1	Exercise equipment	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1
2	Qualification expertise and/or training	0	0	1	1	0	1	0	0	1	1	1	1	0	1	1	1	0
3	Individual or group	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	1	0
4	Supervision	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0
5	Adherence to exercise	1	0	1	1	0	1	1	0	1	0	1	0	1	0	0	1	0
6	Motivation strategies	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
7	Method for exercise progression	0	1	0	1	1	1	1	0	1	0	1	0	0	0	0	0	0
8	Each exercise to enable replication	0	1	0	1	0	1	1	0	1	0	1	0	1	1	0	1	0
9	Any home programme component	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0
10	Non-exercise components	0	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1
11	Type/ number of adverse events	0	1	0	0	1	1	1	1	1	1	1	0	1	1	0	0	0
12	Setting	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1
13	Exercise (sets, repetition, duration, intensity)	0	1	0	1	1	1	1	1	1	0	1	0	0	0	0	1	0
14	Whether the exercises were generic or tailored	0	1	0	1	1	1	1	0	1	1	1	0	0	1	1	1	0
15	Decision rule for initial prescription	0	1	0	1	1	1	1	0	1	0	1	0	0	0	0	1	0
16	Adherence or intervention fidelity	1	0	0	1	0	1	1	0	1	0	1	0	0	0	0	1	0
	TOTAL	4	4	4	4	10	14	12	5	12	6	14	4	5	7	7	13	3

Table 3.5 Scores for the Template for Intervention Description and Replication

		Numbers are as per the reference list																
Item	**Detail**	**12**	**13**	**14**	**17**	**209**	**210**	**211**	**212**	**213**	**214**	**215**	**216**	**218**	**219**	**220**	**221**	**223**
1	Description of intervention	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Rationale for intervention	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
3	Materials used in the intervention	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1
4	Procedures used in the intervention	0	1	0	1	0	1	1	0	0	0	1	0	1	1	1	1	0
5	Intervention provider expertise	0	0	0	1	0	1	0	0	1	1	1	1	0	1	1	1	0
6	Modes of delivery: individual or group	0	0	0	0	0	1	1	0	0	0	1	0	0	1	1	1	0
7	Location(s)	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1
8	Details of delivered intervention	0	1	0	1	1	1	1	1	1	0	1	0	0	0	0	1	0
9	Details of titration etc	0	1	0	1	1	1	1	0	1	0	1	0	0	0	0	1	0
10	Details of modifications	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0
11	Methods for assessing/improving adherence or fidelity	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
12	Assessment of adherence or fidelity	1	0	0	1	0	1	1	0	1	0	1	0	1	0	0	1	0
TOTAL		3	4	4	3	6	11	10	4	8	4	11	5	6	6	7	11	4

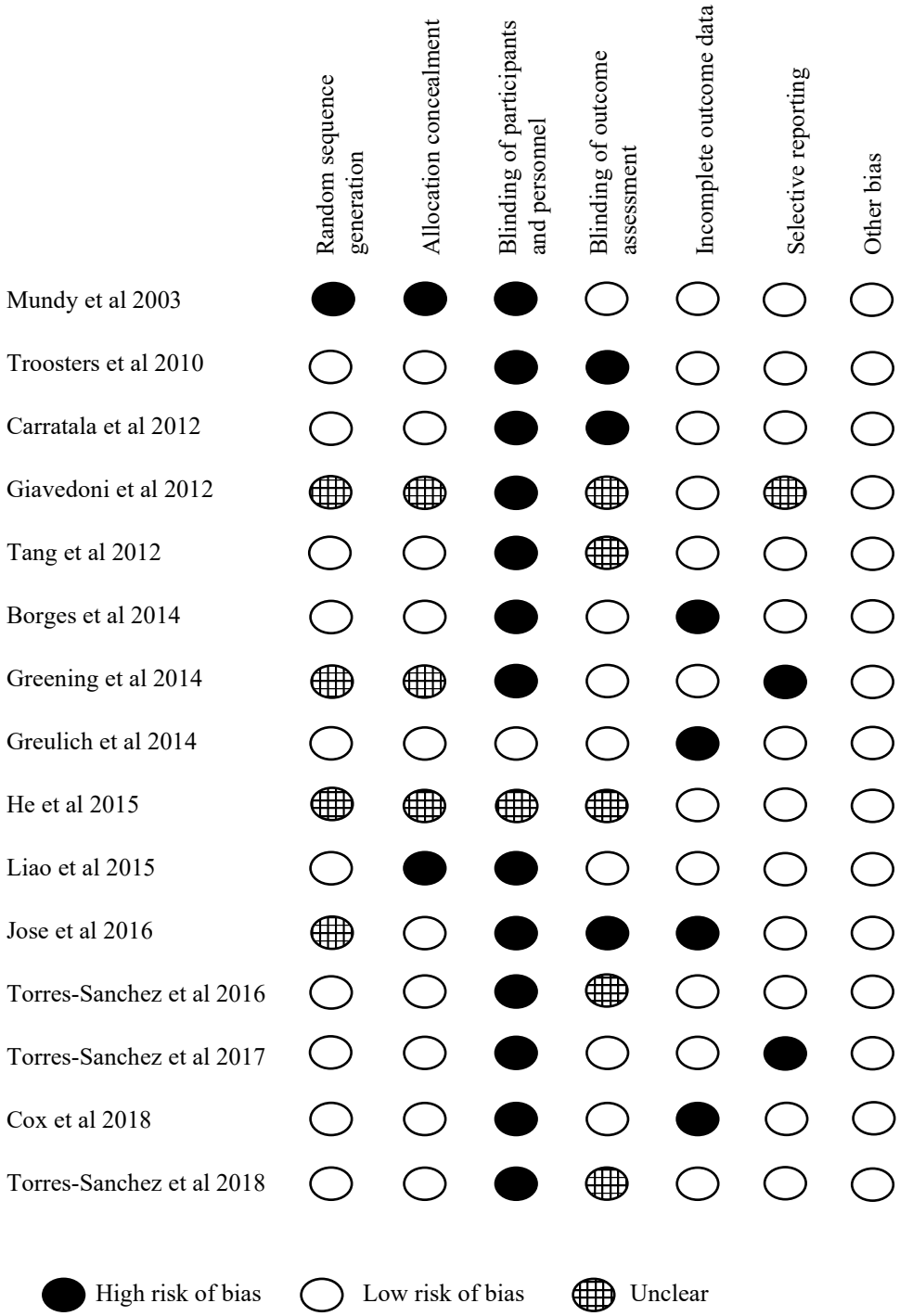

Figure 3.3 Risk of bias for the 15 randomised controlled trials

3.4. Discussion

Despite performing a comprehensive search to find studies that had recruited adults who were hospitalised with any acute or an acute on chronic respiratory condition, the only studies found had been conducted in either adults hospitalised with an exacerbation of COPD or CAP. Within the included studies, the methods used for the prescription of exercise training were disparate. When reported, these exercise training programs were well tolerated, and adverse events were infrequent.

In both health and disease, to optimise the effectiveness of an exercise training program, it is generally accepted that prescription should be individualised and adhere to the principles of overload and specificity.[227] As the body adapts to the imposition of a training load, progression of this load is required in order to stimulate further adaptation and training responses.[227] Without first collecting objective measures of exercise capacity, it is possible the exercise prescription will be suboptimal. Specifically, previous research involving hospitalised adults has shown the distance walked on the ward was, on average, less than 30% of what they achieved during an objective assessment of exercise capacity.[228] In this review, > 70% of studies that prescribed either walking training or resistance training based the initial prescription on objective measures of physical function collected for each individual. In the studies included in this review, walking-based aerobic training programs were most often prescribed based on the results of six-minute walk test and resistance training were most often prescribed based on the measure of a one repetition maximum.[13, 17, 210, 213, 215, 219, 224]

Although it might be ideal to prescribe an exercise training program based on an objective assessment of exercise capacity, one barrier to this may be the tolerance of such measures. Across the studies included in this review the tolerance of objective measures was variable.

In contrast to the one-repetition maximum which appears to have been well tolerated, one study reported that a large proportion of the sample (63%) did not attempt the six-minute walk test.[221] This suggests that a test of this duration may be overly burdensome in this clinical population and explains why other authors have selected shorter tests such as the two-minute walk test[224] or three-minute walk test.[213] Where reported, most studies titrated training load based on symptoms.[13, 17, 209-211, 214, 215, 219, 220]

From the studies that reported on tolerance, it would appear that resistance training had a slightly higher tolerance in comparison to aerobic training (exclusive resistance training [range 86% to 95%][210, 215] versus a combination of aerobic and resistance training [range 71% to 90%][17, 213] versus exclusive aerobic training [73%]).[12] This may be explained by resistance training being associated with a lower ventilatory load and less dyspnoea in comparison to aerobic exercise training.[229] Perhaps for those patients who are severely dyspnoeic and unable to tolerate walking training, exercise training should commence with resistance exercise. Adherence by more than 70% of the sample is comparable to levels of adherence for exercise training conducted during the period of hospitalisation in other populations such as post-stroke (77%),[230] older medical inpatients (63%)[231] and patients in the ICU (60%).[232]

The safety of initiating exercise in adults early during an episode of hospitalisation has been an area of interest across multiple patient populations such as those admitted to ICU[232] and following stroke.[233] In people hospitalised with an exacerbation of COPD, there have been concerns raised regarding possible deleterious outcomes of initiating exercise early during hospitalisation such as increased systemic inflammation and myocardial strain.[234] Across the 18 studies included in this review, a total of only seven adverse events were reported across the 1,146 participants who completed a total of ~ 7,420 training sessions. Only one event was deemed to be ‘major’ and this resolved spontaneously. There was no clear relationship

between the prescription of exercise intensity and adverse events with the only serious adverse event occurring in the 'low' intensity group, not the 'moderate to high' intensity group.[213]

Our finding of infrequent adverse events in people who have been prescribed exercise during periods of hospitalisation is consistent with the studies undertaken of early mobilisation in the ICU. Specifically, a systematic review that investigated the role of mobilisation in adults in the ICU and included data across 48 studies (n = 7,546 participants, 13,974 episodes of mobilisation) reported the incidence of adverse events that required cessation of mobilisation and/or medical attention to be 0.06%.[235] Although there are now data to show that in people hospitalised with an exacerbation of COPD, exercise training is unlikely to worsen systemic inflammation,[236] a study by Greening et al[17] has stimulated discussion regarding the safety of exercise prescription in this population. In this study of people hospitalised with an exacerbation of COPD, when compared with a control group who received 'usual care' (airway clearance, supervised mobilisation, education and nutritional screening), those who participated in exercise training had higher odds for mortality at 12 months following randomisation (odds ratio [OR] 1.74; 95% confidence interval [CI] 1.05 to 2.88). However, it is difficult to attribute this mortality difference to the exercise training program as; (i) the difference in mortality was only seen more than five months after hospital discharge, (ii) the per protocol analysis, which included those who completed the intervention period, did not show a difference in mortality and, (iii) those in the intervention group had lower FEV_1 at baseline and FEV_1 is a strong predictor of mortality in people with COPD.[189]

Regarding the quality of reporting, only half of the studies met the criteria for at least 50% of the items on the Consensus on Exercise Reporting Template scores and Template for Intervention Description and Replication.[13, 17, 209-213, 215, 221] Of the five studies that scored less

than 50%, three were those conducted in adults hospitalised with CAP. This may reflect the large body of previous research that has refined the description of exercise training in COPD versus the small body of work on exercise training for people with CAP.[12, 14, 223] As expected, studies were unable to blind participants or personnel to group allocation, however seven studies reported blinding the outcome assessor(s) to reduce detection bias. To improve the transparency of further studies, adherence to the Consensus on Exercise Reporting Template[206] and Template for Intervention Description and Replication[207] guidelines is recommended. This will allow the methods used for prescription and titration of exercise interventions to be more readily replicated in clinical practice.

Strengths and limitations

The major strength of this study pertains to the restricted inclusion of studies that initiated exercise training within 72 hours of admission. That is, although exercise training in adults hospitalised with a chronic respiratory disease has been the focus of a previous Cochrane review,[11] this earlier review included trials that initiated exercise training at any point during the hospitalisation as well as those that initiated exercise training shortly following hospital discharge. Of the 20 RCTs included in this earlier Cochrane review, only five began the intervention after 72 hours of hospitalisation. Given the focus in many countries on minimising hospital length of stay (LOS), studies that initiated exercise training only after 72 hours of hospitalisation are likely to have limited relevance in contemporary practice.[62, 237] In contrast, the current review provides detailed mapping of parameters reported across 18 studies, that are likely to be of interest and relevance to clinicians working with adults admitted for a respiratory condition.

4. CHAPTER 4: METHODS FOR THE OBSERVATIONAL STUDY REGARDING COMMUNITY-ACQUIRED PNEUMONIA

This chapter describes the methodology used to answer the following research questions:

In adults admitted to a general hospital with community-acquired pneumonia (CAP):

i. What is usual care in terms of medical and physiotherapy management?

Secondary (opportunistic) questions were also addressed. These were: do characteristics such as age, the presence of a chronic respiratory condition, disease severity and frailty influence the following variables (i) number of interactions with a physiotherapist, (ii) number of interactions during which the physiotherapist performed an assessment and/or treatment to address a respiratory problem, (iii) whether or not a referral for rehabilitation following discharge was initiated, (iv) hospital length of stay (LOS) and (v) whether or not the person was readmitted to hospital within 30 days of discharge?

ii. What is the healthcare utilisation, expressed as hospital LOS, the number of readmissions or presentations to any emergency department (ED) and the number of presentations to a general practitioner in the first 30 days following discharge?

Secondary (opportunistic) questions were also addressed. These were: do characteristics such as age, the presence of a chronic respiratory condition, disease severity and frailty influence the variables listed above (see question [i])?

iii. How much walking time and non-walking time is accumulated during the inpatient stay?

iv. Is there a relationship between walking time and age, disease severity, number of co-morbidities, previous level of function, frailty, duration of intravenous antibiotic therapy, use of non-invasive ventilation (NIV) or oxygen therapy?

v. Does daily step count influence healthcare utilisation, expressed as hospital LOS and the number of readmissions in the first 30 days following discharge?

This chapter will describe the study design, approvals from relevant Human Research Ethics Committees (HREC), study criteria, recruitment process, data collection, management and analysis. Some of the information presented has been published in a peer-reviewed journal.[2]

4.1. Study design

This was an observational study, in which participants were recruited from adults admitted to the tertiary Royal Perth Hospital (RPH), with a diagnosis of CAP. Data were collected prospectively. A brief telephone interview was conducted at 30 days following hospital discharge with each participant to capture data regarding healthcare utilisation. To minimise the chance that conducting this study would result in a change in usual clinical practice, details of the study were not shared with the physiotherapy staff working at the RPH.

4.2. Approvals

Approval was gained from RPH HREC (REG 2015-077) with reciprocal approval at Curtin University (HRE2017-0021). All participants gave written informed consent to participate.

4.3. Study criteria

People were eligible for inclusion if they were aged ≥ 18 years and had a formal diagnosis of CAP. For this study, CAP was diagnosed by the respiratory registrar if the person had any new infiltrate on chest radiograph (CXR), and either one major criteria (cough, sputum production, or temperature greater than 37.8°C) or two minor criteria (pleuritic chest pain, dyspnoea, altered mental status, pulmonary consolidation on examination, or leucocyte count

greater than 12,000/μL).[12] Participants were excluded if they: (i) required an admission to the intensive care unit (ICU), (ii) were non-ambulant prior to admission, (iii) declined to, or could not consent to participate in the study due to cognitive impairment or an inability to understand English, (iv) had a diagnosis of aspiration pneumonia or, (v) were not expected to survive the admission (i.e. had a terminal condition).

4.4. Recruitment

Potential participants were identified using the hospital electronic data system 'iSoft Clinical Manager'. Specifically, inpatient ward lists were screened daily for patients who had been admitted with a diagnosis that was captured using any of the following key search terms; 'shortness of breath', 'febrile', 'pneumonia' or 'respiratory infection'. Once identified, to limit the number of potential participants who needed to have a diagnosis of CAP confirmed by the respiratory registrar, exclusion criteria were applied before inclusion criteria.

4.5. Measures

A StepWatch™ Activity Monitor (SAM) (StepWatch™ Orthocare Innovations, Modus Health, Washington, USA) was used to measure walking-based activity. This was placed on the participant's ankle on admission and was worn continuously until hospital discharge. A purpose-built electronic data collection tool was designed using Qualtrics^{XM} Survey Software® (Qualtrics^{XM}, Utah, USA). This was loaded onto an iPad (iPad Mini, first generation, Apple Inc., California, USA) to enable data collection to occur in real-time on the ward. Standardised definitions for all variables were documented *a priori* in a data dictionary (see Appendix 3). The Qualtrics^{XM} tool and data dictionary were piloted for one week before data collection commenced. This was prior to the recruitment of any participants. Minor changes were made to improve efficiency and readability. A data collection sheet was

developed to guide the telephone interview conducted 30 days following hospital discharge. The data dictionary, data collection tool and data collection sheet used during the telephone interview are provided in Appendices 3 and 4. Data were collected by the candidate and one other rater.

4.5.1. Participant characteristics

The variables pertaining to participant characteristics, along with their data source, are shown in Table 4.1.

Table 4.1 Variables, data source and method of collection for participant characteristics

Variable	Data source	Comments
Demographic, anthropometric variables and those describing pre-morbid status		
Age	Hospital electronic data systems	Data verified during participant interview.
ATSI origin	Medical notes	Data verified during participant interview.
Clinical Frailty Scale	Medical notes	Assessment of frailty on admission was performed via the Clinical Frailty Scale (see Appendix 5).[91] Scores were determined by the level of independence with activities of daily living and presence of comorbidities. Scores range from 1 to 7, where higher scores indicate higher frailty.
Comorbidities*	Medical notes	Data were extracted on previous and co-existing medical conditions and these were recorded under 9 major headings.[238]
Height, weight and BMI	Medical notes	Data verified during participant interview.
Previous level of ambulation*	Medical notes	Ambulation prior to admission was described using 5 major categories, based on a scale that was used in another study.[239]

Previous social situation*	Medical notes	Social situation prior to admission was recorded as living at home alone, living at home with others, residential facility or respite.[240, 241]
Sex	Hospital electronic data systems	Data verified during participant interview.
Smoking status*	Medical notes	Participants were classified as a non-smoker, current smoker or ex-smoker.
Clinical variables on admission		
Blood pressure	Medical notes	Data were recorded as either < 90mmHg systolic or 60mmHg diastolic, or > 90mmHg systolic or 60mmHg diastolic (categories based on those used to calculate the CURB-65 score).
Confusion*	Medical notes	The presence of confusion on admission was recorded as yes or no.
CURB-65	Hospital electronic data systems and medical notes	Pneumonia-specific measure of disease severity (see Figure 2.2).[81] Scores were determined by clinical and laboratory findings and range from 0 - 5, where higher scores indicate higher disease severity.
Interhospital transfer	Medical notes	When participants had been transferred from another care facility prior to being admitted to the RPH, this location was classified as a secondary or tertiary hospital, or restorative unit.

Laboratory measures	Hospital electronic data systems	Serum concentrations of white cell count, C-reactive protein, haemoglobin, blood albumin and where reported, the organism detected in sputum sampling, on admission were recorded.
Pleural effusion	Admission CXR report	Presence of a pleural effusion on admission was recorded as yes or no. Where a radiology report was not available this was reported by the respiratory registrar.
Respiratory rate	Medical notes	Data were recorded as either < 30 breaths per minute, or ≥ 30 breaths per minute (categories based on those used to calculate CURB-65 score).

Table legend: *: see Appendix 3 – data dictionary for more details. ATSI: Aboriginal and Torres Strait Islander; BMI: body mass index; CURB-65: Confusion, Urea, Respiratory rate, Blood pressure; CXR: chest-x-ray.

4.5.2. Variables related to medical management

The variables pertaining to medical management, along with their data source, are shown in Table 4.2. These data were updated on a daily basis by the candidate.

Table 4.2 Variables, data source and method of collection for medical management

Variable	Data source	Comments
Antibiotic therapy	Bedside nursing file	Data were extracted on: name of prescribed antibiotics, the administration route (intravenous or oral) and commencement dates.
Medications	Bedside nursing file	Data were extracted on the names (only) of all regular medications and newly charted medications that were administered during hospitalisation.
Medical complications and adverse events	Medical notes	Any unfavourable incident or development that required investigation and altered the course of treatment during the hospitalisation. Examples include empyema, myocardial infarction, drug reaction, fall or dislodgement of an attachment.
Mortality	Medical notes, hospital electronic data systems and phone interview	For inpatient mortality, data were extracted on date and time of death during this hospital admission. At 30 days following discharge: mortality was recorded as yes or no.
Use of supplemental oxygen	Bedside nursing file	Use of domiciliary oxygen prior to the admission was recorded. For participants who were not using domiciliary oxygen, the duration of any supplemental oxygen use during hospitalisation was recorded.
Use of NIV	Bedside nursing file	Use of NIV prior to the admission was captured. For participants who were not using

	domiciliary NIV, the duration of any NIV use during hospitalisation was recorded.

Table legend: *: see Appendix 3 – data dictionary for more details; NIV: non-invasive ventilation.

4.5.3. Variables related to physiotherapy management

The variables pertaining to physiotherapy management, along with their data source, are shown in Table 4.3. These data were entered into Qualtrics on the day written informed consent was obtained and updated on a daily basis by the candidate.

Table 4.3 Variables, data source and method of collection for physiotherapy management

Variable	Data source	Comments
Ambulation (episodes and need for assistance)	Medical notes	The total number of times a physiotherapist accompanied the patient for ambulation was recorded. For each episode, the use of any supplemental oxygen, walking aid and/or need for physical assistance was recorded.
Interactions with a physiotherapist	Medical notes	The number of times a physiotherapist interacted with a patient for the purpose of assessment and/or treatment was recorded. Data were also extracted on the number of interactions during which the physiotherapist performed an assessment and/or treatment to address a respiratory problem (e.g. positioning to relieve dyspnoea).

Table legend: *: see Appendix 3 – data dictionary for more details.

4.5.4. Healthcare utilisation data

Data pertaining to hospital LOS and readmissions to the RPH in the first 30 days following discharge were calculated using hospital electronic systems. If a participant was referred for inpatient, outpatient or community-based rehabilitation on discharge, this was recorded. The possible types of rehabilitation are listed in the data dictionary (Appendix 3). These data were extracted from the medical notes. During the telephone interview conducted at 30 days following hospital discharge, participants were asked to recall and self-report presentations to a general practitioner, hospital readmissions and ED presentations to sites other than RPH. If the participant had presented to a general practitioner or an ED, they were asked the main reason for their presentation. If they were admitted to hospital they were asked about the duration of their admission.

4.5.5. Walking based activity

Walking-based activity was measured using a SAM. This small (75 × 50 × 20 mm), water-resistant micro-processor-controlled step counter was applied to the participants' right ankle via a fabric Velcro strap (Figure 4.1). It records the number of steps taken each minute taken by the right leg. Step count was doubled to determine total step count (i.e. steps taken by the left and right legs). The SAM has been shown to produce accurate measures of walking-based activity[242] in people who walk with very slow gait speeds and/or those who use a walking aid.[243]

The candidate reviewed the position of the SAM each day and checked for signs of skin irritation or discomfort. The candidate liaised with the nursing coordinator to notify them that the participant was wearing a SAM and it was essential that the SAM was to be removed prior to the participant being discharged.

Calibration

To ensure the SAM was providing accurate data throughout the period of data collection, each of the SAM devices was calibrated prior to data collection, every three months during data collection and at the conclusion of data collection. The calibration protocol is outlined in Appendix 6. The SAM was no longer used in the study if it was not possible to extract the data from the SAM or if there was a difference of more than 5% in step count between the observational count and SAM count.[244]

Programming and application

Prior to applying the SAM on the participant's right ankle, the SAM was programmed with the participant's height in centimetres. Walking speed and leg motion were selected as 'Normal', and the range of speeds was selected as 'Moderate range'.

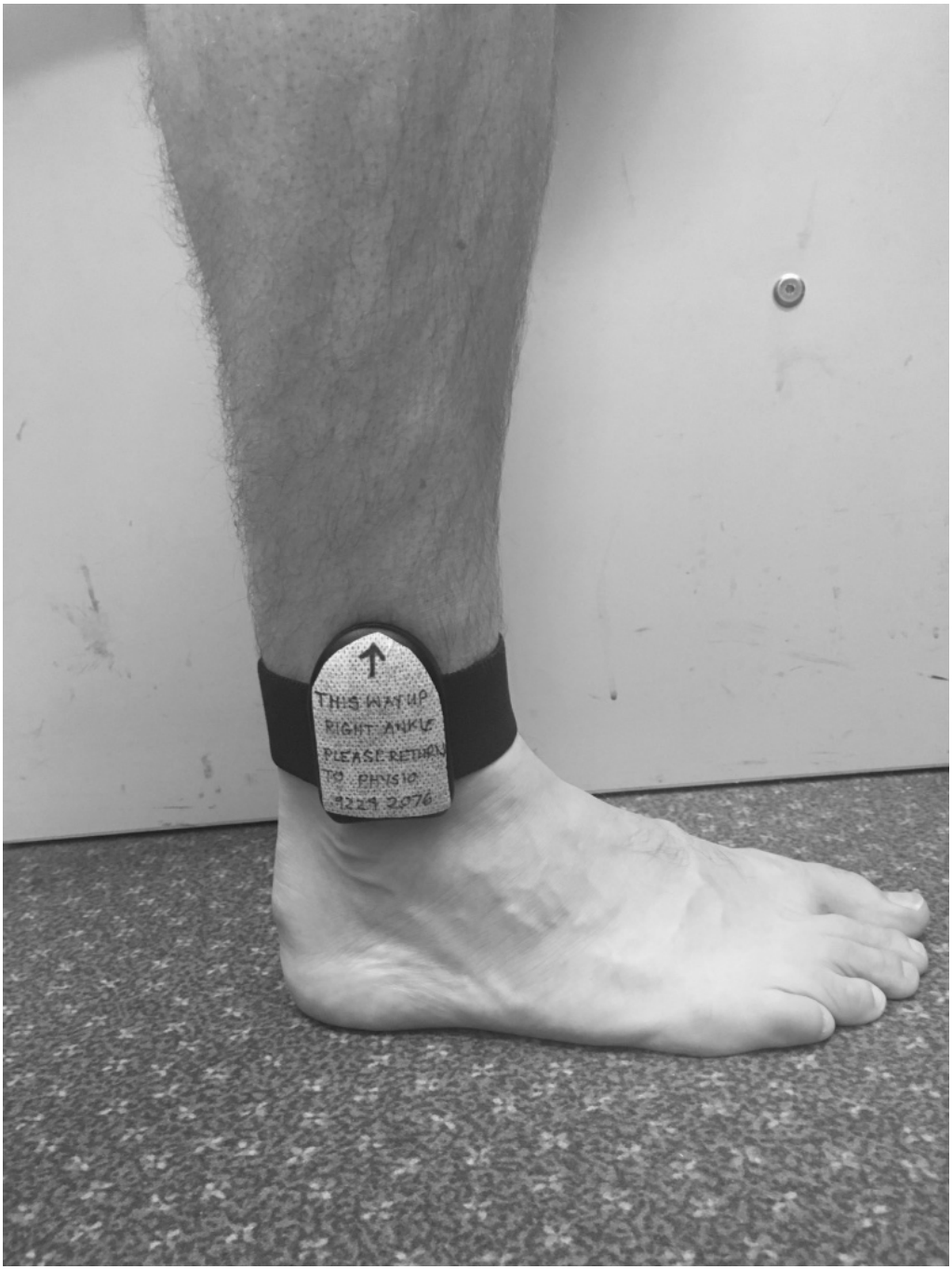

Figure 4.1 StepWatch™ Activity Monitor (SAM) attached to the right ankle

4.6. Management of Qualtrics data

As soon as possible after a participant was discharged from hospital, their data which had been collected using Qualtrics™, were exported to an Excel spreadsheet. On completion of the telephone interview (see section 4.5.4), data recorded on the data collection form were also entered into the Excel spreadsheet. The candidate checked the spreadsheet twice a week for missing data.

4.7. Management of StepWatch™ Activity Monitor data

Once a SAM was removed from a participant's ankle, it was placed onto the StepWatch™ docking station, which connected to a computer, and data were downloaded. These data were exported into an Excel spreadsheet on the day that each individual participant was discharged. To be included in these analyses, participants needed to contribute data over a minimum of one complete 24-hour period.

Data were extracted using a purpose-built program developed in LabVIEW (2017 Service Pack 1 (SPI, National Instruments, Texas, USA) and Sigmaplot (SYSTAT Software Inc., California, USA).

Extraction of variables related to walking time

All one-minute epochs during which the step count was > 0 were classified as walking time. For each participant, over each complete 24-hour sampling period, data were extracted, then averaged, to provide measures of: (i) step count/day, (ii) walking time/day, (iii) the number/day of transitions from non-walking time to walking time, (iv) the time/day spent in cadence bands defined by the United States National Health and Nutrition Examination Survey (NHANES)[245] and (v) one-minute peak cadence/day. The cadence bands defined by

NHANES were based on objective measures of step count and activity data from 3,744 community dwelling adults.[245] For participants who contributed at least one complete 24-hour period, data were averaged over multiple days.

To explore patterns of accumulation, for each participant, usual bout duration for walking time (UBD_{WT}) was calculated using data available across all 24-hour sampling periods. Specifically, UBD_{WT} was defined as the midpoint on the accumulation curve of walking time for each participant. Specifically, the midpoint is where the cumulative sum reaches 50% of the total bout duration. Therefore, half of all bouts of walking time were shorter than the UBD_{WT} and half of all bouts were longer than the UBD_{WT}.[156] This methodology has been used previously in large cohort studies.[155, 246, 247] A worked example is shown in Appendix 7.

To calculate variables related to non-walking time, the confounding effect of overnight sleeping time was removed by restricting data available for these analyses to that collected between 07:00 and 18:59. During this time, all one-minute epochs during which step count = 0 were classified as non-walking time. For each participant, the following variables were extracted for each 12-hour sampling period, then averaged and reported as an 'average' daily measure: (i) total non-walking time, and (ii) the number of transitions from walking time to non-walking time. Thereafter, for each participant, usual bout duration was calculated for non-walking time using data available across all 12-hour sampling periods. Usual bout duration for non-walking time (UBD_{NWT}) was defined as the midpoint on the accumulation curve of non-walking time for each participant. It represents bout duration above and below which half of all non-walking time is accrued.[155, 246, 247]

4.8. Statistical analyses

Analyses were undertaken using the Statistical Package for the Social Sciences (IBM Corp. Released 2017. IBM SPSS Statistics for Macintosh, Version 25.0. Armonk, NY: IBM Corp.). The distribution of all continuous variables was assessed using a Shapiro-Wilk test and by inspecting frequency histograms. Those data that followed a normal distribution were expressed with mean ± standard deviation (SD). Skewed data that did not follow a normal distribution were reported as median [interquartile range (IQR)]. Interquartile range was reported as the first quartile to third quartile.

For all inferential statistics, alpha was set at 0.05 and where possible, results were reported as means and 95% confidence intervals.

For the analyses pertaining to usual medical and physiotherapy management, descriptive statistics (mean ± SD or median [IQR] or percentages) were used.

Secondary (opportunistic) analyses were undertaken to explore differences in physiotherapy management (dependent variable) with participants grouped according to age, the presence of a chronic respiratory condition, disease severity and frailty (independent variables). For these analyses, the number of interactions with a physiotherapist were expressed as: (i) the total number of interactions across the period of hospitalisation and, (ii) the number of interactions per day (to account for the confounding effect of disparities in LOS). Likewise, the number of interactions with a physiotherapist for a respiratory problem were reported as the total number of interactions across the period of hospitalisation and the number of interactions per day.

The independent variables were selected as they seemed most likely to influence average daily step count, based on data in other populations.[24-27] The independent variables were

categorised according to the type of data and to ensure reasonable numbers across group membership (guided by the median values). In all instances, independent variables measured on ordinal scales were collapsed to binary data. Groups were defined as follows;

1. Age: 'younger' if age was less than the median or 'older' if age was above the median. Once data collection was complete, the starting age for 'older' was set as 70 years.[58]
2. Chronic respiratory condition: 'yes' if there was a pre-existing chronic respiratory condition or 'no' if there was no pre-existing chronic respiratory condition.
3. Disease severity: 'less severe' if they had a CURB-65 score of 0 or 1 or 'more severe' if they had a CURB-65 score of 2, 3 or 4.[12, 14]
4. Frailty: 'mild frailty' if they had a Clinical Frailty score of 1 to 3 or 'moderate to severe frailty' if they had a Clinical Frailty score of 4, 5, 6 or 7.[248, 249]

The Mann-Whitney U test was used to assess for between-group differences in physiotherapy management (continuous variable) according to age, the presence of a chronic respiratory condition, disease severity and frailty (categorical variables). To determine whether age, the presence of a chronic respiratory condition, disease severity or frailty were predictors of the number of interactions with a physiotherapist and the number of interactions during which the physiotherapist performed an assessment and/or treatment to address a respiratory problem, negative binomial regression was used. Variables that significantly influenced the number of interactions with a physiotherapist and the number of interactions with a physiotherapist for a respiratory problem in the univariate analysis were then entered into a multivariable model.

For the analyses pertaining to healthcare utilisation data descriptive statistics such as median [IQR] were used. Other measures of healthcare utilisation such as the number of participants who presented to a general practitioner were reported as count data.

Secondary opportunistic analyses were undertaken to explore differences in healthcare utilisation (dependent variable) with participants grouped according to age, the presence of a chronic respiratory condition, disease severity and frailty (independent variable). When the dependent variable was expressed as continuous variable (e.g. hospital LOS) between-group differences (with data grouped according to the independent variables) were explored using the Kaplan-Meier method. When the dependent variable was expressed as binary data (e.g. 30-day readmission [yes or no]) between-group differences (with data grouped according to the independent variables) were explored using Chi-square test. To determine whether age, the presence of a chronic respiratory condition, disease severity or frailty were predictors of healthcare utilisation, two regression models were used. A negative binomial regression was used for continuous data (hospital LOS) and logistic regression was used for binary data (referral to rehabilitation [yes or no] and the number of 30-day readmissions [yes or no]). Variables that significantly influenced healthcare utilisation in the univariate model were then entered into a multivariable model.

For the analyses pertaining to measures of walking time and non-walking time descriptive statistics were used.

For the analyses pertaining to the relationship between walking time and variables of interest, negative binomial regression was used. Average daily step count was the dependent variable and age, disease severity, frailty, presence of a pleural effusion, number of interactions with physiotherapy and use of new supplemental oxygen entered as independent variables. Independent variables measured on ordinal scales were collapsed to binary data. The CURB-

65 and frailty scores were collapsed using the same methodology for the first research question. The number of interactions with physiotherapy were grouped as 0 to 1 interaction and ≥ 2 interactions. Variables that significantly influenced average daily step count in the univariate model and were retained in more than one of the opportunistic multivariable models described previously, were then entered into a multivariable model. Linear regression (with transformation of the dependent variables where necessary) was used to determine whether or not variables retained in the multivariable model were also predictors of UBD_{WT} and one-minute peak cadence.

For the analyses pertaining to the relationship between daily step count and healthcare utilisation, Poisson regression was used to explore the influence of average daily step count on hospital LOS and the number of 30-day hospital readmissions (treated as a continuous variable for this analysis). Specifically, average daily step count was grouped in increments of 500 steps to determine whether an increase in average daily step count of 500 steps was a predictor of LOS or hospital re-admissions.

4.8.1. Sample size expectation

Consideration of sample size that would be recruited to this study was undertaken prior to data collection. To minimise selection bias, the aim was to approach every patient who met the study criteria, regardless of the day of admission (i.e. consecutive sampling including over the weekends and public holidays). As this responsibility was undertaken solely by the MPhil candidate, it was decided a priori, that the recruitment period would extend for no longer than 8 months. Based on data sourced through the RPH prior to commencing this study, it was expected that the number of admissions to the RPH with CAP would be approximately 677 per year. Data from two previous published trials of inpatient mobilisation in patients hospitalised with CAP,[12, 14] suggested that approximately 36% of the total

recruitment pool would not be able or willing to participate in the study. Therefore, over a 6-month period it was expected that recruitment of approximately 216 participants would be possible to this study. Following consultation with a biostatistician, a sample size of 200 participants was considered sufficient to undertake the exploratory analyses that were planned.

5. CHAPTER 5: RESULTS AND DISCUSSION FOR RESEARCH QUESTIONS 1 TO 2

The results of the observational study described in Chapter 4 are presented across two chapters of this thesis. Chapter 5 presents the results and a discussion of the data that answer research questions 1 and 2 (Section 5.1 and 5.2). Chapter 6 presents the results and a discussion of the data that answer research questions 3, 4 and 5 (Section 6.1 and 6.2). The data presented in Chapter 6 have been published in *Respiratory Care* in February 2020 (Appendix 8),[2] and have been expanded for this thesis.

This chapter details the results and discussion that relates to the following two research questions:

In adults admitted to a general hospital with community-acquired pneumonia (CAP):

i. What is usual care in terms of medical and physiotherapy management?

   Secondary (opportunistic) questions were also addressed. These were: do characteristics such as age, the presence of a chronic respiratory condition, disease severity and frailty influence the following variables, (i) number of interactions with a physiotherapist, (ii) number of interactions during which the physiotherapist performed an assessment and/or treatment to address a respiratory problem, (iii) whether or not a referral to rehabilitation following discharge was initiated, (iv) hospital length of stay (LOS) and (v) whether or not the person was readmitted to hospital within 30 days of discharge?

ii. What is the healthcare utilisation, expressed as hospital LOS, the number of readmissions or presentations to any emergency department (ED) and the number of presentations to a general practitioner in the first 30 days following discharge?

Secondary (opportunistic) questions were also addressed. These were: do characteristics such as age, the presence of a chronic respiratory condition, disease severity and frailty influence the variables listed above (see question [i])?

5.1. Results

5.1.1. Participant characteristics

The flow of participants into the study is shown in Figure 5.1. A total of 1,263 patients were screened to determine their eligibility and, of these, 200 met the study criteria. Of the 200 participants recruited to the study, 163 (81%) participants presented directly to the tertiary Royal Perth Hospital (RPH) and 37 (19%) participants were transferred from another healthcare facility prior to being admitted to the RPH. The majority of participants (n = 150; 75%) were admitted to a short stay medical ward, with others admitted to a respiratory ward (n = 32; 16%), haematology ward (n = 7; 4%), cardiology ward (n = 8, 4%) or other wards (n = 3; 1%).

The participant characteristics are summarised in Table 5.1. The median [interquartile range (IQR)] CURB-65 score was 1 [1 to 2]. Of the 200 participants recruited to the study, on admission, 45 (23%) presented with a pleural effusion, and of these 9 (20%) participants required drainage via an intercostal catheter (ICC). Three (2%) participants required subsequent transfer to another hospital for surgical management of a pleural effusion or empyema. Of the 200 participants recruited to the study, 124 (62%) participants had a Clinical Frailty Score of < 4 and 76 (38%) participants had a Clinical Frailty Score of ≥ 4.

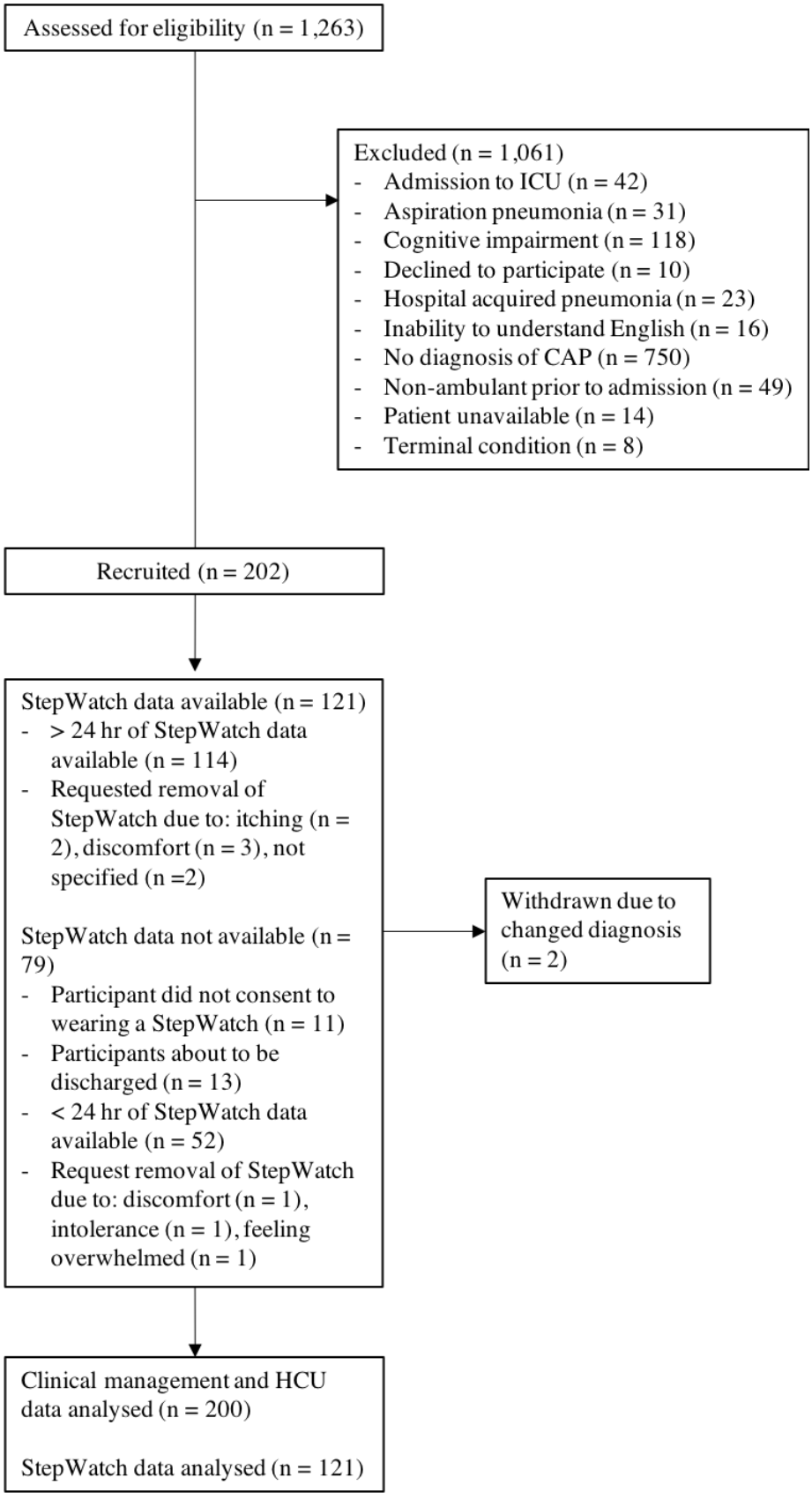

Figure 5.1 Participant flow through the study

CAP: community-acquired pneumonia; HCU: healthcare utilisation; ICU: intensive care unit.

Table 5.1 Participant characteristics

Variable	n = 200
Age (yr)	66.8 ± 18.2
Aboriginal or Torres Strait Islander	22 (11)
Body mass index (kg/m^2)	26.4 ± 7.2
Clinical Frailty Scale (scores 1 to 7) (median [IQR])	3 [3 to 4]
Males	129 (65)
Non (never)-smoker	68 (34)
Presence of a cardiovascular comorbid condition	129 (65)
Presence of a chronic respiratory comorbid condition	80 (40)
Presence of a metabolic comorbid condition	86 (43)
Pre-admission details	
Assisted ambulation	4 (2)
Independent ambulation with a walking frame	31 (16)
Independent ambulation (with or without a walking stick)	165 (82)
Living alone at home	55 (28)
Living at home with others	126 (63)
Living in a hostel or homeless	10 (5)
Living in a residential facility	9 (4)

Data are expressed as (mean ± SD) or number (Y%), unless otherwise stated. IQR: interquartile range; SD: standard deviation; yr: years.

5.1.2. Medical management

Of the 200 participants recruited to the study, 197 (98%) participants received intravenous (IV) antibiotic therapy during the period of hospitalisation. Of the 163 participants who presented directly to the RPH, 139 (85%) participants had commenced IV antibiotic therapy in the ED, prior to being admitted to the ward. The median [IQR] number of IV antibiotic doses given during hospitalisation was 2 [1 to 3]. The most frequently administered IV antibiotics were Ceftriaxone (n = 131, 67%), Azithromycin (n = 119, 60%) and Benzylpenicillin (n = 85, 43%). Intravenous and oral antibiotic therapy were started concurrently in 65 (33%) participants, while a step-down approach from IV to oral antibiotic therapy was used in 81 (41%) participants. Oral antibiotic therapy was started prior to IV antibiotic therapy in 13 (7%) participants. Exclusive IV antibiotic therapy was used for 38 (19%) participants. One participant received oral antibiotic therapy only.

Domiciliary oxygen had been prescribed for 5 (2%) participants prior to hospitalisation. Of the 195 participants who were not using domiciliary oxygen, 109 (56%) received supplemental oxygen therapy during the period of hospitalisation. The median [IQR] duration of oxygen therapy was 36 [12 to 71] hours. One (0.5%) participant had been prescribed domiciliary non-invasive ventilation (NIV) prior to hospitalisation. Of the remaining 199 participants recruited to the study, 12 (6%) participants received NIV therapy during the period of hospitalisation. The median [IQR] duration of NIV therapy was 8 [3 to 33] hours.

At least one medical complication or adverse event occurred in 53 (26%) participants. Of the participants who did have a medical complication or adverse event, the median number of events was 1 [1 to 2]. Across the 53 participants, there were 109 medical complications or adverse events. These are displayed in Table 5.2. Four (2%) participants died during the period of hospitalisation.

Table 5.2 Medical complications and adverse events

Medical complication or adverse event	n (%)
Acute confusion	5 (5)
Acute kidney injury	1 (0.5)
Arrhythmia	5 (5)
Cellulitis	1 (0.5)
Chest pain	2 (2)
Cyanosis	1 (0.5)
Dislodgement of attachment	3 (4)
Drug reaction	2 (2)
Empyema	4 (4)
Fall in haemoglobin	2 (2)
Febrile	6 (6)
Heart failure	1 (0.5)
Hypertension	1 (0.5)
Pancytopenia	1 (0.5)
Pleural effusion on admission	45 (41)
Pulmonary embolism	2 (2)
Reduced consciousness	1 (0.5)
Renal failure	2 (2)
Seizures	1 (0.5)
Sepsis	1 (0.5)
Severe hyperglycaemia	10 (9)
Tachycardia	6 (6)
Type 1 respiratory failure	5 (5)

Wound ooze	1 (0.5)

Data are presented as n (%). Percentages are expressed relative to the 109 participants who experienced medical complications and/or adverse events.

5.1.3. Physiotherapy management

A physiotherapist interacted with 161 (81%) participants for the purpose of assessment and/or treatment of any kind. Specifically, for 131 (66%) participants the physiotherapist chose to ambulate the participant. Ninety (45%) participants received at least one physiotherapy interaction which involved assessment and/or treatment of a respiratory problem. These results are summarised in Table 5.3. Physiotherapy management with participants grouped according to their admission ward is provided in Table 5.4.

Table 5.3 Physiotherapy management during the period of hospitalisation

Variable	**n = 200**
Number of participants who were seen by a physiotherapist	161 (81)
Number of times a participant was seen by a physiotherapist	1 [1 to 4]
Number of times a participant was seen by a physiotherapist, per day	0.5 [0.2 to 0.8]
Number of participants who were seen by a physiotherapist for an assessment and/or treatment of a respiratory problem	90 (45)
Number of times a participant was seen by a physiotherapist for an assessment and/or treatment of a respiratory problem	0 [0 to 1]
Number of times a participant was seen by a physiotherapist for a respiratory problem, per day	0 [0.0 to 0.3]
Number of participants who ambulated with physiotherapy	131 (66)
Number of episodes of supervised ambulation with physiotherapy	1 [0 to 2]
Of participants who received respiratory assessment or treatment (n = 90), number who were treated with:	
Deep breathing exercises	85 (94)
Functional resistance exercises	7 (8)
Positioning	10 (11)
Positive expiratory pressure	18 (20)
Of participants who ambulated with a physiotherapist (n = 131)	
Number who required physical assistance and a gait aid	16 (12)
Number who required physical assistance and no gait aid	1 (1)
Number who required no physical assistance and a gait aid	14 (11)
Number who required no physical assistance and no gait aid	66 (50)
Number who required physical assistance or a gait aid which was	34 (26)

weaned	
Number who required supplemental oxygen	9 (7)
Number who required no supplemental oxygen	94 (72)
Number who required supplemental oxygen which was weaned	28 (21)

Data are expressed as mean ± SD, median [IQR] or n (%). IQR: interquartile range.

Table 5.4 Physiotherapy management with participants grouped by ward of admission

Variable	Cardiology ward n = 8	Haematology ward n = 7	Other ward n = 3	Respiratory ward n = 32	Short stay medical unit n = 150
Number of participants who were seen by a physiotherapist	6 (75)	7 (100)	2 (67)	28 (88)	118 (79)
Number of times a participant was seen by a physiotherapist	4.5 [0 to 10]	1 [1 to 8]	0 [0 to 26]	3 [1 to 8]	1 [1 to 3]
Number of participants who were seen by a physiotherapist for an assessment and/or treatment of a respiratory problem	4 (50)	2 (29)	1 (33)	26 (81)	57 (38)
Number of times a participant was seen by a physiotherapist for an assessment and/or treatment of a respiratory problem	1 [0 to 5]	0 [0 to 1]	0 [0 to 0]	2 [1 to 4]	0 [0 to 1]

Data are expressed as median [IQR] or n (%). IQR: interquartile range.

The number of interactions with a physiotherapist was compared between participants grouped according to age, the presence of a chronic respiratory condition, disease severity, and frailty. These results are presented in Table 5.5. In summary, the number of interactions with a physiotherapist was greater in participants characterised by older age, more severe disease and greater frailty, even when adjusted for LOS.

The results of the analyses that explored predictors of an increased number of interactions with a physiotherapist are presented in Table 5.6. Briefly, in the univariate model, variables that influenced the number of interactions with a physiotherapist were age, disease severity, and frailty. In the multivariable model, only disease severity and frailty were retained.

Table 5.5 Interactions with a physiotherapist

A. Total number of interactions with a physiotherapist

Variable	Between-group difference	Number of interactions	p value
Age	More interactions in those aged ≥ 70 years versus < 70 years	2 [1 to 5] versus 1 [0 to 2]	< 0.001*
Chronic respiratory condition	The number of interactions appeared similar between those who had a chronic respiratory condition versus those who did not	2 [1 to 4] versus 1 [1 to 3]	0.32
Disease severity	More interactions in those with 'more severe' versus 'less severe' disease	3 [1 to 5] versus 1 [0 to 2]	< 0.001*
Frailty	More interactions in those with frailty score ≥ 4 versus frailty score < 4	3 [1 to 6] versus 1 [0 to 2]	< 0.001*

Data are expressed as median [IQR]. IQR: interquartile range.

B. Number of interactions with a physiotherapist when adjusted for LOS

Variable	**Between-group difference**	**Number of interactions per day**	**p value**
Age	More interactions per day in those aged ≥ 70 years versus < 70 years	0.6 [0.5 to 1.0] versus 0.3 [0.0 to 0.5]	< 0.001*
Chronic respiratory condition	The number of interactions per day appeared similar between those who had a chronic respiratory condition versus those who did not	0.5 [0.3 to 0.8] versus 0.5 [0.2 to 0.7]	0.30
Disease severity	More interactions per day in those with 'more severe' versus 'less severe' disease	0.5 [0.3 to 0.9] versus 0.3 [0.0 to 0.7]	< 0.001*
Frailty	More interactions per day in those with frailty score ≥ 4 versus frailty score < 4	0.6 [0.3 to 1.0] versus 0.3 [0.0 to 0.6]	< 0.001*

Data are expressed as median [IQR]. IQR: interquartile range.

Table 5.6 Predictors of an increased number of interactions with a physiotherapist

A. Negative binomial regression: univariate analysis

Variable	Direction of relationship based on IRR	IRR	95% CI	p value
Age	More interactions in those aged ≥ 70 years	2.24	1.60 to 3.10	< 0.001*
Chronic respiratory condition	The effect of a chronic respiratory condition on the number of interactions with a physiotherapist is unclear	1.17	0.84 to 1.63	0.34
Disease severity	More interactions in those with 'more severe' disease	2.30	1.60 to 3.20	< 0.001*
Frailty	More interactions in those with frailty score ≥ 4	2.36	1.70 to 3.29	< 0.001*

B. Negative binomial regression: multivariable analysis

Variable	Direction of relationship based on IRR	IRR	95% CI	p value
Age	The effect of age on the number of interactions with a physiotherapist is unclear	1.36	0.90 to 2.05	0.14
Disease severity	More interactions in those with 'more severe' disease	1.63	1.12 to 2.38	0.01*
Frailty	More interactions in those with frailty score ≥ 4	1.67	1.13 to 2.49	0.01*

A. Univariate models. B. Final multivariable model using those variables that significantly influenced number of interactions with a physiotherapist (count data) in the univariate model. CI: confidence interval; IRR: incidence rate ratio.

The number of interactions with a physiotherapist for a respiratory problem was compared between participants grouped according to age, the presence of a chronic respiratory condition, disease severity and frailty, and these results are presented in Table 5.7. In summary, the number of interactions with a physiotherapist for a respiratory problem was greater in participants characterised by older age, more severe disease and greater frailty, even when adjusted for LOS.

The results of the analyses that explored predictors of an increased number of interactions with a physiotherapist for a respiratory problem are presented in Table 5.8. Briefly, in the univariate model, variables that influenced the number of interactions with a physiotherapist for a respiratory problem were age, disease severity and frailty. In the multivariable model, only disease severity and frailty were retained.

Table 5.7 Number of interactions with a physiotherapist for a respiratory problem

A. Total number of interactions with a physiotherapist for a respiratory problem

Variable	Between-group difference	Number of interactions	p value
Age	More interactions in those aged ≥ 70 years versus < 70 years	1 [0 to 2] versus 0 [0 to 1]	< 0.001*
Chronic respiratory condition	The number of interactions appeared similar between those who had a chronic respiratory condition versus those who did not	1 [0 to 2] versus 0 [0 to 1]	0.07
Disease severity	More interactions in those with 'more severe' versus 'less severe' disease	1 [0 to 3] versus 0 [0 to 1]	< 0.001*
Frailty	More interactions in those with frailty score ≥ 4 versus frailty score < 4	1 [0 to 3] versus 0 [0 to 1]	< 0.001*

Data are expressed as median [IQR]. IQR: interquartile range.

B. Number of interactions with a physiotherapist for a respiratory problem adjusted for LOS

Variable	Between-group difference	Number of interactions	p value
Age	More interactions per day in those aged ≥ 70 years versus < 70 years	0.2 [0.0 to 0.5] versus 0.0 [0.0 to 0.3]	< 0.001*
Chronic respiratory condition	The number of interactions per day appeared similar between those who had a chronic respiratory condition versus those who did not	0.2 [0.0 to 0.4] versus 0.0 [0.0 to 0.3]	0.06
Disease severity	More interactions per day in those with 'more severe' versus 'less severe' disease	0.1 [0.0 to 0.5] versus 0.0 [0.0 to 0.3]	0.01*
Frailty	More interactions per day in those with frailty score ≥ 4 versus frailty score < 4	0.2 [0.0 to 0.5] versus 0.0 [0.0 to 0.3]	< 0.01*

Data are expressed as median [IQR]. IQR: interquartile range.

Table 5.8 Predictors of an increased number of interactions with a physiotherapist for a respiratory problem

A. Negative binomial regression: univariate analysis

Variable	Direction of relationship based on IRR	IRR	95% CI	p value
Age	More interactions in those aged ≥ 70 years	2.42	1.60 to 3.60	< 0.001*
Chronic respiratory condition	The effect of a chronic respiratory condition on the number of interactions with a physiotherapist for a respiratory problem is unclear	1.21	0.83 to 1.76	0.33
Disease severity	More interactions in those with 'more severe' disease	2.23	1.50 to 3.30	< 0.001*
Frailty	More interactions in those with frailty score ≥ 4	2.39	1.60 to 3.50	< 0.001*

B. Negative binomial regression: multivariable analysis

Variable	Direction of relationship based on IRR	IRR	95% CI	p value
Age	The effect of age on the number of interactions with a physiotherapist for a respiratory problem is unclear	1.50	0.93 to 2.42	0.09
Disease severity	More interactions in those with 'more severe' disease	1.59	1.04 to 2.45	< 0.01*
Frailty	More interactions in those with frailty score ≥ 4	1.71	1.10 to 2.66	0.02*

A. Univariate models. B. Final multivariable model using those variables that significantly influenced number of interactions with a physiotherapist for a respiratory problem (count data) in the univariate model. CI: confidence interval; IRR: incidence rate ratio.

5.1.4. Healthcare utilisation

The variables related to measures of healthcare utilisation are shown in Table 5.9. Of the 196 participants who survived the admission, 45 (23%) participants could not be contacted by telephone at 30 days following discharge. In addition, 7 (4%) participants were unable to participate in the telephone interview due to being re-hospitalised (n = 2), being unable to understand the questions of the interview (n = 2) or not surviving to 30 days following discharge (n = 3).

Within 30 days following discharge 21 (14%) participants had at least one presentation to the ED, and 21 (14%) participants had at least one hospital readmission. Twenty participants (14%) had both a presentation to the ED presentation and a hospital readmission. One participant had a presentation to the ED without a readmission and one participant was admitted to a private hospital without a presentation to the ED.

Data pertaining to LOS for participants grouped according to age, the presence of a chronic respiratory condition, disease severity and frailty are shown in Table 5.10. Participants who were characterised by more severe disease and greater frailty had a longer LOS in comparison to participants who did not have these characteristics. There were no pre-specified discharge criteria.

The results of the analyses that explored predictors of increased LOS are presented in Table 5.11. Briefly, in the univariate model, variables that influenced the LOS were disease severity and frailty. Both disease severity and frailty were entered into a multivariable regression model, but no variables remained significant.

Table 5.9 Healthcare utilisation

Variable	Denominator	
ED presentation within 30 days of discharge	n = 146	21 (14)
GP presentation within 30 days of discharge	n = 144	112 (78)
LOS (days)	n = 200	4 [2 to 4]
Readmission within 30 days of discharge	n = 146	21 (14)
Referral for rehabilitation on discharge	n = 196	25 (13)

Data are expressed as median [IQR] or n (%). The number of presentations to the GP and sites other than RPH were self-reported. GP: general practitioner; ED: Emergency Department; IQR: interquartile range; LOS: length of stay.

Table 5.10 Length of stay

Variable	**Between-group difference**	**LOS (days)**	p value
Age	LOS appeared similar between those aged ≥ 70 years and those aged < 70 years	4 [2 to 8] versus 4 [3 to 5]	0.05
Chronic respiratory condition	LOS appeared similar between those who had a chronic respiratory condition and those who did not	4 [3 to 6] versus 3 [2 to 7]	0.09
Disease severity	Increased LOS in those with 'more severe' versus 'less severe' disease	4 [3 to 8] versus 3 [2 to 5]	< 0.001*
Frailty	Increased LOS in those with frailty score ≥ 4 versus frailty score < 4	5 [3 to 8] versus 3 [2 to 5]	< 0.001*

Data are expressed as median [IQR]. LOS: length of stay; IQR: interquartile range.

Table 5.11 Predictors of increased length of stay

A. Negative binomial regression: univariate analysis

Variable	Direction of relationship based on IRR	IRR	95% CI	p value
Age	The effect of age on LOS is unclear	1.23	0.91 to 1.67	0.17
Chronic respiratory condition	The effect of a chronic respiratory condition on LOS is unclear	0.98	0.72 to 1.34	0.91
Disease severity	Increased LOS in those with 'more severe' disease	1.49	1.10 to 2.02	0.01*
Frailty	Increased LOS in those with frailty score ≥ 4	1.50	1.10 to 2.00	0.01*

B. Negative binomial regression: multivariable analysis

Variable	Direction of relationship based on IRR	IRR	95% CI	p value
Disease severity	The effect of disease severity on LOS is unclear	1.33	0.95 to 1.85	0.10
Frailty	The effect of frailty on LOS is unclear	1.34	0.95 to 1.87	0.09

A. Univariate models. B. Final multivariable model using those variables that significantly influenced LOS (continuous data) in the univariate model. CI: confidence interval; IRR: incidence rate ratio; LOS: length of stay.

Data pertaining to the prevalence of referral for inpatient or outpatient rehabilitation on discharge for participants according to age, the presence of a chronic respiratory condition, disease severity and frailty are shown in Table 5.12. The proportion of participants referred for rehabilitation on discharge was greater in those who were characterised by older age, more severe disease and greater frailty in comparison to participants who did not have these characteristics.

The results of the analyses that explored predictors of referral for rehabilitation on discharge are presented in Table 5.13. In the univariate model, variables that influenced referral for rehabilitation on discharge were age and frailty. In the multivariable model, both age and frailty remained significant. Specifically, for every 1-year increase in age, the odds of being referred for rehabilitation on discharge increased by 1.07. Further, those with a frailty score ≥ 4 had a 4.42 times greater odds of being referred for rehabilitation on discharge.

Table 5.12 Referral for rehabilitation on discharge

Variable	Between-group difference	Proportion of participants referred to rehabilitation (%)	p value
Age	More referrals for rehabilitation in those aged ≥ 70 years versus < 70 years	26% versus 1%	< 0.001*
Chronic respiratory condition	The number of referrals for rehabilitation appeared similar between those who had a chronic respiratory condition and those who did not	18% versus 9%	0.09
Disease severity	More referrals for rehabilitation in those with 'more severe' versus 'less severe' disease	18% versus 9%	0.049*
Frailty	More referrals for rehabilitation in those with frailty score ≥ 4 versus frailty score < 4	29% versus 3%	< 0.001*

Table 5.13 Predictors of referral for rehabilitation on discharge

A. Logistic regression: univariate analysis

Variable	Direction of relationship based on OR	OR	95% CI	p value
Age	More referrals for rehabilitation with increasing age	1.10	1.05 to 1.15	< 0.001*
Chronic respiratory condition	The effect of a chronic respiratory condition on referral for rehabilitation is unclear	2.08	0.89 to 4.85	0.09
Disease severity	The effect of disease severity on referral for rehabilitation is unclear	2.33	0.99 to 5.49	0.05
Frailty	More referrals for rehabilitation in those with frailty score ≥ 4	12.35	4.04 to 37.80	< 0.001*

B. Logistic regression: multivariable analysis

Variable	Direction of relationship based on OR	OR	95% CI	p value
Age	More referrals for rehabilitation with increasing age	1.07	1.00 to 1.12	< 0.01*
Frailty	More referrals for rehabilitation in those with frailty score ≥ 4	4.42	1.30 to 15.00	0.02*

A. Univariate models. B. Final multivariable model using those variables that significantly influenced referral for rehabilitation (binary data; 0 readmissions or ≥ readmissions) in the univariate model. CI: confidence interval; OR: odds ratio.

Data pertaining to readmissions to hospital within 30 days of discharge for participants according to age, the presence of a chronic respiratory condition, disease severity and frailty are shown in Table 5.14. The proportion of participants that were readmitted within 30 days of discharge was greater in those who were characterised by greater frailty.

The results of the analyses that explored predictors of 30-day readmissions are presented in Table 5.15. In the univariate model, the only variable that influenced readmission to hospital within 30 days of discharge was frailty. Specifically, those participants with a frailty score ≥ 4 had 2.9 times higher odds of being readmitted within 30 days of discharge.

Table 5.14 30-day readmissions

Variable	Between-group difference	Proportion of participants readmitted within 30 days (%)	p value
Age	The number of readmissions appeared similar between those aged ≥ 70 years and those aged < 70 years	15% versus 13%	0.71
Chronic respiratory condition	The number of readmissions appeared similar between those who had a chronic respiratory condition and those who did not	16% versus 13%	0.71
Disease severity	The number of readmissions appeared similar between those with 'more severe' versus 'less severe' disease	13% versus 16%	0.63
Frailty	More readmissions in those with frailty score ≥ 4 versus frailty score < 4	22% versus 9%	0.03*

The number of readmissions to sites other than RPH were self-reported.

Table 5.15 Predictors of 30-day readmissions

A. Logistic regression: univariate analysis

Variable	Direction of relationship based on OR	OR	95% CI	p value
Age	The effect of age on readmissions is unclear	1.01	0.98 to 1.04	0.53
Chronic respiratory condition	The effect of a chronic respiratory condition on readmissions is unclear	1.20	0.47 to 3.02	0.71
Disease severity	The effect of disease severity on readmissions is unclear	0.81	0.31 to 2.09	0.66
Frailty	More readmissions in those with frailty score ≥ 4	2.90	1.11 to 7.50	0.03*

The number of readmissions to sites other than RPH were self-reported. CI: confidence interval; OR: odds ratio.

5.2. Discussion

This was an observational study in which data were prospectively collected on 200 adults who were hospitalised in a tertiary hospital with a diagnosis of CAP. The data demonstrate that clinical frailty was an independent predictor of multiple unfavourable outcomes, such as referral for rehabilitation on discharge and readmission to hospital within 30 days of discharge. Other important findings included: (i) a physiotherapist assessed and/or treated 81% of participants, (ii) the most commonly used intervention was supervised ambulation and (iii) factors such as more severe disease and increased frailty characterised those participants who had a higher number of interactions with a physiotherapist.

Frailty has been described as an increased vulnerability and decreased physical reserve to cope with acute stressors.[28] It would therefore seem reasonable that an episode of acute illness is more likely to result in poor health outcomes in adults characterised by frailty. The data in this study demonstrated that increased frailty was a predictor of the need for rehabilitation on discharge, readmission to hospital within 30 days of discharge and a higher number of interactions with a physiotherapist. Consistent with these findings, previous work conducted in older adults hospitalised with a general medical condition[26] and older adults presenting to the ED,[27] has demonstrated that increased frailty is a predictor of adverse outcomes. These include increased hospital LOS and inpatient mortality.[26, 27] In the current study presented in this thesis of adults hospitalised with CAP, increased frailty was a predictor of an increased number of interactions with a physiotherapist. This was not simply a consequence of the more frail participants requiring an increased LOS as differences remained even when the number of interactions with a physiotherapist were adjusted for differences in LOS. The increased number of interactions with a physiotherapist in the more frail participants may be explained by previous research that has shown that a period of

hospitalisation for CAP is associated with an impairment in physical function[3, 4, 141] and that those participants who are more frail are more vulnerable with decreased physical reserve. Therefore, these frail participants could be at greater risk of an impairment in physical function at the time of hospital discharge and considered a clear target for physiotherapy interventions.

Disease severity was also demonstrated to be a predictor of increased LOS and increased number of interactions with a physiotherapist. Other observational studies in CAP have demonstrated that increased disease severity is associated with increased LOS.[250-252] This is a reflection of the increased time to clinical stability with increasing disease severity.[253-255] Even after considering differences in LOS, increased disease severity was a predictor of an increased number of interactions with a physiotherapist. This is most likely explained by the fact that participants with more severe disease are likely to experience symptoms of dyspnoea and fatigue, which are known barriers to mobilisation in hospital.[29, 30] Those participants who are more likely to experience difficulty in mobilising on the ward may be a priority to a physiotherapist.

Lastly, increased age was a predictor of referral for rehabilitation. This may be due to the known influence of increasing age on functional decline during a period of hospitalisation in older adults,[256] which would require rehabilitation after hospital discharge.

Physiotherapy practices in adults hospitalised with CAP, who were not in the intensive care unit (ICU), are currently unknown. In this observational study of adults hospitalised with CAP, physiotherapists chose supervised ambulation as an intervention in the majority (66%) of participants, whereas functional resistance exercise was used infrequently (8%). Similar findings have been identified in other hospitalised populations. Specifically, an Australian survey revealed that 94% of physiotherapists utilised corridor ambulation in ≥ 60% of adults

hospitalised with an exacerbation of chronic obstructive pulmonary disease (COPD).[19] Functional resistance exercise and equipment based exercise were used less frequently.[19] The frequent use of supervised ambulation as an intervention can be explained by two reasons. First, ambulation does not require any exercise equipment and is accessible in any setting. Second, ambulation based exercise training has been demonstrated as an effective tool to increase exercise capacity in adults hospitalised with CAP[13] and other respiratory conditions.[17, 216, 224] The infrequent use of functional resistance exercise seen in our study may be a reflection of the paucity of exercise training trials in adults hospitalised with CAP. For a physiotherapist working on a busy hospital ward, supervised ambulation may be an easier and more practical intervention to deliver in comparison to a structured exercise program.

Assessment or treatment specific to a respiratory problem was used in less than half of the participants. This may be due to not all participants presenting with a productive cough,[69] and the absence of evidence demonstrating the efficacy of airway clearance techniques in adults with CAP.[182-184] The low prevalence of airway clearance techniques being used in this study is reinforced by recommendations from the Association of Chartered Physiotherapists in Respiratory Care (ACPRC) in the United Kingdom (UK) who advise that airway clearance techniques should not be used routinely in adults hospitalised with CAP.[186]

Consistent with the American Thoracic Society (ATS) and Infectious Diseases Society of America (IDSA) clinical practice guidelines published in 2019,[257] almost all participants (98%) in the current study received IV antibiotic therapy, which was usually initiated in the ED. This is important given that previous data have shown that antibiotic therapy initiated within eight hours of presenting to the ED is associated with lower 30-day mortality (odds ratio [OR] 0.85; 95% confidence interval [CI] 0.75 to 0.96).[258] Early initiation of IV

antibiotic therapy reduces the time to clinical stability,[257] which would allow participants to participate in physical activity sooner and reduce LOS.[14]

Oxygen therapy was required in half of the participants in the current study, but the duration was short (median [IQR] duration 36 [12 to 71] hours) and even fewer participants required NIV therapy (6%, median [IQR] duration 8 [3 to 33] hours). Given that physical attachments are a known barrier to physical activity during hospitalisation,[29, 30] the short duration of oxygen and NIV therapy was of benefit to the participants in this study, allowing them to mobilise earlier without these attachments.

The median [IQR] CURB-65 score in this study was 1 [1 to 2]. This is unusual given that a CURB-65 score of 1 is often associated with outpatient management.[259] Earlier work has shown that disease severity tools such as the Pneumonia Severity Index (PSI) or CURB-65 score are used infrequently by ED and respiratory physicians.[85] Therefore, disease severity, calculated using these scales, may have little weight in the decision for hospitalisation. Treatment guidelines do suggest that other patient characteristics that indicate a poor prognosis, such as frailty, should be considered in the decision for hospitalisation.[257] This may explain the low CURB-65 score in the study presented.

To our knowledge, this is the first study to document baseline physiotherapy practices in adults hospitalised with CAP, who were not mechanically ventilated. These data are essential in informing future studies exploring physiotherapy interventions in adults hospitalised with CAP. It is also the first study to explore the relationship between clinical frailty and health outcomes in this patient population. A limitation of this study is that measures such as exercise capacity and peripheral muscle strength were not possible. This is because we decided *a priori* to observe current clinical practice and minimise change. Other measures of frailty, such as the Frailty Index or the Fried phenotype, require additional data such as grip

strength or weight loss over 12 months, and therefore, were not possible to calculate in this study. In order to not bias the study, direct observations of ward physiotherapists were not possible. Data pertaining to physiotherapy management were extracted from the medical record. As physiotherapists are legally required to document their interactions with patients in the medical record, it was considered that these notes would be a robust source of information. A final limitation of this study is that the number of presentations to a GP and hospital sites other than RPH were self-reported. There are known limitations in the accuracy of self-reported data. Specifically in comparison to formal records, self-reported episodes of healthcare utilisation are higher.[260] This may have impacted the accuracy of the data pertaining to the number of presentations to the GP and hospital sites other than RPH.

Increased frailty and disease severity were demonstrated as useful measures that affected the clinical trajectory of adults hospitalised with CAP. These data highlight the importance of assessing clinical frailty and disease severity on initial hospital presentation. For a physiotherapist working on a busy hospital ward, frailty should be strongly considered in the prioritisation of physiotherapy interventions.

6. CHAPTER 6: RESULTS AND DISCUSSION FOR RESEARCH QUESTIONS 3 TO 5

This chapter describes the results and discussion for the following three research questions: In adults admitted to a general hospital with community-acquired pneumonia (CAP):

i. How much walking time and non-walking time is accumulated during the inpatient stay?
ii. Is there a relationship between walking time and age, disease severity, number of co-morbidities, previous level of function, frailty, duration of intravenous antibiotic therapy, use of non-invasive ventilation (NIV) or oxygen therapy?
iii. Does daily step count influence healthcare utilisation, expressed as hospital length of stay (LOS) and the number of readmissions in the first 30 days following discharge?

Some of the information presented in this chapter was published in *Respiratory Care* in February 2020 (Appendix 8).[2] This has been expanded for this thesis. The methodology related to this study is described in Chapter 4. Other data describing the participant characteristics are described in Chapter 5.

6.1. Results

6.1.1. Participant characteristics

Of the 200 participants recruited to the study, a total of 175 participants agreed to wear the StepWatch™ Activity Monitor (SAM), of whom 121 contributed data to the final analyses. The SAM data were available for median [interquartile range (IQR)] 3 [1 to 5] days. The characteristics of those who contributed SAM data are presented in Table 6.1.

Table 6.1 Participant characteristics of those who contributed StepWatch™ Activity Monitor data

Variable	n = 121
Age (yr)	67.8 ± 16.8
Aboriginal or Torres Strait Islander	8 (7)
Body mass index (kg/m^2)	26.6 ± 7.1
Clinical Frailty Scale (scores 1 - 7) (median [IQR])	3 [3 to 4]
CURB-65 score (scores 0 - 5) (median [IQR])	1 [1 to 2]
Males	74 (61)
Presence of a cardiovascular comorbid condition	79 (65)
Presence of a chronic respiratory comorbid condition	53 (44)
Presence of a metabolic comorbid condition	61 (50)
Non (never)-smoker	35 (29)
Number of interactions with a physiotherapist (median [IQR])	2 [1 to 4]
Presence of a pleural effusion	32 (26)
Use of new supplemental oxygen	80 (66)
Pre-admission details	
Assisted ambulation	3 (2)
Independent ambulation with a walking frame	17 (14)
Independent with ambulation (with or without a walking stick)	101 (84)
Living alone at home	34 (28)
Living at home with others	79 (65)
Living in a hostel or homeless	5 (4)
Living in a residential facility	3 (3)

Data are expressed as (mean ± SD) or n (%), unless otherwise stated. CURB-65, Confusion, Urea, Respiratory rate, Blood pressure, Age ≥ 65 score; IQR: interquartile range; SAM: StepWatch™ Activity Monitor; SD: standard deviation.

6.1.2. Variables pertaining to walking and non-walking time

The average daily step count was a median [IQR] of 926 [457 to 1,706] which is shown in Figure 6.1. These steps were taken over a median [IQR] 66 [41 to 121] minutes, which was equivalent to median [IQR] 9 [6 to 17] % of a 12-hour day. The median [IQR] number of transitions from non-walking time to walking time was 31 [20 to 46]. The median [IQR] usual bout duration of walking time (UBD_{WT}) was 3 [2 to 4] minutes. The amount of time spent in each cadence band is reported in Table 6.2. The median [IQR] one-minute peak cadence was 56 [43 to 74] steps/minute.

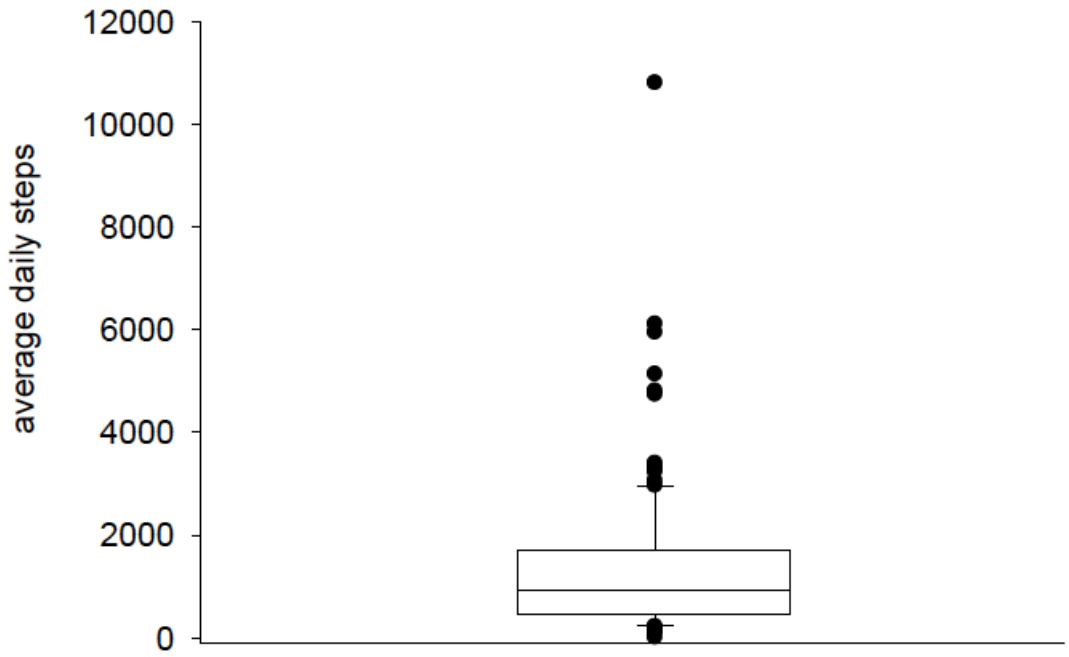

Figure 6.1 Average daily step count

The box and whisker plot shows the distribution of data for average daily step count. Average daily step count is plotted on the Y axis, with the first and third quartiles marked by the upper and lower borders of the box. The median average daily step count is indicated by the line dividing the box. Outliers are displayed by the upper and lower whiskers.

Table 6.2 Time spent in each cadence band expressed as minutes and percentages of total 24-hour period

	Time spent at 0 steps/ min	Time spent undertaking 'incidental movement' 0 to 19 steps/ min	Time spent undertaking 'sporadic movement' 20 to 39 steps/min	Time spent undertaking 'purposeful steps' 40 to 59 steps/min	Time spent undertaking 'slow walking' 60 to 79 steps/min	Time spent undertaking 'medium walking' 80 to 99 steps/min	Time spent undertaking 'brisk walking' 100 to 119 steps/min	Time spent undertaking 'all faster movement' ≥ 120 steps/min
Total (n = 117)	1376 [1319 to 1399] min 96 [91 to 97] %	48 [31 to 85] min 3 [2 to 6] %	12 [6 to 22] min 1 [0 to 1] %	2 [1 to 6] min 0 [0 to 0] %	1 [0 to 3] min 0 [0 to 0] %	0 [0 to 1] min 0 [0 to 0] %	0 [0 to 0] min 0 [0 to 0] %	0 [0 to 0] min 0 [0 to 0] %
'Frailty score < 4' (n = 69)	1363 [1311 to 1390] min 95 [91 to 97] %	55 [37 to 93] min 4 [2 to 6] %	15 [8 to 24] min 1 [1 to 2] %	3 [1 to 6] min 0 [0 to 0] %	1 [0 to 5] min 0 [0 to 0] %	0 [0 to 0] min 0 [0 to 0] %	0 [0 to 0] min 0 [0 to 0] %	0 [0 to 0] min 0 [0 to 0] %
'Frailty score ≥ 4' (n = 48)	1392 [1364 to 1405] min 97 [95 to 98] %	35 [29 to 63] min 2 [2 to 4] %	7 [2 to 13] min 1 [0 to 1] %	2 [0 to 5] min 0 [0 to 0] %	1 [0 to 2] min 0 [0 to 0] %	0 [0 to 0.3] min 0 [0 to 0] %	0 [0 to 0] min 0 [0 to 0] %	0 [0 to 0] min 0 [0 to 0] %

Data are expressed as median [IQR]. IQR: Interquartile range; min: minute.

During waking hours, the average non-walking time was a median [IQR] 672 [639 to 691] minutes (equivalent to 11.2 [10.7 to 11.5] hours), which was equivalent to 93 [89 to 96] % of waking hours. The number of transitions from walking time to non-walking time was 32 [21 to 47]. The usual bout duration of non-walking time (UBD_{NWT}) was 85 [55 to 128] minutes, as shown in Figure 6.2.

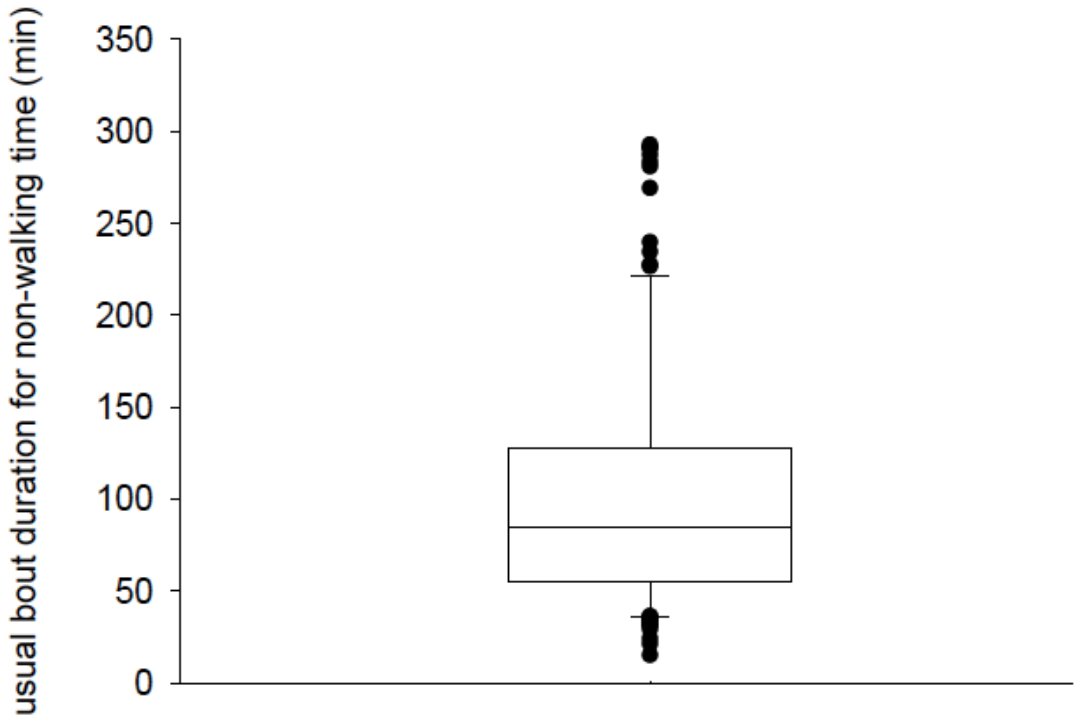

Figure 6.2 Usual bout duration for non-walking time

The box and whisker plot shows the distribution of data for usual bout duration of non-walking time (UBD_{NWT}). The UBD_{NWT} is plotted on the Y axis, with the first and third quartiles marked by the upper and lower borders of the box. The UBD_{NWT} is indicated by the line dividing the box. Outliers are displayed by the upper and lower whiskers.

6.1.3. Predictors of daily step count, usual bout duration of walking time and one-minute peak cadence

The results of the analyses that explored the predictors of average daily step count are presented in Table 6.3. In the univariate model, variables that influenced average daily step count were disease severity, frailty and the number of interactions with a physiotherapist. The characteristics of participants grouped according to clinical frailty are presented in Appendix 9. In the multivariable model, only frailty was retained. Frailty was also found to be a significant predictor of UBD_{WT} ($r^2 = 0.17$; $p < 0.001$) and one-minute peak cadence ($r^2 = 0.05$; $p = 0.01$).

Table 6.3 Predictors of average daily step count

A. Negative binomial regression: univariate analysis

Variable	Direction of relationship based on IRR	IRR	95% CI	p value
Age	Less steps in those with greater age	0.98	0.97 to 1.00	< 0.01*
Chronic respiratory condition	The effect of a chronic respiratory condition on daily step count is unclear	0.74	0.52 to 1.06	0.10
Disease severity	Less steps in those with 'more severe' disease	0.65	0.46 to 0.94	0.02*
Frailty	Less steps in those with 'frailty score ≥ 4'	0.56	0.39 to 0.81	< 0.01*
ICC	The effect of an ICC on daily step count is unclear	1.51	0.70 to 3.24	0.29
NIV	The effect of NIV on daily step count is unclear	0.84	0.49 to 1.40	0.52
Number of physiotherapy interactions	Less steps in those who received more interactions with a physiotherapist	0.64	0.44 to 0.92	0.02*
Oxygen	The effect of age on daily step count is unclear	0.71	0.49 to 1.04	0.08
Pleural effusion	The effect of a pleural effusion on daily step count is unclear	0.80	0.53 to 1.19	0.29

CI: confidence interval; ICC: intercostal catheter; IRR: incidence rate ratio; NIV: non-invasive ventilation.

B. Negative binomial regression: multivariable analysis

Variable	Direction of relationship based on IRR	IRR	95% CI	p value
Disease severity	The effect of disease severity on daily step count is unclear	0.70	0.49 to 1.00	0.06
Frailty	Less steps in those with frailty score ≥ 4 versus frailty score < 4	0.59	0.41 to 0.85	< 0.01*

A. Univariate models. B. Final multivariable model using those variables that significantly influenced daily steps in the univariate model and had been retained in more than one of the opportunistic multivariable models presented in Chapter 5. CI: confidence interval; ICC: intercostal catheter; IRR: incidence rate ratio.

6.1.4. Daily step count as a predictor of healthcare utilisation

For every increase in average daily step count of 500 steps, LOS reduced by 11%, (incidence rate ratio [IRR] 0.89; 95% confidence interval [CI] 0.80 to 0.99, p = 0.04). There was no clear effect of an increase in average daily step count (by 500 steps) on 30-day readmissions (IRR 1.12; 95% CI 0.80 to 1.56, p = 0.51).

6.2. Discussion

In this prospective observational study, adults hospitalised with CAP had an average daily step count of median [IQR] 926 [457 to 1,706] steps. These steps were accumulated over a median [IQR] 66 [41 to 121] minutes and in short bursts (median [IQR] 3 [2 to 4] minutes). A large proportion of waking hours were spent in non-walking time (median [IQR] 93 [89 to 96]%). A frailty score of ≥ 4 was identified as a predictor of lower daily step count (IRR 0.59; 95% CI 0.41 to 0.85). Further, greater average daily steps were associated with a reduced LOS (IRR 0.89; 95% CI 0.80 to 0.99).

Data reporting walking-based activity in adults who are hospitalised are scarce. Earlier research has shown that adults hospitalised with an exacerbation of chronic obstructive pulmonary disease (COPD) took a mean ± standard deviation (SD) of 602 ± 610 steps per day[20] and older adults hospitalised with a general medical condition took a mean ± SD of 764 ± 706 steps per day.[40] Our data reveal a slightly higher average daily step count of median [IQR] 926 [457 to 1,706] in adults hospitalised with CAP. This difference is not likely to relate to the sensitivity of the monitors as validated accelerometers were used in all three studies.[243, 261] It is possible that in the study conducted in adults with a general medical condition, the older age of the sample (mean ± SD = 77 ± 7 years), contributed to the lower average daily step count report.[40] It has been well established that participation in physical

activity decreases with advancing age.[262] In the study conducted in adults with an exacerbation of COPD, the lower step count does not appear to be related to differences in the age nor the time spent walking, expressed as a percentage of a 12-hour day, both of which were remarkably similar between the two studies.[2,20]

It seems that the lower number of steps reported in the study of people hospitalised with an exacerbation of COPD was due the participants adopting a slower average cadence during periods of waking, which possibly reflects the chronicity of their condition. Nevertheless, it is worth noting that the one-minute peak cadence reported in our study (median [IQR] 56 [43 to 74] steps/minute) was considerably lower than that reported in a large sample of community dwelling older adults aged ≥ 70 years (mean 82 steps/minute; 95% CI 79 to 84)[263] and those with metabolic syndrome (mean ± SD 103 ± 13 steps/min).[264] Further, our study also demonstrated that the little time spent in walking-based activity was at slow walking speeds (see Table 6.2). The time spent in 'medium walking' in our study (median [IQR] 0 [0 to 1] min) was even less in comparison to the time spent in 'medium walking' in male adults with stable COPD (mean ± SD 5 ± 4 min).[265]

Our data show that walking in adults hospitalised with CAP was accumulated in very short bouts. This is notable as the participants included in these analyses received on average, a median [IQR] of 2 [1 to 4] interactions with a physiotherapist. This highlights the need for a multidisciplinary approach to facilitate and encourage participation in physical activity on the ward. As identified in a recent Delphi study,[190] facilitating participation in physical activity on the ward and reducing sedentary time is a responsibility that should be met by all members of the multidisciplinary team.

This current study identified frailty as a significant predictor of daily step count ($p < 0.01$), UBD_{WT} ($p < 0.01$) and one-minute peak cadence ($p = 0.01$). In several clinical populations,

there is increasing recognition that frailty is a predictor of poor health outcomes. Specifically, following hospital discharge for an exacerbation of COPD, compared with those classified as 'not frail', those classified as 'severely frail' had a higher odds of being readmitted to hospital within 90 days of discharge (odds ratio [OR] 5.19; 95% CI 1.26 to 21.50).[266] Our study extends the findings of this earlier work by showing that frailty is a predictor of daily step count, UBD_{WT} and one-minute peak cadence in adults hospitalised with CAP. That is, frailty influences not only daily steps, but also the way in which walking time is accumulated on the ward and the intensity at which walking was undertaken. Given that daily step count was a predictor of LOS, when prescribing a walking-based exercise program in a busy clinical environment, those who present with moderate to severe clinical frailty should be prioritised.

In the univariate model, increased number of interactions with a physiotherapist was demonstrated as a predictor of a lower daily step count. This result reads counter-intuitively to suggest that the more physiotherapy input one receives, the less walking-based activity they undertake. This result may be explained by the previous analysis in Chapter 5 which demonstrated that participants with more severe disease or greater frailty received more physiotherapy input. Or perhaps, those individuals who were more unwell and were seen more often by physiotherapy but were less able to ambulate. It is also possible that the increased number of physiotherapy interactions related to treatment of respiratory problems and did not include ambulation.

This study was also able to explore non-walking time and the way in which it is accumulated, expressed as UBD_{NWT}, in adults with CAP during a hospital admission. In the general population, there are now robust data demonstrating the deleterious health consequences are associated with sedentary time, especially sedentary time that is accumulated in prolonged

uninterrupted bouts,[154] and there is increased recognition that reducing sedentary time is a separate lifestyle goal to increasing participation in physical activity.[150-153]

Our study has shown that during hospitalisation for CAP, adults are inactive for almost all of their waking hours (total non-walking time median [IQR] 672 [639 to 691] minutes, 93 [89 to 96] % of waking hours) and accumulate this time in prolonged bouts (UBD_{NWT} median [IQR] 85 [55 to 128] minutes). Although there are a paucity of data in other hospitalised populations, this level of inactivity was less than previously described in adults with stable COPD (total sedentary time 493; 95% CI 383 to 629 minutes, 68% of waking hours).[267] Of note, the UBD_{NWT} in our participants was almost three times longer than that reported in office workers (i.e. usual bout duration mean ± SD 32 ± 15 mins).[268] Taken together, both the large proportion of waking time spent in non-walking time coupled with the fact it is accumulated in prolonged uninterrupted bouts makes this behaviour a potential target for inpatient rehabilitation.

Strengths and limitations

Although this study has provided objective measurements of walking and non-walking time in adults hospitalised with CAP, we could not report on specifically sedentary time. This is because the SAM cannot differentiate between standing (which is light intensity physical activity) from sitting and laying down (which are sedentary behaviours). Future research using accelerometers combined with inclinometers would provide greater clarity in separating standing from sitting and laying down and allow data to be extracted on sedentary time.[269-271]

7. CHAPTER 7: CONCLUSION

This body of research addressed the following research questions:

i. What research has been reported on exercise training in adults hospitalised with an acute or an acute on chronic respiratory condition and,
ii. Specifically, in adults hospitalised with community-acquired pneumonia (CAP);
    a. What is usual care in terms of medical and physiotherapy management?
    b. What is the healthcare utilisation?
    c. How much walking time and non-walking time is accumulated during the inpatient stay?
    d. Does average daily step count influence healthcare utilisation?

This chapter summarises the novel and important findings of this program of research as well as the possible implications for clinical practice and directions for future research.

7.1. Engaging in exercise training or walking-based physical activity during periods of hospitalisation; how these data inform possible barriers

The research presented in this thesis has identified that, although there is a growing body of data to support the role of exercise training initiated during the period of hospitalisation for a respiratory condition,[11-14] there are some limitations in the current evidence. Specifically, there is a lack of transparency, precision and clarity regarding the prescription, titration and delivery of exercise training programs in adults hospitalised with an acute or an acute on chronic respiratory condition. Without clarity and structure, the uptake of walking-based activity and exercise training programs in clinical practice is likely to be limited.

Regarding the body of evidence to support the role of exercise training in adults hospitalised with a respiratory condition, these data are from studies involving adults hospitalised with an exacerbation of chronic obstructive pulmonary disease (COPD) and adults hospitalised with CAP.[11-14] Regarding the data in adults hospitalised with an exacerbation of COPD, a Cochrane review[11] published in 2016 explored the effect of exercise training with usual care (i.e. no exercise training) in people who were hospitalised, or who had been recently discharged from hospital, with an exacerbation of COPD. Exercise training programs used a variety of training modalities such as aerobic training, resistance training, a combination of aerobic and resistance training, and other tools such as neuromuscular electrical stimulation (NMES).[17] The Cochrane review demonstrated that exercise training was effective at improving exercise capacity, health-related quality of life (HRQOL) and reduced the odds of readmission in adults hospitalised with an exacerbation of COPD.

The evidence for adults hospitalised with CAP are from three randomised controlled trials (RCTs) that have explored the effect of initiating an exercise training program during the period of hospitalisation.[12-14] Of these, one described a combination of aerobic and resistance training,[13] and two studies described movement out of bed within 24 hours of hospitalisation with progressive daily movement.[12, 14] Data from these studies revealed that, in adults hospitalised with CAP, when compared to a usual care group that did not receive any exercise training, initiating exercise training during hospitalisation resulted in increased exercise capacity measured at the time of discharge[13] and a reduction in hospital length of stay (LOS) by one day.[12, 14]

Despite the presence of multiple RCTs[12-14] and a Cochrane Review[11] that have highlighted the benefit of exercise for adults hospitalised with a respiratory condition, the implementation of exercise training in clinical practice appears to be challenging.[16, 19] Surveys of clinical

practice in adults hospitalised with an exacerbation of COPD suggest there are disparities between individual healthcare professionals and organisations.[16, 19] Some sites prioritise exercise training while other centres give greater attention to airway clearance techniques.[16, 19] These data suggest there is an implementation gap, and further clarity and structure are required for clinicians to implement exercise training programs consistently on the ward.

The scoping review presented in Chapter 3 of this thesis revealed 18 studies that have explored the effect of initiating an exercise training program within 72 hours of hospitalisation for an acute or an acute on chronic respiratory condition.[12-14, 17, 209-216, 218-221, 223] The data presented in the scoping review revealed a lack precision in the studies regarding the methods used for initial exercise prescription and titration. Although it is ideal to individually prescribe an exercise program based on the results of an objective exercise assessment,[227] a third of the studies did not do this. When reported, adverse events were uncommon, and programs were well tolerated. The quality of reporting was inconsistent between the studies. Specifically, only half of the studies met the criteria for at least 50% of the items on the Consensus on Exercise Reporting Template scores and Template for Intervention Description and Replication. A lack of essential detail makes it difficult for clinicians to replicate these interventions in clinical practice. Given the limited structure and clarity around exercise training in adults hospitalised with a respiratory condition, it is understandable that there is inconsistent translation into clinical practice.

As well as inconsistencies and gaps in the literature, barriers to mobilisation are also likely to influence the implementation of exercise training programs in the clinical setting on the ward. Potential barriers to mobilisation of adults hospitalised with a respiratory condition have been reported as symptoms including dyspnoea, pain, weakness and fatigue,[29-31] a lack of space, physical attachments such as continuous oxygen therapy, time constraints and limited

staffing.[29-34] Regarding safety, the scoping review described in Chapter 3 revealed that exercise training initiated within 72 hours of hospitalisation for an acute or an acute on chronic respiratory condition was well tolerated and adverse events were infrequent.[210, 213] The data presented in Table 5.2 revealed that of the 109 medical complications or adverse events in adults hospitalised with CAP, none were related to walking-based activity. These data suggest there is little cause for concern in initiating an exercise training program in adults hospitalised with a respiratory condition. However, it is important to acknowledge that the studies included in the scoping review had exclusion criteria which ensured participants were appropriate for exercise training. Additionally, it is important to note that the participants in the observational study presented in Chapters 5 and 6 were assessed by a trained healthcare professional before engaging in walking-based activity.

In addition to potential barriers to mobilisation, work-based cultural differences may influence walking-based activity. The data presented in Table 5.4 revealed differences between the number of physiotherapy interactions by ward of admission in adults hospitalised with CAP. Specifically, participants who were admitted to a respiratory ward appeared to have more interactions with a physiotherapist in comparison to those participants admitted to a short stay medical ward. Possible reasons for this disparity may be differences in work-based culture and the prioritisation of physical activity on the ward. Further, staff and time resources may vary between wards.[29-33] The possible way that cultural differences between wards may affect participation in walking-based activity on the ward is hypothesis generating research. Although it was not in the scope of this body of research, further investigation into cultural differences would be an area of interest for further work.

Considering the data describing walking-based activity across all of the wards, adults hospitalised with CAP accumulated low levels of walking-based activity on the ward. This is

consistent with data from other hospitalised populations, such as adults with an exacerbation of COPD[20] and older adults hospitalised with a general medical condition.[40, 148, 149] The data presented in this thesis regarding walking-based activity suggest that there is a need to change the target for physical activity in adults hospitalised with CAP. Rather than a single burst of physical activity, short and frequent bouts of activity spread across waking hours could be a way to increase total physical activity. This pattern of activity may be better tolerated in those who are limited by symptoms, other comorbidities or frailty.

To achieve frequent bouts of walking-based activity on the ward there is a need to engage the whole multidisciplinary team (MDT). A cultural shift is required to ensure all members of the MDT are empowered to take responsibility for encouraging participation in physical activity. For example, nursing staff could facilitate walking to the toilet rather than bedside toileting. Every interaction between a patient and a member of the MDT should be seen as an opportunity to encourage participation in walking-based activity on the ward.

The efforts of the MDT could be supplemented with the use of behaviour change techniques (BCTs). Examples of BCTs include goal setting, motivational interviewing, feedback and monitoring.[191] By embedding BCTs in other interventions such as exercise training, it could facilitate independence with physical activity outside of interactions with health professionals. Simple exercises could be performed at the bedside, such as sit-to-stands, or patients could engage in independent walking-based activity. To ensure that safety issues are addressed and variables such as frailty and other comorbidities are considered, an assessment by a trained health professional is required.

7.2. Data to support new mobility targets

As well as the gross measure of average daily step count, the data presented in Chapter 6 were able to describe the patterns of accumulation of walking-based activity on the ward in adults hospitalised with CAP. Not only did adults hospitalised with CAP achieve very low levels of walking-based activity, but very little time was spent in walking-based activity. In total, participants spent a median [interquartile range (IQR)] of 66 [41 to 121] minutes in walking time, which was equivalent to median [IQR] 9 [6 to 17] % of a 12-hour day. The usual bout duration of walking time (UBD_{WT}) was median [IQR] 3 [2 to 4] minutes. These data suggest that when adults with CAP were in walking-based activity, it was of very short duration. Low levels of walking-based activity are a concern given the data in other hospitalised populations that have demonstrated that low levels of physical activity are associated with adverse outcomes, such as increased hospital readmission and mortality.[41, 126, 127]

In regard to non-walking time, the study discussed in Chapter 6 showed that a high proportion of waking hours were spent in non-walking time (median [IQR] 93 [89 to 96] % of waking hours). Non-walking time was often spent in long, uninterrupted bouts (usual bout duration of non-walking time (UBD_{NWT}) median [IQR] 85 [55 to 128] mins). These data are important, given that there are convincing data in the general population that demonstrate that the pattern of accumulation of sedentary behaviour is an independent risk factor for cardiometabolic disease.[154]

Together the data pertaining to walking time and non-walking time suggest that there are new mobility targets for adults hospitalised with CAP. Interventions targeted at (i) increasing walking-based activity, (ii) reducing total non-walking time and (iii) breaking up bouts of non-walking time are indicated. Rather than people accumulating a single burst of walking-

based activity during an interaction with a health professional, short and frequent bouts of low intensity physical activity spread across the day could be considered. Frequent bouts of activity during waking hours would take people out of non-walking time and break up prolonged periods of non-walking time. To achieve these new mobility targets, it requires a shift in attitude of ward staff, patients and carers, whereby walking-based activity is prioritised along with other activities of daily living.[190] Education and engagement of patients, carers and all MDT members will be required for meaningful change to occur.

7.3. Emergence of frailty as a new prognostic measure

In the observational study presented, frailty was demonstrated as an independent predictor of multiple unfavourable outcomes in adults hospitalised with CAP. These outcomes were low average daily step count, referral for rehabilitation on discharge, readmission to hospital within 30 days of discharge and increased interactions with a physiotherapist. In comparison, increased disease severity was a predictor only of increased interactions with a physiotherapist, and increased age was a predictor only for referral for rehabilitation on discharge. Thus, over and above any other variable, clinical frailty was demonstrated as the most informative measure in predicting patient outcomes.

7.4. Strengths and limitations

The scoping review presented in this body of research has highlighted the lack of precision around the prescription and titration of exercise training programs in adults who are hospitalised with a respiratory condition. The data presented in the scoping review potentially explains some of the inconsistencies that have been documented in practice patterns regarding the physiotherapy management of adults hospitalised with an exacerbation of COPD.[16, 19] The results of this review have demonstrated the need for future studies to

provide clarity and structure to improve the implementation of exercise training programs in clinical practice.

To our knowledge, the observational study presented in this body of research is the first to document physiotherapy practices in adults hospitalised with CAP, who were not in the intensive care unit (ICU). Further, it is potentially the first study to objectively measure walking-based activity in this cohort. These data are important before undertaking research exploring the role of interventions like exercise training. A limitation of these data is that it was not possible to report specifically on sedentary time. This is because the biaxial StepWatch™ activity monitor (SAM) cannot separate standing (which is light intensity physical activity) from sitting and lying down (which are sedentary behaviours). In comparison, the use of accelerometers combined with inclinometers would provide greater clarity in separating standing from sitting and lying down and allow data to be extracted on sedentary time.[269-271] Further, this body of work has highlighted the novel relationship between frailty and health outcomes in adults hospitalised with CAP. It has demonstrated the importance of assessing frailty on initial presentation to foresee the likely clinical trajectory, such as the need for rehabilitation at the end of hospitalisation, hospital readmissions and low levels of walking-based activity on the ward.

7.5. Future directions

To improve the uptake of exercise training programs in clinical practice for adults who are hospitalised with a respiratory condition, future studies must be transparent. Clinicians require clarity and structure to safely and successfully implement an exercise training program in adults who are acutely unwell with a respiratory condition. Specifically, adherence to the Consensus on Exercise Reporting Template[206] and Template for Intervention Description and Replication[207] guidelines is recommended. Essential detail regarding the

methods used for prescription, titration, and feasibility will allow clinicians to replicate these programs in clinical practice.

In adults hospitalised with CAP, clinical frailty has shown to be a valuable measure that should be considered by clinicians and researchers working with adults with CAP. These data can be applied in clinically by health professionals measuring frailty at the time of initial presentation. By assessing frailty on patient presentation clinicians can be informed about likely patient outcomes, such as the need for rehabilitation at the end of hospitalisation, readmission to hospital within 30 days of initial discharge and low levels of walking-based activity on the ward. These data may inform clinical decision making throughout the period of hospitalisation. For physiotherapists working on a busy hospital ward, these data may guide the prioritisation of walking-based interventions to those adults with CAP who are frail. Adults who are characterised by frailty are those who are most vulnerable and are at greatest risk of adverse outcome without physiotherapy intervention. The research presented in this thesis has also identified an opportunity for physiotherapists working in clinical practice. Physiotherapists are well positioned to lead a cultural change on the ward, whereby short and regular bursts of physical activity during waking hours are encouraged.

In regards to research, future work should be directed towards exploring the effectiveness of interventions that are targeted at increasing walking-based activity during a period of hospitalisation for CAP. Specifically, it would be of value to explore the relationship between participation in walking-based activity and non-walking time, and the effect on outcomes such as measures of physical function and HRQOL. Future studies that explore the use exercise training in adults with CAP should consider focussing recruitment on adults who are frail, either by exclusively recruiting frail adults or stratifying for frailty. By recruiting adults

who are frail, it will increase the opportunity to demonstrate the effect of a walking-based intervention on measures of physical function and HRQOL.

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9. APPENDICES

Appendix 1: Scoping review publication

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Exercise training for adults hospitalized with an acute respiratory condition: a systematic scoping review

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Abstract

Objective: In adults hospitalized with an acute or chronic respiratory condition, to determine what has been reported regarding exercise programmes in terms of content, tolerability, evaluation and adverse events.

Data sources: A systematic search was conducted of electronic databases (PubMed, EMBASE, CINAHL, PEDro, The Cochrane Library), trial registries and conference abstracts (Thoracic Society of Australia and New Zealand Annual Scientific Meeting, the European Respiratory Society Congress, the American Thoracic Society International Conference).

Review methods: Studies were included if they (1) recruited adults hospitalized with an acute or chronic respiratory condition, (2) described an exercise programme that targeted peripheral muscles and (3) reported that ⩾80% of the sample had initiated training within 72 hours of hospitalization.

Results: The last search was conducted on 2 June 2019. Of the 6282 records identified, 20 met the study criteria. These described 18 separate studies (2018 participants). Studies were conducted in adults hospitalized with an exacerbation of chronic obstructive pulmonary disease or with community-acquired pneumonia. The content of exercise programmes included aerobic and/or resistance training, neuromuscular electrical stimulation, whole-body vibration or movement out of bed. In eight studies (44%), the initial session was prescribed using objective measures of exercise capacity, peripheral muscle force and the ability to undertake activities of daily living. Across 7420 training sessions, seven adverse events were reported.

Conclusion: Methods used to prescribe and titrate exercise programmes in adults hospitalized with an acute or an exacerbation of a chronic respiratory condition were disparate. When reported, programmes were well tolerated and adverse events were infrequent.

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Exercise training, respiratory conditions, hospitalization, physiotherapy, respiratory

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Introduction

Over the past decade, there has been increased interest in the role of implementing an exercise training programme to improve functional outcomes in people hospitalized with an acute respiratory condition.[1–4] This interest has emerged, at least in part, in response to data showing that hospitalization for a respiratory condition results in increased dyspnoea, peripheral muscle deconditioning and reductions in exercise capacity, daily physical activity and health-related quality of life.[5,6] These consequences can persist for several weeks following hospital discharge and may increase the risk of repeated admissions.[7]

Despite the emerging evidence that in adult populations hospitalized with a respiratory condition early exercise training programmes improve functional outcomes, the implementation of such programmes by clinicians is challenging.[8] Individuals who are hospitalized as a result of their respiratory condition are acutely unwell and may be receiving medical therapies, such as non-invasive ventilation, which makes mobilization away from the bedside challenging.[9] These constraints, especially when coupled with symptoms such as dyspnoea, fatigue and cough, make initiating exercise training during this period difficult.[10]

In clinical practice, exercise training during the period of hospitalization for a respiratory condition is not consistently prioritized. Practice patterns in some centres suggest regular implementation of exercise training, while other centres give greater attention to airway clearance techniques.[11] Inconsistencies in the implementation of exercise training in adults hospitalized with an acute respiratory condition may reflect the disparate approaches described by earlier work regarding (1) initial prescription of exercise intensity, (2) titration of exercise intensity and (3) methods used to objectively evaluate the effect of the programme. Furthermore, there have been some concerns raised regarding the safety of initiating an exercise training programme in a population of adults who are acutely unwell.[12] To address these issues, the aim of this scoping review was, in adults hospitalized with an acute respiratory condition or an exacerbation of a chronic respiratory condition, to determine the prescription and titration of exercise training, together with the tolerability, evaluation and occurrence of any observed adverse events during inpatient exercise training. Furthermore, where possible, the quality of reporting of the exercise intervention and risk of bias were assessed.

Methods

This scoping review was undertaken in accordance with established methodological frameworks[13] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[14] A protocol was developed a priori and published on-line at Open Science Framework.[15] Studies were eligible for inclusion if (1) they recruited adults who were hospitalized with an acute or an exacerbation of a chronic respiratory condition, (2) they described implementing an exercise training programme that targeted the peripheral muscles and (3) at least 80% of the sample had initiated training within 72 hours of hospitalization. Studies were excluded if they (1) performed all exercise training in an outpatient or home-based setting; (2) recruited a sample in which more than 20% had hospital-acquired pneumonia, aspiration pneumonia or lung cancer or were admitted to an intensive care unit; (3) had prescribed either stretching or inspiratory or expiratory muscle training as the only forms of exercise or (4) were written in a language other than English or Portuguese.

A systematic search of electronic databases, clinical trial registries and conference abstracts

Table 1. Domains for data extraction.

1	Study and sample characteristics
2	Quality of reporting using the Consensus on Exercise Reporting Template (higher scores indicating detailed reporting, maximum score = 16)[16] and the Template for Intervention Description and Replication (higher scores indicating detailed reporting, maximum score = 12)[17]
3	Risk of bias using the Cochrane Risk of Bias Assessment[18]
4	Variables related to exercise programmes in terms of content, tolerability, evaluation and adverse events

was undertaken. An example of the search string is presented in Supplemental Material S3. The last search was conducted on 2 June 2019. The records retrieved during the search were entered into an EndNote library and duplicates were removed. The full text of any record was obtained if, based on title and abstract, it seemed eligible or could not be excluded.

A data dictionary was developed to ensure consistency in data extraction. Data were extracted on the four domains shown in Table 1. Regarding the exercise sessions, information was sought on the following variables:

- Content of the exercise training sessions, such as mode of exercise, the method used for initial prescription and to titrate exercise intensity and level of supervision;
- Tolerability of and adherence to the programme, such as the number of exercise training sessions completed by the participants, symptoms during exercise training and modifications made to the prescribed exercise training protocol;
- Objective methods used to assess exercise capacity, peripheral muscle force, mobility, physical activity, balance and/or frailty;
- Adverse events experienced during exercise training, which were categorized as minor or major, where minor adverse events were defined as any incident that did not require medical attention, such as transient arterial oxygen desaturation, and major adverse events were defined as any incident that required medical attention such as myocardial infarction;
- The quality of reporting of the exercise intervention and risk of bias, where possible.

Results

A total of 6282 records were identified, of which 5371 (85%) records were excluded based on title and abstract. Of the 84 records that underwent full text review, 65 (77%) were excluded. Five (6%) were protocols for studies that met the study criteria and were found on clinical trial registries, but no unpublished data were made available by the authors. A total of 20 records for 18 studies met the criteria for inclusion in this review (Figure 1).

Of the studies included in this review, 19 (95%) were published in peer-reviewed journals[2–4,12,19–33] and 1 (5%) was a published abstract for which further information was obtained from the author[34] (see Supplemental Table S1). These 20 studies described 16 unique randomized controlled trials,[2–4,12,19–26,29–31,34] and 2 were single-group studies.[28,33] Two studies were qualitative analyses which utilized responses from participants recruited to two of the randomized controlled trials.[27,32] The 16 randomized controlled trials and 2 single-group studies were conducted across 13 countries and report data on 1146 participants who were prescribed an exercise training programme and 872 participants who did not participate in any exercise training. Consistent with previous reviews,[35,36] study characteristics have been presented as a Harvest plot (Figure 2). The mean age of the participants who were prescribed exercise training ranged from 51 to 76 years, and 600 (52%) participants were male. Studies were conducted in adults hospitalized with an exacerbation of chronic obstructive pulmonary disease (N = 1100 participants)[12,19–26,28–32,34] or with community-acquired pneumonia (N = 918 participants).[2–4,33]

Across the 16 randomized controlled trials and 2 single-group studies, participants allocated to the

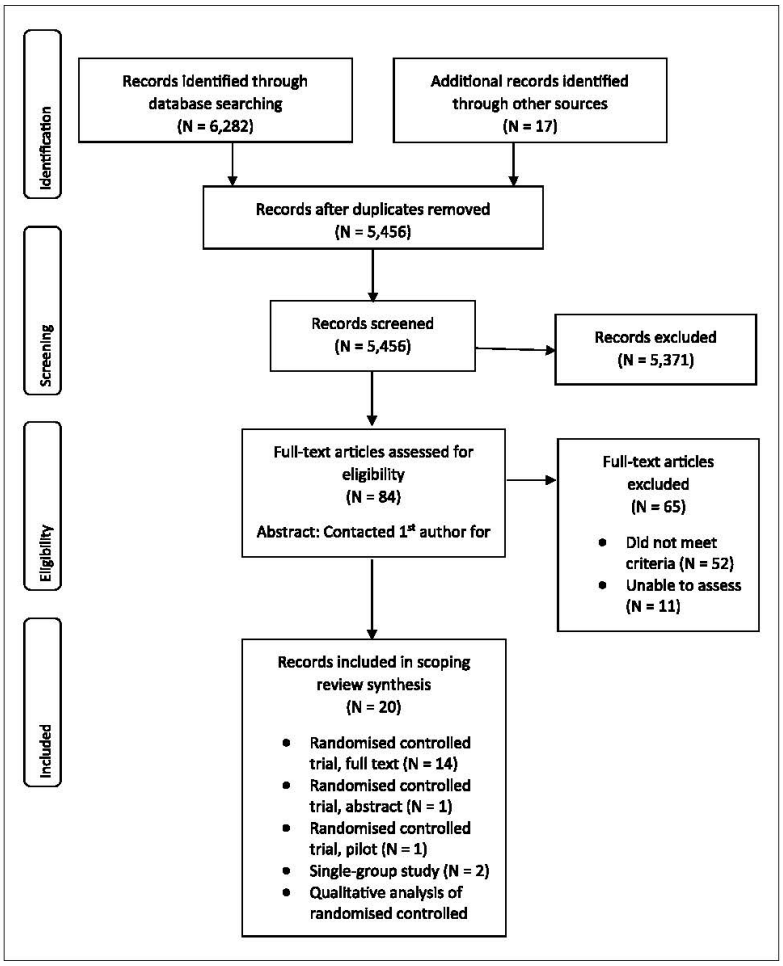

Figure 1. Process for study selection

intervention groups completed ~7420 training sessions over a period of 4–14 days.[2–4,12,19–26,28–31,33,34] The content of the training programmes is summarized in Figure 2 and Supplemental Table S2. Approaches to exercise training included exclusive aerobic training,[24,26,31] exclusive resistance training,[20,25,29,30] a combination of aerobic and resistance training,[3,12,19,23,34] neuromuscular electrical stimulation,[21,28] whole-body vibration[22] and movement out of bed within 24 hours of hospitalization with progressive daily movement.[2–4,33] Eight studies individualized the prescription of the initial exercise training session using objective measures of exercise capacity,[3,12,19,23,34] peripheral muscle force,[12,19,20,23,25,31] and tasks commonly undertaken during activities of daily living.[34]

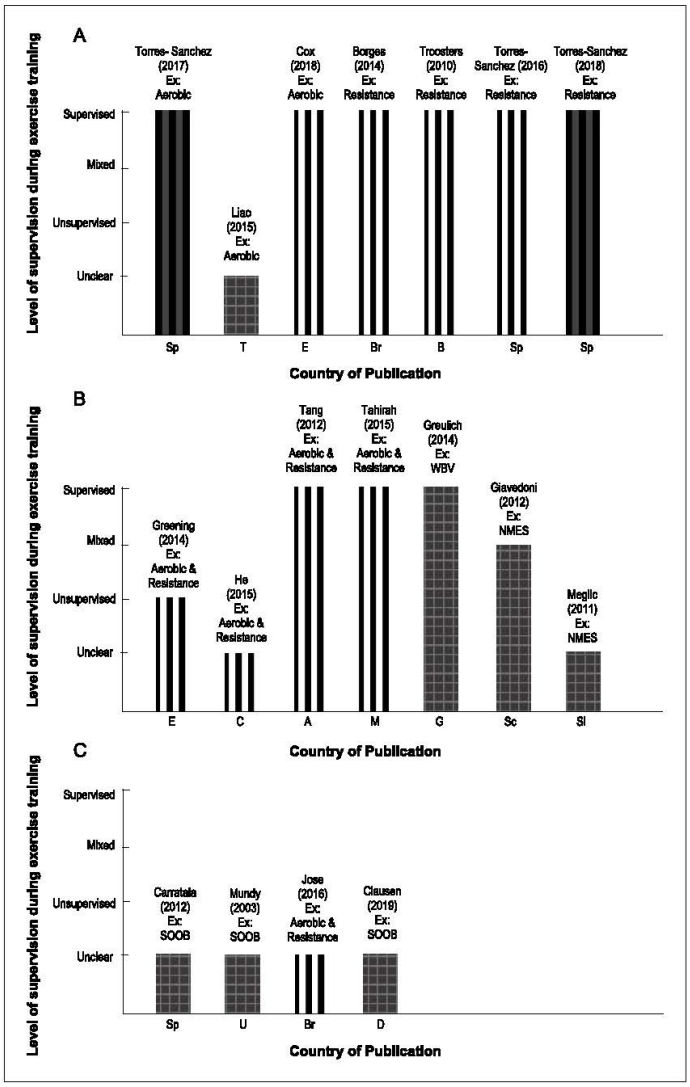

Figure 2. Harvest plot summarizing methodological design: (a, b) studies conducted in adults hospitalized with exacerbation of COPD and (c) studies conducted in adults hospitalized with community-acquired pneumonia.
A: Australia; Br: Brazil; B: Belgium; C: China; D: Denmark; E: England; Ex: Exercise; G: Germany; M: Malaysia; NMES: neuromuscular electrical stimulation; Sc: Scotland; Sl: Slovenia; Sp: Spain; SOOB: sit out of bed; T: Taiwan; U: USA; WBV: whole-body vibration.
Initial exercise training session prescribed based on the results of an initial exercise assessment, with structured titration of exercise training.
Initial exercise training session prescribed based on the results of an initial exercise with no structured titration of exercise training.
Initial exercise training session is identical across all participants, with structured titration of exercise training.
Initial exercise training session is identical across all participants, with no structured titration of exercise training.

Regarding prescription, walking-based exercise was prescribed at intensities that ranged from 40% average speed achieved during a 3-minute walk test[23] to a speed equivalent to 85% of peak oxygen consumption estimated from the distance walked on the incremental shuttle walk test.[3,12,19] Upper and lower limb cycling was prescribed at an intensity of 80% of the maximal resistance against which participants were able to complete two pedal revolutions.[31] Resistance training was prescribed at intensities that ranged from 40% of one-repetition maximum[23] to 80% of one-repetition maximum.[3,12,20,25]

Regarding titration of exercise dose, 11 studies described doing this based on symptoms.[3,12,19–21,23–25,29–31] Generally, when described, exercise intensity was progressed with the goal of participants reporting dyspnoea, fatigue or exertion that was perceived to be 'moderate to sev ere',[3,12,19–21,23,25] with only one study titrating exercise dose to have participants report dyspnoea that was 'above severe to very severe'.[24]

Tolerability, defined as the average number of exercise training sessions that were completed as a percentage of the number of those prescribed, was reported in seven randomized controlled trials and one single-group study (N = 549 participants allocated to the intervention group) and ranged from 31% to 100%.[4,12,20,21,23,25,28,31] The reasons for not completing exercise sessions were feeling unwell or fatigued (N = 38 sessions), interruptions by medical staff or family (N = 15 sessions), the participant being unavailable (N = 17 sessions), the therapist being unavailable (N = 36 sessions), participant declined (N = 42 sessions), muscle soreness (number of sessions not reported), dyspnoea (number of sessions not reported) and increased confusion (number of sessions not reported).[2,20,23,31] In two studies, the intensity of dyspnoea resulted in modifications to the prescribed exercise training protocol, including single-leg rather than double-leg resistance training (N = 7 participants)[25] and the use of non-invasive ventilation during exercise (used in 35% of sessions, number of participants not reported).[20] Two studies reported on adherence, defined as the proportion of participants who completed the training prescribed. In the study by Mundy et al.,[4] 73% of the sample completed the initial training session, but adherence beyond this was not reported. The study by Cox et al.[31] reported that, of the training sessions that were started, 100% were completed as prescribed.

During the period of hospitalization, 15 (83%) studies described collecting objective measures for the purpose of exercise prescription or evaluation. These measures quantify exercise capacity, peripheral muscle force, the ability to undertake activities of daily living, physical activity or balance. Specific tests that were used were either the 6-minute walk test,[19,20,22,25,26,31] 3-minute walk test,[23] 2-minute walk test,[31,34] 2-minute step in place test,[29] incremental shuttle walk test,[3,12] sit-to-stand tests,[22,24,34] one-repetition maximum,[3,12,20,21,23–25,29,34] the Glittre Test,[3] Timed Up and Go[34] or one-leg stance balance assessment.[24] Physical activity was measured in three (17%) studies using a physical activity monitor.[24,33,34] The Barthel Index was recorded in one study.[30] Data on outcomes that may be used to evaluate the longer-term effectiveness of an exercise training intervention, such as hospital readmissions, were not extracted.

Across all training sessions completed by those allocated to the intervention group, seven adverse events were reported. The presence or absence of adverse events was not reported in four studies[26,29,30,33] or in the published abstract.[34] Of the remaining 13 studies, 11 reported no adverse events and 2 reported adverse events in six and five participants, respectively.[20,23] Minor adverse events were reported in six participants[20,23] and these comprised transient arterial oxygen desaturation and increased dyspnoea during exercise training. Regarding major adverse events, one participant experienced chest pain during 'low-intensity walking' and was found to be in atrial fibrillation which resolved spontaneously after 1 hour.[23]

The qualitative analyses[27,32] and the study reported in abstract form only[34] were not assessed using the Consensus on Exercise Reporting Template, Template for Intervention Description and Replication or risk of bias assessment. Across the 17 studies that were assessed, the mean (SD) Consensus on Exercise Reporting Template scores and Template for Intervention Description and

Replication scores were 8.4 (4.0) (range = 3–14) and 6.8 (2.7) (range = 3–11). The scores for each scale and risk of bias results are presented in Supplemental Tables S4 and S5 and Supplemental Material S6.

Discussion

Despite performing a comprehensive search to find studies that had recruited adults who were hospitalized with any acute respiratory condition or an exacerbation of any chronic respiratory condition, the only studies found had been conducted in either adults hospitalized with an exacerbation of chronic obstructive pulmonary disease or community-acquired pneumonia. Within the included studies, the methods used for the prescription of exercise training were disparate. When reported, these exercise training programmes were well tolerated and adverse events were infrequent.

In both health and disease, to optimize the effectiveness of an exercise training programme, it is generally accepted that prescription should be individualized and adhere to principles of overload and specificity.[37] As the body adapts to the imposition of a training load, progression of this load is required to stimulate further adaptation and training responses.[37] Without first collecting objective measures of exercise capacity, it is possible that the exercise prescription will be suboptimal. Specifically, earlier work in hospitalized adults has shown that the distance walked on the ward was, on average, less than 30% of what they achieved during an objective assessment of exercise capacity.[38] In this review, more than 70% of studies that prescribed either walking training or resistance training were based on the initial prescription on objective measures of physical function collected in each individual. Walking-based aerobic training programmes were most often prescribed based on the results of 6-minute walk test and resistance training programmes were most often prescribed based on the measure of a one-repetition maximum.[3,12,20,23,25,29,34]

Although it might be ideal to prescribe an exercise training programme based on an objective assessment of exercise capacity, one barrier to this may be the tolerance of such measures. Across the studies included in this review, the tolerance of objective measures was variable. In contrast to the one-repetition maximum which appears to have been well tolerated, one study reported that a large proportion of the sample (63%) did not attempt the 6-minute walk test.[31] This suggests that a test of this duration may be overly burdensome in this clinical population and explains why other authors have selected shorter tests such as the 2-minute walk test[34] or 3-minute walk test.[23] Where reported, most studies titrated training load based on symptoms.[3,12,19–21,24,25,29,30]

From the studies that reported on tolerance, it would appear that resistance training had a slightly higher tolerance in comparison to aerobic training (exclusive resistance training (range = 86%–95%)[20,25] vs. a combination of aerobic and resistance training (71%–90%)[12,23] vs. exclusive aerobic training (73%)).[4] This may be explained by resistance training being associated with lower ventilatory load and less dyspnoea in comparison to aerobic exercise training.[39] Perhaps, for those patients who are severely dyspnoeic and unable to tolerate walking training, exercise training should commence with resistance exercise. Adherence by more than 70% of the sample is comparable to levels of adherence for exercise training conducted during the period of hospitalization in other populations such as post-stroke patients (77%),[40] older medical inpatients (63%)[41] and patients in the intensive care unit (60%).[42]

The safety of initiating exercise in adults early during hospitalization has been an area of interest across multiple patient populations such as those admitted to intensive care[42] and following stroke.[43] In people hospitalized with an exacerbation of chronic obstructive pulmonary disease, there have been concerns raised regarding possible deleterious outcomes of initiating exercise early during hospitalization such as increased systemic inflammation and myocardial strain.[44] Across the 18 studies included in this review, a total of seven adverse events were reported across the 1146 participants who completed a total of ~7420 training sessions. Only one event was deemed to be 'major' and this resolved spontaneously. There was no clear relationship between the prescription of exercise

intensity and adverse events with the only serious adverse event occurring in the 'low' intensity group, not the 'moderate to high' intensity group.[23]

Our finding of infrequent adverse events in people who have been prescribed exercise during periods of hospitalization is consistent with the studies undertaken of early mobilization in the intensive care unit. Specifically, a systematic review that investigated the role of mobilization in adults in the intensive care unit and included data across 48 studies (N = 7546 participants, 13,974 episodes of mobilization) reported the incidence of adverse events that required cessation of mobilization and/or medical attention to be 0.06%.[45] Although there are now data to show that, in people hospitalized with an exacerbation of chronic obstructive pulmonary disease, exercise training is unlikely to worsen systemic inflammation,[46] a study by Greening et al.[12] have stimulated discussion regarding the safety of exercise prescription in this population. In this study of people hospitalized with an exacerbation of chronic obstructive pulmonary disease, when compared with a control group who received 'usual care' (airway clearance, supervised mobilization, education and nutritional screening), those who participated in exercise training had higher odds for mortality at 12 months following randomization (odds ratio = 1.74; 95% confidence interval (CI) = 1.05–2.88). However, it is difficult to attribute this mortality difference to the exercise training programme as (1) the difference in mortality was only seen more than five months after hospital discharge; (2) the per-protocol analysis, which included those who completed the intervention period, did not show a difference in mortality and (3) those in the intervention group had lower FEV_1 at baseline and FEV_1 is a strong predictor of mortality in people with chronic obstructive pulmonary disease.[47]

Regarding the quality of reporting, only half of the studies met the criteria for at least 50% of the items on the Consensus on Exercise Reporting Template scores and Template for Intervention Description and Replication.[3,12,19–23,25,31] Of the five studies that scored less than 50%, three were those conducted in adults hospitalized with community-acquired pneumonia. This may reflect the large body of earlier work that has refined the description of exercise training in chronic obstructive pulmonary disease vs. the small body of work on exercise training for people with community-acquired pneumonia.[2,4,33] As expected, studies were unable to blind participants or personnel to group allocation; however, seven studies reported blinding the outcome assessor to reduce detection bias. To improve the transparency of further studies, adherence to the Consensus on Exercise Reporting Template[16] and Template for Intervention Description and Replication[17] guidelines is recommended. This will allow the methods used for prescription and titration of exercise interventions to be more readily replicated in clinical practice.

Strengths and limitations

The major strength of this study pertains to the restricted inclusion of studies that initiated exercise training within 72 hours of admission. That is, although exercise training in adults hospitalized with a chronic respiratory disease has been the focus of a previous Cochrane review,[1] this earlier review included trials that initiated exercise training at any point during the hospitalization as well as those that initiated exercise training shortly following hospital discharge. Of the 20 randomized controlled trials included in this earlier review, only 5 began the intervention after 72 hours of hospitalization. Given the focus in many countries on minimizing hospital length of stay, studies that first initiated exercise training after 72 hours of hospitalization are likely to have limited relevance in contemporary practice.[48,49] In contrast, this review provides detailed mapping of parameters reported across 18 studies, which are likely to be of interest and relevance to clinicians working with adults admitted for a respiratory condition.

We chose, a priori, to conduct a scoping review rather than a meta-analysis. This is because most of the studies included in this review have been used in previous meta-analyses, to demonstrate the effect of exercise training in people hospitalized for a respiratory condition. We felt the gap in our knowledge pertained largely to the practical implementation of these programmes, and a

scoping review allowed us to review and map the parameters necessary for clinicians to apply these programmes. It is also possible that there were papers written in languages other than English and Portuguese.

Clinical messages

- The most frequently used objective test that was used to prescribe the initial dose of resistance exercise was the one-repetition maximum.
- The most frequently used objective test that was used to prescribe the initial dose of walking-based aerobic training was the 6-minute walk test.
- Exercise training programmes were well tolerated in this population and appeared to pose little risk.

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Supplemental material

Supplemental material for this article is available online.

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Appendix 2: Example of the search string

Initial search strategy used for MEDLINE. Date: 05/03/2017

1. hospital*
2. exacerbat*
3. exp. infection
4. exp. symptom flare up
5. deteriorate mp.
6. decline mp.
7. Combine #1 OR #2 OR #3 OR #4 OR #5 OR #6
8. exp. chronic obstructive pulmonary disease
9. exp. cystic fibrosis
10. exp. asthma
11. exp. pneumonia
12. exp. bronchiectasis
13. exp. interstitial lung disease
14. exp. lung
15. respiratory mp.
16. pulmonary mp.
17. Combine #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16
18. exp. exercise
19. exp. exercise therapy
20. exp. resistance training
21. exp. walking
22. exp. bicycling
23. exp. early ambulation

24. early mobili*
25. aerobic mp.
26. exp. muscle strength
27. strength mp.
28. ambulation mp.
29. mobility mp.
30. Combine #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29
31. Combine #7 AND #19 AND #30
32. Limits: Humans, adults, English and Portuguese, publication date: 1990- current
33. **Results**: 2121

Appendix 3: Data dictionary

'999'	Missing data
'888'	Not applicable
30-day readmissions	The number of readmissions to the RPH in the 30 days following discharge, as per iSoft-ICM.
30-day ED presentations	The number of presentations to the RPH Emergency Department that did not result in hospital admission, in the 30 days following discharge, as per iSoft-ICM.
Acapella	A gravity-dependent, oscillatory positive pressure device used to assist airway clearance.[186]
Active cycle of breathing technique (ACBT)	Active cycle of breathing technique is an airway clearance technique consisting of a cycle of breathing control, deep breathing with emphasis on inspiration and force expiratory manoeuvers such as a huff or cough.[186]
Acute confusion	Temporary, reversible cognitive disturbance.[272]
Admission blood albumin	The participant's first recorded CRP during this hospital admission, as per iSoft-ICM, measured in grams per liter.
Admission C-reactive protein (CRP)	The participant's first recorded CRP, as per iSoft-ICM, measured in milligrams per liter.
Admission CRP date	The date of first recorded CRP count during this hospital admission (dd/mm/yyyy).
Admission haemoglobin (Hb)	The participant's first recorded Hb during this hospital admission, as per iSoft-ICM, as grams per liter.
Admission Hb date	The date of first recorded Hb (dd/mm/yyyy).
Acute renal failure	Sudden kidney damage, irrespective of cause and may require dialysis.[273]
Admission white cell count (WCC)	The participant's first recorded WCC for this hospital admission, as per iSoft-ICM, measured in 1000 cells/ microliter.
Admission WCC date	The date of first recorded WCC (dd/mm/yyyy).
AKHS	Armadale Kelmscott Health Service
Ambulation	Walking away from the bed/chair for at least 5 meters.[274]

Ambulation distance	Total ambulation distance documented for first the episode of ambulation. This should be found in the medical record.
Arrhythmia	An abnormal heart rhythm, confirmed by ECG monitoring.[275]
Aspiration pneumonia	An infectious process secondary to inhalation of foreign material into the airways beyond the vocal cords.[276]
Average daily number of steps	The average number of steps taken per day of hospitalisation, as per the StepWatch™.
Average daily stepping cadence	The average daily number of steps per minute, as per the StepWatch™.
Bubble PEP	The use of a column of water and tubing to generate oscillation and positive expiratory pressure, to assist in airway clearance.[186]
Community acquired pneumonia (CAP)	CAP is defined as: new infiltrate on chest radiograph, and either one major criteria (cough, sputum production, or temperature greater than thirty 37.8 degrees) or two minor criteria (pleuritic chest pain, dyspnoea, altered mental status, pulmonary consolidation on examination, or leucocyte count greater than 12, 000 per microliter).
Comorbidities	Defined as previous and co-existing medical conditions that are documented in the medical record as official past medical history. The number of comorbidities in each of the following groups will be recorded.[238] Cardiovascular • Ischaemic heart disease, left heart failure, right heart failure, atrial fibrillation, myocardial infarction, unstable angina, heart block, valve disease, congenital heart disease, pulmonary hypertension, hypertension, cerebrovascular accident with residual impairment. Metabolic • Type 1 diabetes mellitus, type 2 diabetes mellitus, hypercholesterolaemia, dyslipidaemia, gout. Respiratory • Chronic obstructive pulmonary disease, asthma, bronchiectasis, cystic fibrosis, interstitial lung disease,

	obstructive sleep apnoea, obesity hypoventilation. Neurodegenerative disease with residual mobility impairment • Parkinson's disease, multiple sclerosis, motor neuron disease, dementia. Rheumatological with mobility impairment • Rheumatoid arthritis, osteoarthritis. Musculoskeletal with mobility impairment • Total joint replacement, chronic spinal pain. Haematological • Deep vein thrombosis, pulmonary embolism. Renal • Chronic renal failure. Cancer • This includes any type of cancer such as acute myeloid leukaemia, breast, bone, bladder, lymphoma, prostate, pancreatic, mesothelioma, gastric and skin cancer.
CURB-65	A scale used to calculate disease severity and stratify risk, using the information from the medical record.
Current smoker	The patient reports smoking over 100 cigarettes in their lifetime, and at the time of asking, smoked either every day or some days.[277]
Crutches	This can include any type of crutches e.g. axillary, elbow or gutter.
Date of birth	The patient's date of birth, as per the medical record (dd/mm/yyyy).
Date of commencement of NIV therapy	The date of commencement of NIV therapy. This will be found in the bedside nursing file or in the medical record (dd/mm/yyyy).
Date of commencement of oxygen therapy	The date of commencement of new oxygen therapy for this patient during this admission. This will be found in the bedside nursing file (dd/mm/yyyy).
Date of consent	The date of patient consent (dd/mm/yyyy).
Date of discharge from inpatient physiotherapy	The date that the patient was discharged from inpatient physiotherapy, as per the medical record (dd/mm/yyyy).

Date of first ambulation	The date of first ambulation, as per the medical record (dd/mm/yyyy).
Date of first IVAB	The date of the initial intravenous antibiotic (IVAB) dose during this admission as recorded in the medication chart (dd/mm/yyyy).
Date of first oral antibiotic (AB)	The date of the initial oral AB dose for this patient during this admission. This will be found in the medication chart (dd/mm/yyyy).
Date of first transfer out of bed	The date of first transfer out of bed, as per the medical record (dd/mm/yyyy).
Date of initial data collection	The date of initial data collection (dd/mm/yyyy).
Date of medical complication or adverse event	The date of medical complication or adverse event. This will be found in the medical record (dd/mm/yyyy).
Date of oxygen wean	The documented date that supplemental oxygen was not required for more than 12 hours to maintain saturations in the target range, as set by the treating medical team. This will be documented in the medical record and bedside nursing file (dd/mm/yyyy).
Date of StepWatch application	The date that the StepWatch was applied (dd/mm/yyyy).
Date of StepWatch removal	The date that the StepWatch was removed (dd/mm/yyyy).
Date of successful daytime NIV wean	The date where daytime NIV was first ceased and the patient remained off daytime NIV for at least 24 hours. This will be found in the bedside nursing file or in the medical record (dd/mm/yyyy).
Date of successful nocte NIV wean	The date where nocte NIV was first ceased and the patient remained off nocte NIV for at least 24 hours. This will be found in the bedside nursing file or in the medical record (dd/mm/yyyy).
Date of successful oxygen therapy wean	The date where oxygen therapy was first ceased and the patient remained on room air for at least 4 hours without oxygen therapy being replaced. This will be found in the bedside nursing file (dd/mm/yyyy).
Date of walking aid wean	The documented date that the mobility status changed, with the patient no longer requiring a walking aid. This is documented by a

	physiotherapist in the medical record (dd/mm/yyyy).
Empyema	Pus in the pleural space, as confirmed by chest , +/- ultrasound.
Ex-smoker	The patient reports smoking over 100 cigarettes in their lifetime, and at the time of asking, does not smoke.[277]
Fall	'A fall is defined as an event which results in a person coming to rest inadvertently on the ground or floor or other lower level' (WHO 2012).[278]
Flutter	A small oscillatory device that generates a positive pressure during expiration which reduces sputum viscoelasticity and assists in airway clearance.[186]
Frame	This can include a wheeled zimmer frame (WZF) defined by two front wheels and two rear stoppers, and a four wheeled walker (4WW) defined by four wheels +/- brakes.
FSH	Fiona Stanley Hospital
Functional capacity measure	An objective outcome measure that assesses function. Accepted outcome measures are the Timed Up and Go (TUG) and the 10-meter walk test. If one of these measures were performed at discharge, the following will be recorded, as per the medical record: • The specific outcome measure • The date and time of administration o If the specific time of physiotherapy review was not documented, the time of documentation will be recorded.
Functional resistance exercise	This includes whole body movement such as marching on the spot or sit-to-stand.
Heart failure	Inability of the heart to generate sufficient cardiac output, often due to ischaemic damage, hypertension, valve disease, cardiomyopathy or arrhythmias.[279]
Height	The patient's most recent height in meters, as documented in the medical record or the patient care plan.
Hospital admission date	The date that the patient was admitted to the RPH, as per iSoft-ICM (dd/mm/yyyy).

Hospital admission time	The time that the patient was admitted to the RPH, as per iSoft-ICM (24-hour format).
Hospital discharge date	The date that the patient was discharged from the RPH as per iSoft-ICM (dd/mm/yyyy).
Hospital discharge destination	The patient's discharge destination. ☐ Home ☐ Residential care ☐ Transitional Care Program ☐ Private hospital ☐ Rehabilitation hospital ☐ Other:
Hospital discharge time	The time that the patient was discharged from the RPH as per iSoft-ICM (24 hour format).
HPH	Hollywood Private Hospital
Influenza vaccine in last 12 months	Administration of the influenza vaccine in the last 12 months, as documented in the medical record.
Inpatient mortality	Defined as death during this hospital admission, as per the medical record.
Interactions with a physiotherapist	The number of times a physiotherapist interacted with a patient for the purpose of assessment and/or treatment was recorded. This included assessment and/or treatment of any kind, related to musculoskeletal, cardiorespiratory or neurological systems. Data were also extracted on the number of interactions during which the physiotherapist performed an assessment and/or treatment to address a respiratory problem (e.g. positioning to relieve dyspnoea).
Intravenous antibiotic (IVAB) therapy	The intravenous antibiotic used for this patient for the treatment of CAP and is commenced during this admission. This will be recorded as per the bedside nursing file. ☐ Amoxycillin ☐ Roxithromycin ☐ Gentamicin ☐ Ceftriaxon ☐ Meropenem

	☐ Other (if applicable):
Isolation precautions	The RPH infection control instructions that were used during the entire admission. This will be recorded as the precaution card colour used by the RPH infection control team (white, orange, green, blue, red or none).
JHC	Joondalup Health Campus
Length of stay (LOS)	The total number of days of hospital admission, as per iSoft-ICM.
Level of ambulation prior to admission	The patient's level of ambulation prior to admission, as per the medical record:[239] ☐ Independent (+ / - walking stick) ☐ Independent with frame ☐ Mobile with walking aid but erratic / unsafe ☐ Needs physical help to walk or constant supervision ☐ Other:
Level of assistance required for first transfer out of bed	The level of assistance required transferring out of bed for the first time, as per the medical record. ☐ Independent (+ / - walking stick) ☐ Independent with frame ☐ Mobile with walking aid but erratic / unsafe ☐ Needs physical help to walk or constant supervision ☐ Other:[239]
Manual techniques	This includes shaking, vibrations and compression that are applied to the patient by the physiotherapist. This vibration aims to augment expiratory flow and assist in airway clearance.[186]
Medical specialty	The defined clinical area for the consultant under which the patient has been admitted. e.g. Dr Tobin is a consultant of Respiratory Medicine.
Medical complications and adverse reactions	Defined as any unfavourable development that required investigation and altered the course of treatment during the hospitalisation. Examples include empyema, myocardial infarction, drug reaction, fall or dislodgement of an attachment.[13, 213]
Medications during admission	List all medications during admission. This includes regular medications and newly charted medication. This will be found in the RPH medication chart.

Mobilisation	Defined as '… movement out of bed with change from horizontal to upright position for at least 20 minutes…' (Mundy et al 2003). It can include the transfer out of bed to a chair/commode, or ambulation.[12] Mobilisation during this admission will be recorded as: • The first episode of transfer out of bed • The first episode of ambulation • The total number of walks during hospitalization, on and off oxygen
Mobility level at discharge	The patient's level of mobility at discharge, as per the last documented physiotherapy entry in the medical record. ☐ Independent (+ / - WS) ☐ Independent with frame ☐ Mobile with walking aid but erratic / unsafe ☐ Needs physical help to walk or constant supervision ☐ Non-ambulant ☐ Other:[239]
Myocardial infarction	A clinical event caused by myocardial ischemia with evidence of myocardial injury or necrosis such as raised troponin.[280]
Nocte NIV	Nocte NIV will be defined as NIV therapy used during sleeping.
Non- instrumental ADL	These are defined as basic self-care tasks that are essential for daily living within the home. These include:[281] • Bed mobility • Transfers • Short distance ambulation within the home • Bathing and showering • Dressing • Feeding • Toileting
Non-invasive ventilation (NIV) therapy	Non-invasive ventilation (NIV) is defined as positive pressure, ventilatory support via a non-invasive interface such as a face mask, nasal mask, or nasal pillows, which is initiated during admission for the presenting respiratory condition. This can include

	any type of NIV such as bilevel (BiPAP) or continuous (CPAP) positive pressure and excludes those patients who receive domiciliary NIV. This will be recorded as whether the patient received NIV during this admission (Yes or No).
Non-smoker	The patient has never smoked cigarettes.[277]
Nosocomial infection	'defined as those occurring within 48 hours of hospital admission, 3 days of discharge or 30 days of an operation' (Inweregbu et al 2005).[282]
Organism in sputum	The identified organism in the patient's sputum. This will be documented in the patient's medical record and reported on iSoft-ICM.
Oxygen therapy	This will be recorded whether the patient received oxygen therapy during this admission (Yes or No). This excludes patients that receive domiciliary oxygen. Oxygen therapy is defined as supplemental oxygen delivered through an interface including nasal canulae, simple/Hudson mask, Venturi mask, high flow nasal canulae, and non-rebreather mask.
Palliation	When treatment is focused on improving '…quality of life of patients and their families facing the problem associated with life-threatening illness'.[283] This must be documented and confirmed by the treating medical team.
Patient initials	The first letter of the patient's first, middle and surname (LLL).
Patient care plan	A RPH document found in the bedside nursing file. This includes detail about each patient and their specific care needs. For example, • Demographics e.g. age, weight • Previous level of function e.g. mobility, feeding, toileting, • Social history • Falls history • Micro-alerts • Cognition • Language barriers • Current mobility status • Identification for additional charts e.g. oxygen prescription

PHC	Peel Health Campus
Positioning	The purposeful positioning of a patient to address a specific respiratory problem. For example, positioning in side lye to optimize ventilation/ perfusion matching in unilateral lung disease.[186]
Premorbid frailty	Frailty will be recorded per the Clinical Frailty Scale (CFS). Details of how to complete the CFS are outlined in Appendix 3. This will be representative of patient's function over the past month. This will be made on clinical judgment of the research physiotherapist based on the medical record.
Previous living situation	Select the patient's previous living situation:[284] ☐ Living at home alone ☐ Living at home with others ☐ Residential facility (including Transitional Care Program) ☐ Respite

Rehabilitation referral	Rehabilitation can include:
	• Inpatient based
	  o Restorative unit, secondary hospital
	• Outpatient based
	  o Day therapy, outpatients
	• Home based
	  o Rehabilitation in the Home, Silverchain via Personal Enablement Program.

Referral to rehabilitation on discharge	Referral to rehabilitation on discharge will be recorded as per the medical record or discharge summary.
Respiratory treatments received during admission	All of the respiratory physiotherapy treatments received during admission: ☐ Active cycle of breathing technique ☐ Flutter ☐ Acapella ☐ Bubble PEP ☐ Manual techniques

	☐ Positioning ☐ Other
RGH	Rockingham General Hospital
RPH	Royal Perth Hospital
SCGH	Sir Charles Gairdner Hospital
Sepsis	'…defined as life-threatening organ dysfunction caused by a dysregulated host response to infection' (Singer et al 2016).[285]
Severe hyperglycaemia	Defined as glucose levels greater than 15 mmol/L.[286]
Sex	The sex of the patient, recorded as female, male or other.
Shock	Defined as 'a state of cellular and tissue hypoxia due to reduced oxygen delivery and/or increased oxygen consumption or inadequate oxygen utilization'. There are four main categories of shock: • Distributive (septic, non-septic) • Cardiogenic (cardiomyopathic, arrhythmogenic, mechanical) • Hypovolemic (haemorrhagic and non-haemorrhagic) • Obstructive (pulmonary vascular and mechanical)[287]
SJOG	Saint John of God
Smoking pack years	The number of smoking pack years, as documented in the medical record. 1 'pack year' is defined as 20 cigarettes smoked every day, for 1 year.
Smoking status	Current smoking status, as documented in the medical record. The statuses that will be accepted are: • Non-smoker • Ex-smoker • Current smoker
Staff present for the first episode of ambulation	The individual/s that was present during the first episode of ambulation: ☐ Nursing ☐ Independent/un-witnessed

	☐ Physiotherapist ☐ Allied health assistance ☐ Other
Staff present for first transfer out of bed	The individual/s that was present during the transfer out of bed: ☐ Nursing ☐ Independent/unwitnessed ☐ Physiotherapist ☐ Allied health assistance ☐ Other
StepWatch	A small, non-invasive monitor that will be attached to the right ankle of the participant from the time of consent until discharge.
Time of cessation of oxygen therapy	The time where oxygen therapy was first ceased and the patient remained off oxygen therapy for at least 4 hours. This will be found in the bedside nursing file (24-hour format).
Time of commencement of NIV therapy	The time of commencement of NIV therapy. This will be found in the bedside nursing file (24-hour format).
Time of commencement of oxygen therapy	The time of commencement of new oxygen therapy. This will be found in the bedside nursing file (24-hour format).
Time of first ambulation	The time of the first episode of ambulation, as per the medical record (24-hour format).
Time of first IVAB	The time of initial IVAB dose. This will be found in the medication chart (24-hour format).
Time of first oral AB	The time of the initial oral AB dose for this patient during this admission. This will be found in the medication chart (24-hour format).
Time of first transfer out of bed	The time of first transfer out of bed, as per the medical record (24-hour format).
Time of StepWatch application	The time that the StepWatch was applied (24-hour format).
Time of StepWatch removal	The time that the StepWatch was removed (24 hour format).

Time of successful daytime NIV wean	The time where daytime NIV was first ceased and the patient remained off daytime NIV for at least 24 hours. This will be found in the bedside nursing file (24-hour format).
Time of successful nocte NIV wean	The time where nocte NIV was first ceased and the patient remained off nocte NIV for at least 24 hours. This will be found in the bedside nursing file (24-hour format).
Total number of respiratory treatments	The total number of documented physiotherapy interactions that include respiratory assessment (oxygen requirement, work of breathing) and/or treatment (mobilisation, airway clearance, positioning).
Total number on walks on oxygen	The total number of documented episodes of ambulation with supplemental oxygen. This includes ambulation with physiotherapy and nursing staff, family members and independently.
Total number off walks on oxygen	The total number of documented episodes of ambulation on room air. This includes ambulation with physiotherapy and nursing staff, family members and independently.
Transfer out of bed	A change in position from resting in bed, to seated on either a chair (high back, recliner), a commode or to standing. The individual does not move more than 5 meters from the bedside. This will be recorded in as the date/time of first transfer out of bed, as per the medical record, and includes include hoist and sling transfers.
Transferred from other hospital	This includes inter-hospital transfer from a secondary or tertiary hospital, or restorative unit.
Treating consultant	The consultant who is recorded as the primary care doctor for this patient on this admission as per iSoft-ICM and the medical record.
Ward of admission	The ward that the patient was first admitted to, excluding the Emergency Department observations ward.
Weight	The patient's most recent weight in kilograms, as documented in the medical record or the patient care plan.
WS	Walking stick. This can include a single point walking stick or quad stick.

Appendix 4: Data collection tool

Data collection for period of hospitalisation

Participant number: _____ Date of data collection: ___/___/_____

Date of participant consent: ___/_____/_____

Name of data collector: _____

Participant data:

Date of birth: __/_____/_____

Male: No ☐ Yes ☐ Other ☐

Height (m): _____ Weight (kg): _____

Aboriginal or Torres Straight Islander: No ☐ Yes ☐

Baseline data

Date of admission: _____/_____/_____ Time (24hr): _____

Ward:

☐ AMU ☐ 9A

☐ 10A ☐ 9C ☐ Other _____

Consultant:

☐ Ati ☐ Kilshaw ☐ John

☐ Kok ☐ Warne ☐ Nolan

☐ Myhill ☐ Loh ☐ Roddy- Coote

☐ Patankar ☐ Waring ☐ Schultz

☐ Puri ☐ Bennett ☐ Spiro

☐ Tobin ☐ Perera ☐ Powell

☐ Chee ☐ Yee ☐ Alcock

☐ Fernandez ☐ Carnley ☐ Stoyanov

☐ Arenson ☐ Coordingley ☐ Hillis

☐ Donaldson ☐ Tan ☐ Other

Speciality:

☐ General medical ☐ Immunology ☐ Cardiology

☐ Geriatrics ☐ Haematology

☐ Respiratory ☐ Rheumatology

☐ Other

Select cardiovascular comorbidities as per medical record:

☐ Ischaemic heart disease ☐ Valve disease

☐ Left heart failure ☐ Congenital heart disease

☐ Right heart failure ☐ Pulmonary hypertension

☐ Atrial fibrillation ☐ Hypertension

☐ Myocardial infarction ☐ Cerebrovascular accident with residual impairment

☐ Unstable angina

☐ Heart block ☐ Other:

Select the metabolic comorbidities, as per the medical record:

☐ Type 1 diabetes mellitus
☐ Type 2 diabetes mellitus
☐ Hypercholesterolaemia
☐ Dyslipidaemia
☐ Gout
☐ Other:

Select the respiratory comorbidities, as per the medical record:

☐ Chronic obstructive pulmonary disease
☐ Asthma
☐ Bronchiectasis
☐ Cystic fibrosis
☐ Interstitial lung disease
☐ Obstructive sleep apnoea
☐ Obesity hypoventilation
☐ Other:

Select the neurodegenerative comorbidities, as per the medical record:

☐ Parkinson's disease
☐ Multiple sclerosis
☐ Motor neuron disease
☐ Dementia
☐ Other:

Select the rheumatological comorbidities, as per the medical record:

☐ Rheumatoid arthritis
☐ Osteoarthritis
☐ Other:

Select the musculoskeletal comorbidities, as per the medical record:

☐ Total joint replacement
☐ Chronic spinal pain
☐ Other:

Select the haematological comorbidities, as per the medical record:

☐ Deep vein thrombosis
☐ Pulmonary embolism
☐ Other:

Select the renal comorbidities, as per the medical record:

☐ Chronic renal failure
☐ Other

Select the cancer comorbidities, as per the medical record:

☐ Acute myeloid leukaemia
☐ Breast
☐ Bone
☐ Bladder
☐ Lymphoma
☐ Prostate
☐ Pancreatic
☐ Mesothelioma
☐ Gastric
☐ Skin cancer
☐ Other:

Smoking status:

☐ Non-smoker ☐ Ex-smoker ☐ Current smoker

Smoking pack years: _____

Influenza vaccine in the last 12 months: ☐ Yes ☐ No

Level of ambulation prior to admission:

☐ Independent (+ / - WS)
☐ Independent with frame
☐ Mobile with walking aid but erratic/unsafe
☐ Needs physical help to walk or constant supervision
☐ Other:

Previous social situation:

☐ Living at home alone
☐ Living at home with others
☐ Residential facility
☐ Respite
☐ Other tertiary hospital
☐ Secondary hospital
☐ Other:

Interhospital transfer: ☐ Yes ☐ No

Clinical Frailty Score:

☐ 1: Very fit
☐ 2: Well
☐ 3: Well, with treated comorbid disease
☐ 4: Apparently vulnerable
☐ 5: Mildly frail
☐ 6: Moderately frail
☐ 7: Severely frail

Medical progress:

Admission WCC: _____ Admission WCC date: __/__/____
Admission CRP: _____ Admission CRP date: __/__/____
Admission Hb: _____ Admission Hb date: __/__/____
Blood albumin levels: _____ Blood albumin levels date: __/__/__

Organism in sputum:

☐ Streptococcus pneumoniae
☐ Staphyloccus areus
☐ Mycoplasma pneumonia
☐ Other:

CURB-65 score:

☐ 0
☐ 1
☐ 2
☐ 3
☐ 4
☐ 5

Pleural effusion: ☐ Yes ☐ No
Intercostal catheter (ICC): ☐ Yes ☐ No ☐ Not applicable
ICC on suction: ☐ Yes ☐ No ☐ Not applicable

Isolation precautions:

☐ None
☐ White
☐ Orange
☐ Green
☐ Blue
☐ Red

IV antibiotic therapy:

☐ Amoxycillin
☐ Roxithromycin
☐ Gentamicin
☐ Ceftriaxone
☐ Meropenem
☐ Other _____

First dose of IV antibiotic:

Date: __/__/____ Time (24 hour): _____

First oral antibiotic:

Date: __/__/____ Time (24 hour): _____

Commencement of oxygen therapy:

Date: __/__/____ Time (24 hour): _____

Cessation of oxygen therapy:

Date: __/__/____ Time (24 hour): _____

Commencement of NIV therapy:
Date: ____/____/____ Time (24 hour): _____
Cessation of daytime NIV:
Date: ____/____/____ Time (24 hour): _____
Cessation of nocte NIV:
Date: ____/____/____ Time (24 hour): _____

Medications during admission: _____
_____
_____
_____
_____
_____
_____
_____
_____

Medical complications during this admission:

- ☐ Empyema
- ☐ Arrhythmia
- ☐ MI
- ☐ Heart failure
- ☐ Acute confusion
- ☐ Renal failure
- ☐ Sepsis
- ☐ Nosocomial infection
- ☐ Severe hyperglycaemia
- ☐ Shock
- ☐ Febrile (T> 37.8 degrees)
- ☐ Hypotensive (SBP< 100 mmHg)
- ☐ Tachycardic (HR> 100bpm)
- ☐ Type 1 respiratory failure (Pa02 <60mmHg)
- ☐ Type 2 respiratory failure (Pa02 <60mmHg, PaC02 >55mmHg)

Other: _____
_____
_____

Date of medical complication: ___/___/____
Detail of medical complication: _____
_____
_____

Adverse events:

- ☐ Drug reaction
- ☐ Dislodgment of attachment
- ☐ Medication error
- ☐ Falls
- ☐ Chest pain
- ☐ Arrhythmia
- ☐ Significant oxygen desaturation (Sp02 <80%)
- ☐ Syncope
- ☐ Altered consciousness
- ☐ Heart rate greater than 85% of maximal heart rate (220-age)
- ☐ Shortness of breath greater >7 on Borg Scale
- ☐ Other:

Date of adverse event: ___/___/____
Detail of adverse event: _____
_____
_____

Inpatient mortality:
☐ Yes ☐ No
If yes, detail:

_____

_____

_____

Mobilisation data:
First transfer out of bed:
Date: _____/_____/_____ Time (24 hour): _____
Transferred to:
☐ Chair ☐ Commode
Level of assistance required:
☐ Independent (+ / - WS) ☐ Needs physical help to walk or constant supervision
☐ Independent with frame
☐ Mobile with walking aid but erratic / unsafe ☐ Other:

Staff present:
☐ Nursing ☐ Allied health assistance
☐ Independent/unwitnessed ☐ Other:
☐ Physiotherapist

First episode of ambulation:
Date: _____/_____/_____ Time (24 hour): _____
Level of assistance required:
☐ Independent (+ / - WS) ☐ Needs physical help to walk or constant supervision
☐ Independent with frame
☐ Mobile with walking aid but erratic / unsafe ☐ Other:

Staff present:
☐ Nursing ☐ Allied health assistance
☐ Independent/unwitnessed ☐ Other:
☐ Physiotherapist

Total ambulation distance (m): _____

Physiotherapy data:
Total number of physio sessions: _____
Total number of refusals to physio sessions: _____
With physio staff:
Total number of episodes of ambulation: _____
Total number of walks with physical assistance, with a gait aid:_____
Total number of walks with physical assistance, without a gait aid:_____
Total number of walks without physical assistance, with a gait aid:_____
Total number of walks without physical assistance, without a gait aid:_____

If weaned from walking aid, date: _____/____/_____
Total number of walks on oxygen:_____
Total number of walks off oxygen:_____
If weaned from oxygen, date: ____/____/_____

Total number of respiratory treatments:_____

Patient received which of the following respiratory treatments:

☐ ACBT ☐ Acapella ☐ Manual techniques
☐ Flutter ☐ PEP ☐ Positioning
☐ Other _____

Longest distance walked during inpatient admission:_____(m)

StepWatch data:
StepWatch application:
Date: _____/_____/_____ Time (24 hour): _____

StepWatch removal:
Date: _____/_____/_____ Time (24 hour): _____
Average number of daily steps:_____
Average daily cadence: _____

Mobility level at discharge:

☐ Independent (+ / - WS)
☐ Independent with frame
☐ Mobile with walking aid but erratic / unsafe
☐ Needs physical help to walk or constant supervision
☐ Non-ambulant
☐ Other:

Functional capacity measure: ☐ Yes ☐ No
If yes, name of measure: _____
Date of administration: _____/_____/_____ Time (24hr): _____

Discharge details:

Date of discharge: ____/_____/_____

Date of discharge from inpatient physiotherapy:___/___/_____

Discharge destination:

☐ Home
☐ Private hospital
☐ Residential care
☐ Rehabilitation hospital
☐ Transitional Care Program
☐ Other:_____

Referral to rehab on discharge: ☐ Yes ☐ No

If yes, rehab destination: _____

Comments

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Data collection for phone call at 30 days post discharge

Participant number: _____
Date of discharge: ____/____/____
Date of 30-days post discharge: ____/____/____
Initials of data collector: _____

Participant mortality within 30-days of discharge?
No ☐ Yes ☐

Was the participant a current inpatient at 30-days?
No ☐ Yes ☐ If yes, where: _____

In the last 30 days, how many times have you visited your GP? _____

GP Presentation 1:
What was the main symptom(s) that took you to your GP?

_____

_____

☐ Shortness of breath
☐ Pain
☐ Fall
☐ Other _____
_____
_____

GP Presentation 2:
What was the main symptom(s) that took you to your GP?

_____

_____

☐ Shortness of breath
☐ Pain
☐ Fall
☐ Other _____
_____
_____

GP Presentation 3:
What was the main symptom(s) that took you to your GP?

_____

_____

☐ Shortness of breath
☐ Pain
☐ Fall
☐ Other _____
_____
_____

In the last 30 days, how many times have you presented to a hospital emergency department (ED)?

_____

ED Presentation 1:
Which hospital ED did you present to?

☐ Armadale and Kelmscott Health Service (AKHS)
☐ Fiona Stanley Hospital (FSH)
☐ Hollywood Private Hospital (HPH)
☐ Joondalup Health Campus (JHC)
☐ Peel Health Campus (PHC)

☐ Rockingham General Hospital (RGH)
☐ Royal Perth Hospital (RPH)
☐ Sir Charles Gairdner Hospital (SCGH)
☐ St John of God Mount Lawley
☐ St John of God Murdoch
☐ St John of God Subiaco
☐ The Mount Hospital
☐ Other _____

On THIS occasion, what was the main symptom that took you to ED?

_____
_____
_____
_____

☐ Shortness of breath
☐ Pain
☐ Fall
☐ Other _____

Did an ambulance bring you in to hospital?
No ☐ Yes ☐
Did this presentation lead to hospital admission?
No ☐ Yes ☐
If yes, how many days were you in hospital for? _____
Comments:

_____
_____
_____
_____
_____

ED Presentation 2:
Which hospital ED did you present to?
☐ Armadale and Kelmscott Health Service (AKHS)
☐ Fiona Stanley Hospital (FSH)
☐ Hollywood Private Hospital (HPH)
☐ Joondalup Health Campus (JHC)
☐ Peel Health Campus (PHC)
☐ Rockingham General Hospital (RGH)
☐ Royal Perth Hospital (RPH)
☐ Sir Charles Gairdner Hospital (SCGH)
☐ St John of God Mount Lawley
☐ St John of God Murdoch
☐ St John of God Subiaco
☐ The Mount Hospital
☐ Other _____

On THIS occasion, what was the main symptom that took you to ED?

_____
_____
_____
_____

☐ Shortness of breath
☐ Pain
☐ Fall
☐ Other _____

Did an ambulance bring you in to hospital?
No ☐ Yes ☐
Did this presentation lead to hospital admission?
No ☐ Yes ☐
If yes, how many days were you in hospital for? _____

Comments:

_____
_____
_____
_____

ED Presentation 3:

Which hospital ED did you present to?

☐ Armadale and Kelmscott Health Service (AKHS)
☐ Fiona Stanley Hospital (FSH)
☐ Hollywood Private Hospital (HPH)
☐ Joondalup Health Campus (JHC)
☐ Peel Health Campus (PHC)
☐ Rockingham General Hospital (RGH)
☐ Royal Perth Hospital (RPH)
☐ Sir Charles Gairdner Hospital (SCGH)
☐ St John of God Mount Lawley
☐ St John of God Murdoch
☐ St John of God Subiaco
☐ The Mount Hospital
☐ Other _____
_____
_____

On THIS occasion, what was the main symptom that took you to ED?

_____
_____
_____
_____

☐ Shortness of breath
☐ Pain
☐ Fall
☐ Other _____
_____
_____
_____

Did an ambulance bring you in to hospital?
No ☐ Yes ☐
Did this presentation lead to hospital admission?
No ☐ Yes ☐

If yes, how many days were you in hospital for? _____

Comments:

_____

_____

_____

_____

Appendix 5: Clinical Frailty Scale

1. Very fit	People who are robust, active, energetic and motivated. These people commonly exercise regularly. They are amongst the fittest for their age.
2. Well	People who have no active disease but are less fit than category 1. Often, they exercise or are very active occasionally e.g. seasonably.
3. Managing well	People whose medical problems are well controlled but not regularly active beyond routine walking.
4. Vulnerable	While not dependent on other for daily help, often symptoms limit activities. A common complaint is being "slowed up", and/or being tired during the day.
5. Mildly frail	These people often have more evident slowing and need help in high order IADLs (finances, transportation, heavy housework, medications). Typically, mild frailty progressively impairs shopping and walking outside alone, meal preparation and housework.
6. Moderately frail	People need help with all outside activities and with keeping house. Inside they often have problems with stairs and need help with bathing and might need minimal assistance (cuing, standby) with dressing.
7. Severely frail	Completely dependent for personal care from whatever cause (physical or cognitive). Even so, they seem stable and not at high risk of dying (within ~6 months).

Scale taken from Rockwood, K et al. (2005)[91]; pp 490.

Appendix 6: StepWatch™ Activity Monitor calibration protocol

Each StepWatch device was calibrated at the beginning of the study, every three months during data collection and at the conclusion of data collection.

Each device was programmed with the following settings:

1. Default settings for:
    a. 'LED flashes'
    b. 'Days to record'
    c. 'Percentage time active'
    d. 'Auto-exclude'
    e. 'Activity level definitions'
    f. 'Display options'
2. Subject description:
    a. Researchers height: entered in centimetres (cm)
    b. Quick stepping: selected 'No'
    c. Walking speed: 'Normal'
    d. Range of speeds: 'Moderate range'
    e. Leg motion: 'Normal'

Each device was tested as per the following protocol by the researcher:[243, 288-290]

1. The iPad device was positioned to give view of the treadmill. The researcher started video recording.
2. The StepWatch device was placed on the researcher's right ankle.
3. On the treadmill,
    i. The researcher stood still for 2 minutes.
    ii. The treadmill speed was set to 1 kilometre per hour (kph). The researcher walked at this speed for 3 minutes.

iii. The treadmill was stopped. The researcher stood still for 2 minutes.

iv. The treadmill speed was set to 3.5 kph. The researcher walked at this speed for 3 minutes.

v. The treadmill was stopped. The researcher stood still for 2 minutes.

vi. The treadmill speed was set to 7 kph. The researcher walked at this speed for 3 minutes.

vii. The researcher stood still for 2 minutes.

4. The researcher stopped the video recording.
5. The total step count taken by the right foot via observation of the video was directly compared to the data downloaded from the StepWatch device.
6. If the difference between the observational count and the StepWatch count is less than 5%, the device was defined as acceptable and continued to be used in the study.
7. Devices were no longer be used in the trial if:
    i. Unable to download data onto the docking station
    ii. There was a difference of more than 5% in step count between the observational count and StepWatch count

Step Watch SN:	**Observational count**	**StepWatch count**
Date of testing (dd/mm/yyyy):		
Time of testing (24 hour):		
Total number steps taken by the right foot		
Raw difference in the number of steps		
% Difference		

Device eligibility criteria:

Could the information be downloaded from the StepWatch onto the docking station?	☐
Did the device capture any steps?	☐
Is the difference between the observational count and the StepWatch count less than 5%?	☐
Can the device continue to be used in the study?	**Yes** ☐ **No** ☐

Comments:

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_____

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Appendix 7: Working example of usual bout duration for walking time

A single 24-hour sampling period for participant 81.

Day 1.	Walking bouts	Duration (mins)	Cumulative sum (mins)	%
	1	1	1	2.5
	2	1	2	5
	3	2	4	10
	4	2	6	15
	5	1	7	17.5
	6	1	8	20
	7	1	9	22.5
	8	1	10	25
	9	3	13	32.5
	10	2	15	37.5
	11	1	16	40
	12	1	17	42.5
	13	2	19	47.5
	14	**1**	**20**	**50**
	15	1	21	52.5
	16	1	22	55
	17	1	23	57.5
	18	1	24	60
	19	1	25	62.5
	20	1	26	65
	21	1	27	67.5
	22	1	28	70
	23	1	29	72.5
	24	1	30	75
	25	1	31	77.5
	26	2	33	82.5
	27	2	35	87.5
	28	1	36	90
	29	2	38	95
	30	1	39	97.5
	31	1	40	100

Table A.1. UBD_{WT} is shown at bout number 14, where the midpoint is where the cumulative sum of reaches 50% of the total bout duration. In this example, UBD_{WT} is 1 minute. UBD_{WT}: Usual bout duration for walking time.

Appendix 8: Observational study publication

Reduced Step Count and Clinical Frailty in Hospitalized Adults With Community-Acquired Pneumonia

Hayley Rice, Kylie Hill, Robin Fowler, Carol Watson, Grant Waterer, and Megan Harrold

BACKGROUND: In adults hospitalized with community-acquired pneumonia (CAP), increasing ward-based walking may reduce length of stay (LOS). There are few data to describe ward-based walking in this population. In adults hospitalized with CAP, we aimed to report variables of walking and non-walking time, to determine whether demographic or clinical variables influenced daily step count, and to determine whether daily step count influenced LOS. METHODS: Following admission, daily step count and variables related to walking and non-walking time were quantified using the StepWatch Activity Monitor. Details regarding demographics, clinical characteristics, clinical care, and LOS were extracted from the medical records and hospital electronic data systems. Frailty was calculated via the 7-point Clinical Frailty Scale; disease severity was measured via the CURB-65 score. Health care utilization at 30 d following discharge was measured via telephone interview. RESULTS: Two hundred participants completed the study, of whom 121 contributed ≥ 24 h of data from the StepWatch Activity Monitor. The median (interquartile range (IQR)) number of daily steps was 926 (457–1706). These were accumulated over 66 (41–121) min/d, with a usual bout duration of 3 (2–4) min and 1-min peak cadence of 56 (43–74) steps/min. An average of 93% (89–96) of waking hours was spent in non-walking time. In the multivariable model, increased frailty was retained as a predictor of lower step count (incidence rate ratio [IRR] 0.59, 95% CI 0.41–0.85). For every increase in 500 steps/d, LOS reduced by 11% (IRR 0.89, 95% CI 0.80–0.99). CONCLUSIONS: Subjects hospitalized with CAP did very little walking, most of which was accumulated in short bouts at a low intensity. Compared with subjects with mild frailty, those with moderate to severe frailty took 59% fewer steps per day. Those with a higher daily step count had a shorter LOS. *Key words: community-acquired pneumonia; hospital; physical activity; physiotherapy; rehabilitation; respiratory.* [Respir Care 2020;65(4):455–463. © 2020 Daedalus Enterprises]

Introduction

Community-acquired pneumonia (CAP) is defined as an acute infection of the lower respiratory tract occurring in a patient who has not resided in a hospital or health care facility in the previous 14 d.[1] Earlier work has shown that, following a hospitalization for CAP, adults report a decline in exercise capacity and difficulty undertaking activities of daily living.[2,3] The reasons for these impairments are likely to be multifactorial but include cardiovascular and skeletal muscle deconditioning that results from convalescence.[4-6] Given what is known in other hospitalized populations,[7,8] we would expect that adults hospitalized with CAP accumulate very little walking-based activity.

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The authors have disclosed no conflicts of interest.

Supplementary material related to this paper is available at http://www.rcjournal.com.

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To date there is a lack of objective data describing baseline physical activity and physiotherapy practice patterns in adults hospitalized with CAP.

There are 3 randomized controlled trials in adults hospitalized with CAP that have examined the effect of increasing ward-based physical activity during hospitalization by initiating exercise training or ambulation as a strategy to ameliorate these sequelae.[9-11] Data from these studies suggest that, in adults hospitalized with CAP, those who engaged in an intervention designed to increase physical activity during hospitalization had better exercise capacity at the time of discharge and a shorter hospital length of stay (LOS) when compared to a usual care group. However, a limitation of these studies was that the characteristics of those who undertook the least physical activity were not reported. In a busy clinical environment, information regarding factors that influence walking-based activity in adults hospitalized with CAP will assist health care professionals in targeting those who are most likely to benefit from an in-patient walking-based program.

The aims of this study were to report variables pertaining to walking and non-walking time, to determine whether demographic or clinical variables influenced daily step count, and to determine whether daily step count influenced health care utilization in adults who had been admitted to a teaching hospital with CAP.

QUICK LOOK

Current knowledge

Adults report a decline in exercise capacity and difficulty undertaking activities of daily living at the time of discharge following hospitalization for community-acquired pneumonia (CAP). Studies have investigated the effect of increasing ward-based physical activity during the period of hospitalization for CAP. The data suggest that, compared to a group that received usual care, subjects who engaged in an intervention designed to increase physical activity during hospitalization had better exercise capacity at the time of discharge and a shorter hospital stay.

What this paper contributes to our knowledge

This prospective, observational study objectively measured walking-based activity in a large sample of adults hospitalized with CAP. This study indicated that adults hospitalized with CAP do very little walking, in very short bouts at low intensity, and spend > 90% of their waking hours in mostly uninterrupted non-walking time. Greater clinical frailty was associated with a lower daily step count, and a lower daily step count was associated with a longer hospital stay.

Methods

A prospective, observational study was undertaken in which patients who met the study criteria were approached within 24 h of admission to Royal Perth Hospital, a 500-bed teaching hospital in Western Australia. Approval was obtained from the Royal Perth Hospital Human Research Ethics Committee (REG 2015-077) with reciprocal approval at Curtin University (HRE 2017-0021). All participants gave written informed consent to participate.

Subjects

Patients were eligible for inclusion if they were ≥ 18 y old and had a diagnosis of CAP. Diagnostic criteria comprised any new infiltrate on chest radiograph and either 1 major criteria (eg, cough, sputum production, or temperature > 37.8°C) or 2 minor criteria (eg, pleuritic chest pain, dyspnea, altered mental status, pulmonary consolidation on examination, or leukocyte count > 12,000/μL).[11] Patients were excluded if they required admission to the ICU, were non-ambulant prior to admission (as determined using the medical notes), had a diagnosis of aspiration pneumonia, were not expected to survive the admission (ie, were deemed terminal), or consent was not obtained (eg, patient declined to consent, or patient could not consent to participate in the study due to cognitive impairment or an inability to understand English).

Recruitment

Potential subjects were screened daily using the hospital electronic data system. Specifically, bed lists of wards were examined for patients who had been admitted with a diagnosis that was captured using any of the following key search terms: shortness of breath, febrile, pneumonia, or respiratory infection. Once identified, study criteria were applied.

Measurement

Variables Used to Describe Subject Characteristics. Patients admitted to a ward had been assessed by staff in the emergency department and the ward medical team. Assessment results were extracted from the medical notes or hospital electronic data systems and used to describe the characteristics of the study subjects. Clinical variables included breathing frequency, blood pressure, and the presence of confusion at the time of admission. Other variables included age, gender, level of independence with ambulation, social situation, and smoking history. Laboratory vari-

Table 1. Clinical Frailty Scale

Category	Category Name	Description
1	Very fit	People who are robust, active, energetic, and motivated. These people commonly exercise regularly. They are amongst the fittest for their age.
2	Well	People who have no active disease but are less fit than category 1. Often, they exercise or are very active occasionally (eg, seasonably).
3	Managing well	People whose medical problems are well controlled but are not regularly active beyond routine walking.
4	Vulnerable	While not dependent on others for daily help, their symptoms often limit activities. A common complaint is being "slowed up" or being tired during the day.
5	Mildly frail	These people often have more evident slowing and need help in high-order IADLs (eg, finances, transportation, heavy housework, medications). Typically, mild frailty progressively impairs shopping and walking outside alone, meal preparation, and housework.
6	Moderately frail	People need help with all outside activities and with keeping house. Inside they often have problems with stairs and need help with bathing, and they might need minimal assistance (eg, cuing, standby) with dressing.
7	Severely frail	Completely dependent for personal care from any cause (physical or cognitive). Even so, they seem stable and not at high risk of dying (ie, within ~6 months).

IADL = instrumental activities of daily living

ables included white cell count, C-reactive protein, hemoglobin, blood albumin, and organisms detected in sputum sampling. Radiographic data included pulmonary consolidation and pleural effusion.

Walking and Non-Walking Time. Variables related to walking and non-walking time were measured using a StepWatch Activity Monitor (StepWatch Modus Health, Washington, DC). This small (75 × 50 × 20 mm), water-resistant, microprocessor-controlled step counter was applied to the participants' right ankle. The StepWatch Activity Monitor produces accurate measures of step count,[12] even for individuals who walk with very slow gait speeds and those who use a walking aid.[13] Participants were instructed to wear the device continuously from the time of recruitment until hospital discharge.

Possible Predictors of Daily Step Count. Variables related to participant characteristics that were assessed as possible predictors of average daily step count included age, disease severity, presence of a pleural effusion, and frailty. Disease severity was calculated via the pneumonia-specific CURB-65 score, which is a validated disease severity tool used in adults with CAP (see the supplementary materials at http://www.rcjournal.com).[14,15] The scores are determined from clinical and laboratory findings and range from zero to five, with higher scores indicating higher disease severity. Data for this score were obtained from the medical notes.

Frailty was calculated for all participants at the time of admission via the 7-point Clinical Frailty Scale (see Table 1).[16] Information used to derive the score, such as the level of independence with activities of daily living and personal care, and the presence of comorbidities were extracted from the medical notes. Scores range from 1 to 7, with higher scores indicating higher frailty. This tool, developed by Rockwood et al,[16] has been validated in community-dwelling older adults, and it has been used in clinical practice and research conducted in hospitalized older adults and other respiratory populations.[17-20]

Variables related to medical management that were assessed as possible predictors of average daily step count were new use of supplemental oxygen, new use of noninvasive ventilation, presence of a pleural effusion, and presence of an intercostal catheter. The number of occasions of physiotherapy service was also assessed as a possible predictor of average daily step count. This was the reported number of occasions of physiotherapy service per patient, per episode of hospitalization.

Health Care Utilization Data. Data pertaining to LOS were calculated using hospital electronic systems. At 30 d following hospital discharge, a brief telephone interview was conducted to capture data regarding the number of presentations to a general practitioner or emergency department and the number of hospital readmissions.

Management of StepWatch Activity Monitor Data

Data from the StepWatch Activity Monitor were analyzed using purpose-built programs developed in LabVIEW Service Pack 1 (National Instruments, Austin, Texas) and SigmaPlot (SYSTAT Software, San Jose, California). To be included in these analyses, subjects needed to contribute data over a minimum of one 24-h period and thereafter; all days during which the participant wore the activity monitor for a complete 24-h period were included in the

analyses. All 1-min epochs during which step count was > 0 were classified as walking time. For each subject, the following variables were extracted for each 24-h sampling period, then averaged and reported as an average daily measure: step count, walking time, the number of transitions from non-walking time to walking time, the time spent in cadence bands defined by the United States National Health and Nutrition Examination Survey,[21] and 1-min peak cadence, which was used as a measure of walking intensity. The cadence bands were used to stratify the speed of walking and represent the time spent in each increment.

Thereafter, to explore patterns of accumulation for each subject, usual bout duration for walking time (UBD_{WT}) was calculated using data available across all 24-h sampling periods. The methodology used to calculate UBD_{WT} has been described elsewhere[22-24]; it represents bout duration above and below which half of all walking time is accrued and is akin to the half-life in pharmaceutical studies.[22-24]

To calculate variables related to non-walking time, the confounding effect of overnight sleeping time was removed by restricting data available for these analyses to that collected between 0700 to 1859. During this time, all 1-min epochs during which step count = 0 were classified as non-walking time. For each subject, the following variables were extracted for each 12-h sampling period, then averaged and reported as an average daily measure: total non-walking time, and the number of transitions from walking time to non-walking time. Thereafter, for each subject's usual bout duration for non-walking time (UBD_{NWT}) was calculated using data available across all 12-h sampling periods.

Statistical Analyses

Analyses were performed using the Statistical Package for the Social Sciences 25 (IBM, Armonk, New York). To address the first research aim, descriptive statistics were used to report variables pertaining to walking and non-walking time.

To address the second research aim, negative binomial regression was used with daily step count as the dependent variable; the following characteristics were used as independent variables: age, disease severity, presence of a pleural effusion, frailty, new prescription of supplemental oxygen, new prescription of noninvasive ventilation, presence of a pleural effusion, presence of an intercostal catheter, and number of occasions of physiotherapy service were entered as independent variables. Independent variables measured on ordinal scales were collapsed to binary categories. Specifically, CURB-65 scores of 0–1 were grouped as less severe, and scores 2–5 were grouped as more severe. Frailty scores of 1–3 were grouped as frailty score < 4, and scores of 4–7 were grouped as frailty score ≥ 4. Physiotherapy occasions of service was grouped as 0–1 occasion of service and ≥ 2 occasions of service. Linear regression (with, where necessary, bootstrapping to manage departures from normality) was used to determine whether the variables retained in the multivariable model were also predictors of UBD_{WT} and 1-min peak cadence. *P* values < .05 denoted statistical significance.

To address the third research aim, negative binomial regression was used to explore the association between daily step count and hospital LOS, and between daily step count and the number of 30-d hospital readmissions.

Results

Subjects

The flow of subjects into the study is shown in Figure 1. A total of 1,263 patients were screened to determine their eligibility; of these, 200 subjects met the study criteria. Characteristics of the sample are shown in Table 2. A total of 175 subjects agreed to wear the StepWatch Activity Monitor, of whom 121 contributed data to the final analyses (Fig. 1). Data from the StepWatch Activity Monitor were available for 3–4 d. See the supplementary materials at http://www.rcjournal.com for the characteristics of those who contributed activity data.

Antibiotic Therapy

All subjects received antibiotic therapy consistent with antibiotic guidelines. Most participants received a β-lactam and a macrolide, although the individual agent varied depending on physician preference and a subject's allergies.

Variables Pertaining to Walking and Non-Walking Time

The average daily step count was median (IQR) 926 (457–1706). These steps were taken over 66 (41–121) min, which was equivalent to 9% (6–17) of a 12-h day. The number of transitions from non-walking time to walking time was 31 (20–46). The UBD_{WT} was 3 (2–4) min. The amount of time spent in each cadence band is reported in Table 3. The median 1-min peak cadence was 56 (43–74) steps/min.

During waking hours, the average non-walking time was 672 (639–691) min, which was equivalent to 93% (89–96) of waking hours. The number of transitions from walking time to non-walking time was 32 (21–47). The UBD_{NWT} was 85 (55–128) mins.

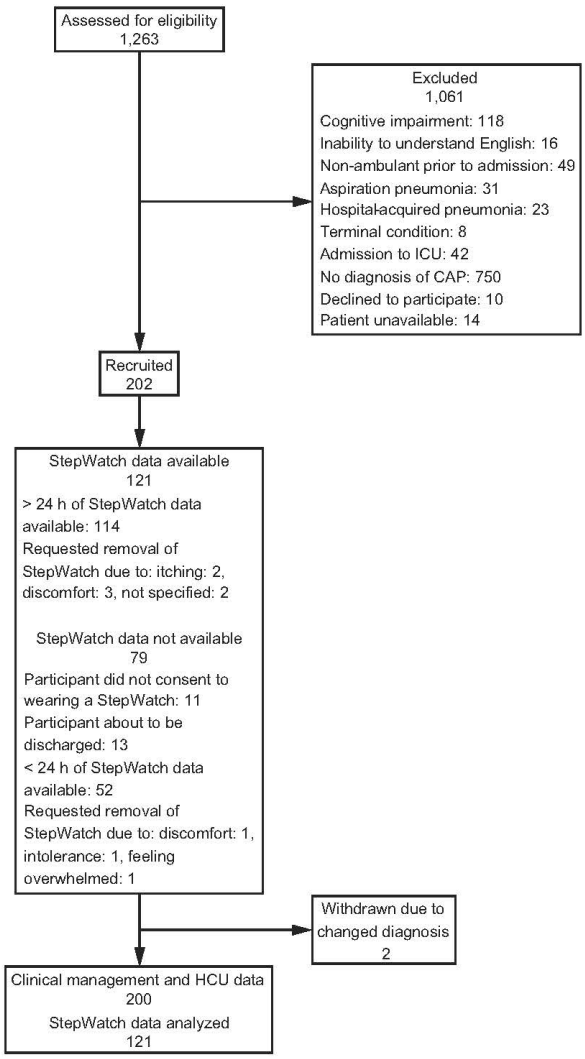

Fig. 1. Flow chart. CAP = community-acquired pneumonia; HCU = health care utilization.

Predictors of Daily Step Count, UBD_{WT}, and 1-min Peak Cadence

The results of the analyses that explored predictors of average daily step count are presented in Table 4. Briefly, in the univariate model, variables that influenced average daily step count were frailty, disease severity, and physiotherapy occasions of service. See the supplementary materials at http://www.rcjournal.com for the characteristics of subjects grouped according to these variables. In the multivariate model, only frailty was retained. Frailty was also found to be a significant predictor of UBD_{WT} ($r^2 = 0.17$, $P < .001$) and 1-min peak cadence ($r^2 = 0.05$, $P = .01$).

Table 2. Subject Characteristics

Age, y	66.8 ± 18.2
Male	129 (65)
Clinical Frailty Scale (scores 1–7)	3 (3–4)
CURB-65 (scores 0–5)	1 (1–2)
Presence of a pleural effusion	45 (23)
Total number of occasions of physiotherapy service	1 (1–4)
Use of new supplemental oxygen	116 (58)
Independent ambulation with or without a walking stick prior to admission	165 (83)
Ambulation with some form of assistance	34 (17)
Non (never)-smoker	68 (34)
Aboriginal or Torres Strait Islander	22 (11)
Presence of a chronic respiratory comorbid condition	80 (40)
Presence of a cardiovascular comorbid condition	129 (65)
Presence of a metabolic condition	86 (43)
Length of stay, d	4 (2–6)
30-d GP presentations (n = 144)	112 (78)
30-d ED presentations (n = 145)	20 (14)
30-d readmissions (n = 147)	22 (15)
30-d mortality (n = 151)	3 (2)

N = 200 subjects. Data are expressed as mean ± SD, median (IQR), or n (%).
CURB-65 = confusion, urea, respiratory rate (ie, breathing frequency), blood pressure, age ≥ 65 y
GP = general practitioner
ED = emergency department

Daily Step Count as a Predictor of Health Care Utilization

For every increase in average daily step count of 500 steps, LOS reduced by 11% (IRR 0.89, 95% CI 0.80–0.99, P = .037). There was no clear effect of an increase in average daily step count (by 500 steps) on 30-d readmission (IRR 1.12, 95% CI 0.80–1.56, P = .51).

Discussion

In this prospective, observational study, adults hospitalized with CAP had an average daily step count of 926 (457–1706) steps. These steps were accumulated over 66 (41–121) mins and in short bursts (ie, 3 (2–4) mins). A large proportion of waking hours were spent in non-walking time (93% (89–96)). A frailty score of ≥ 4 was identified as a predictor of lower daily step count (IRR 0.59, 95% CI 0.41–0.85). Further, greater average daily steps were associated with a reduced LOS (IRR 0.89, 95% CI 0.80–0.99).

Data reporting walking-based activity in adults who are hospitalized are scarce. Earlier work has shown that adults hospitalized with an exacerbation of COPD took an average of 602 steps/d (SD 610),[7] and older adults hospitalized with a general medical condition took an average of

Table 3. Time Spent in Each Cadence Band Expressed as Minutes and Percentage of Total 24-h Period

	Time Spent at 0 steps/min	Time Spent on Incidental Movement (0–19 steps/min)	Time Spent on Sporadic Movement (20–39 steps/min)	Time Spent on Purposeful Steps (40–59 steps/min)	Time Spent on Slow Walking (60–79 steps/min)	Time Spent on Medium Walking (80–99 steps/min)	Time Spent on Brisk Walking (100–119 steps/min)	Time Spent on All Faster Movement (≥ 120 steps/min)
Total	1,376 (1319–1399) min	48 (31–85) min	12 (6–22) min	2 (1–6) min	1 (0–3) min	0 (0–1) min	0 (0–0) min	0 (0–0) min
	96 (91–97) %	3 (2–6) %	1 (0–1) %	0 (0–0) %	0 (0–0) %	0 (0–0) %	0 (0–0) %	0 (0–0) %
Frailty score < 4	1,363 (1311–1390) min	55 (37–93) min	15 (8–24) min	3 (1–6) min	1 (0–5) min	0 (0–0) min	0 (0–0) min	0 (0–0) min
	95 (91–97) %	4 (2–6) %	1 (1–2) %	0 (0–0) %	0 (0–0) %	0 (0–0) %	0 (0–0) %	0 (0–0) %
Frailty score ≥ 4	1,392 (1364–1405) min	35 (29–63) min	7 (2–13) min	2 (0–5) min	1 (0–2) min	0 (0–0.03) min	0 (0–0) min	0 (0–0) min
	97 (95–98) %	2 (2–4) %	1 (0–1) %	0 (0–0) %	0 (0–0) %	0 (0–0) %	0 (0–0) %	0 (0–0) %

n = 117 subjects; Frailty score < 4: n = 69 subjects; Frailty score ≥ 4: n = 48 subjects. Data are expressed as median (IQR).

Table 4. Negative Binomial Regression

Variable	Direction of Relationship Based on IRR	IRR (95% CI)	*P*
Univariate analysis			
Age	Fewer steps in those with greater age	0.98 (0.97–1.00)	< .001
Disease severity	Fewer steps in those with more severe disease	0.65 (0.46–0.94)	.02
Clinical frailty	Fewer steps in those with frailty score ≥ 4	0.56 (0.39–0.81)	< .002
Oxygen	Fewer steps in those who received oxygen	0.71 (0.49–1.04)	.08
NIV	Fewer steps in those who received NIV	0.84 (0.49–1.40)	.52
Pleural effusion	Fewer steps in those with a pleural effusion	0.80 (0.53–1.19)	.29
ICC	Fewer steps in those without an ICC	1.51 (0.70–3.24)	.29
POS	Fewer steps in those who received more POS	0.64 (0.44–0.92)	.02
Multivariable analysis*			
Disease severity	Fewer steps in those with more severe disease	0.70 (0.49–1.00)	.060
Clinical frailty	Fewer steps in those with frailty score ≥ 4	0.59 (0.41–0.85)	< .003

*Final multivariable model using the variables that significantly influenced daily steps in the univariate model.
IRR = incident rate ratio
NIV = noninvasive ventilation
ICC = intercostal catheter
POS = physiotherapy occasions of service

764 steps/d (SD 706).[8] Our data reveal a slightly higher average daily step count of 926 (IQR 1,249) steps in adult subjects hospitalized with CAP. This difference does not relate to the sensitivity of the monitors because validated accelerometers were used in all 3 studies.[13,25] It is possible that, in the study conducted in adults with a general medical condition, the older age of the sample (ie, 77 ± 7 y), contributed to the lower average daily step count report.[8] It has been well established that participation in physical activity decreases with advancing age.[26] In the study conducted in adults with a COPD exacerbation, lower step count was unrelated to differences in the age or time spent walking, expressed as a percentage of a 12-h day, both of which were remarkably similar between the 2 studies.[7]

It seems that the lower number of steps reported in the study of people hospitalized with an exacerbation of COPD was due to the subjects adopting a slower average cadence during periods of waking, which possibly reflects the chronicity of their condition.[7] Nevertheless, it is worth noting that the 1-min peak cadence reported in our study (ie, 56 [31] steps/min) was considerably lower than that reported in a large sample of community-dwelling older adults aged ≥ 70 y (ie, 82 steps/min, 95% CI 79–84)[27] and those with metabolic syndrome (103 ± 13 steps/min).[28] Further, our study also demonstrated that the little time spent in walking-based activity was at slow walking speeds (see Table 3). The time spent in medium walking in our study (0 [1] min) was even less in comparison to the time spent in medium walking in male adults with stable COPD (5 ± 4 mins).[29]

Our data show that walking in adult subjects hospitalized with CAP was accumulated in very short bouts. This is notable because the subjects included in these analyses received, on average, 2 (3) occasions of service by a physiotherapist. This highlights the need for a multidisciplinary approach to facilitate and encourage participation in physical activity on the ward.

Our study identified frailty as a significant predictor of daily step count ($P < .01$), UBD_{WT} ($P < .001$), and 1-min peak cadence ($P = .01$). In several clinical populations, there is increasing recognition that frailty is a predictor of poor health outcomes. Specifically, after hospital discharge for a COPD exacerbation, subjects classified as severely frail had higher odds of being readmitted to hospital within 90 d of discharge compared with those classified as not frail (odds ratio 5.19, 95% CI 1.26–21.50).[30] Our study extends the results of this earlier work by showing that frailty is a predictor of daily step count, UBD_{WT}, and 1-min peak cadence in subjects hospitalized with CAP. That is, frailty influences not only daily steps, but also the way in which walking time is accumulated on the ward and the intensity at which walking is undertaken. Given that daily step count was a predictor of LOS, patients who present with moderate to severe clinical frailty should be targeted with a walking-based exercise program.

This study was also able to explore non-walking time and the way in which it is accumulated, expressed as UBD_{NWT}, in adult subjects during a hospital admission. In the general population, there are now robust data demonstrating the deleterious health consequences associated with sedentary time, especially sedentary time that is accumulated in prolonged uninterrupted bouts,[31] and increased recognition that reducing sedentary time is a separate lifestyle goal to increasing participation in physical activity.[32-35]

Our study indicates that, during hospitalization, adults are inactive for almost all of their waking hours (total non-walking time 673 (52) min, 93% (4%) of waking hours) and accumulate this time in prolonged bouts (UBD_{NWT} 85 [73] min). Although there is a paucity of data in other hospitalized populations, subjects in our study were less active than previously described in adults with stable COPD (total sedentary time 493 min [383 to 629] minutes, 68% of waking hours).[36] Of note, the UBD_{NWT} in our subjects was 3 times longer than that reported in office workers (ie, usual bout duration 27 [19] min).[37] Taken together, both the large proportion of waking time spent in non-walking time coupled with the fact that it is accumulated in prolonged uninterrupted bouts makes this behavior a potential target for in-patient rehabilitation.

Strengths and Limitations

Although this study has provided objective measurements of walking and non-walking time in adult subjects hospitalized with CAP, we could not specifically report on sedentary time. This is because the StepWatch Activity Monitor cannot separate standing, which is a light-intensity physical activity, from sitting and lying down, which are sedentary behaviors. Accelerometers combined with inclinometers would provide greater clarity in separating standing from sitting and laying down and allow data to be extracted on sedentary time.[38-40]

Conclusions

This prospective, observational study is the first to describe walking-based activity in a large sample of adult subjects hospitalized with CAP. Similar to other hospitalized populations, adults hospitalized with CAP do very little walking, in very short bouts at low intensity. Just over 90% of waking hours are spent in mostly uninterrupted non-walking time. During the period of hospitalization when a patient is acutely unwell, it can be challenging to implement an exercise training program. Strategies to increase light-intensity physical activity and interrupt sedentary time may be more feasible. This requires further investigation.

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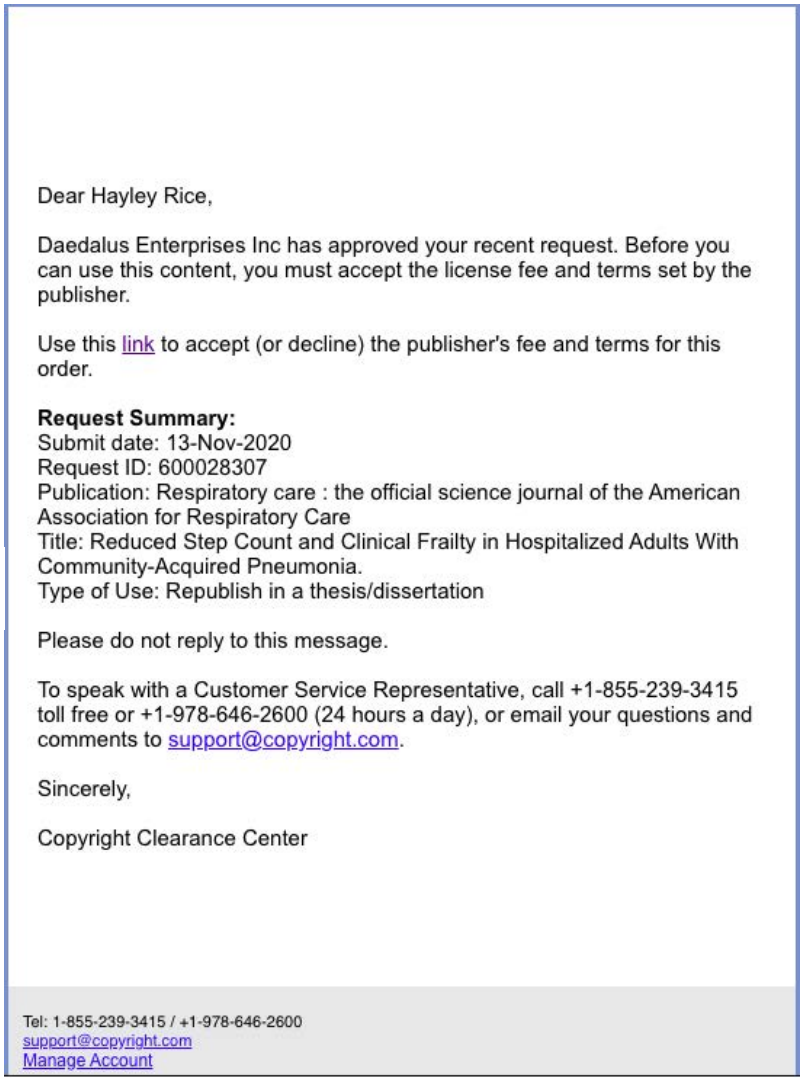

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Appendix 9: Participants grouped according to frailty

Variable	'Frailty score < 4' n = 124	'Frailty score ≥ 4' n = 76	p value
Age (yr)	59 ± 17	79 ± 12	< 0.01*
Aboriginal or Torres Strait Islander	16 (13)	6 (8)	0.36
Average daily step count (n = 121)	1,201 [714 to 2069]	516 [262 to 1,013]	0.14
CURB-65 score (scores 0 to 5)	1 [0 to 2]	2 [1 to 2]	0.12
ED presentations within 30-days of discharge (n = 146)	9 (10)	12 (21)	0.35
GP presentations within 30-days of discharge (n = 144)	65 (76)	47 (81)	0.29
Inpatient mortality	0 (0)	4 (5)	< 0.01*
LOS (days)	3 [2 to 5]	5 [3 to 8]	< 0.01*
Males	89 (72)	40 (53)	0.01*
Mortality within 30-days of discharge (n = 197)	0 (0)	3 (4)	< 0.01*
Non (never)-smoker	41 (33)	27 (36)	0.43
Previous independent ambulation with or without a walking stick	122 (98)	43 (57)	< 0.01*
Readmissions within 30-days of discharge (n = 146)	8 (9)	13 (22)	< 0.01*

Data are expressed as mean ± SD, median [IQR] or n (%). CURB-65, Confusion, Urea, Respiratory rate, Blood pressure, Age ≥ 65 score; ED: Emergency Department; GP: general practitioner; IQR: interquartile range; LOS: length of stay; SD: standard deviation.

Appendix 10: Author contribution statement

Rice H, Hill K, Fowler R, Watson C, Waterer G, Harrold M. Reduced step count and clinical frailty in hospitalized adults with community-acquired pneumonia. *Respir Care* 2019; 65: 455-463.

Conception and Design	**Acquisition of Data and Method**	**Data Conditioning/ Manipulation**	**Analysis and Statistical Method**	**Interpretation and Discussion**	**Final Approval**	**Total % contribution**
Co-Author 1: Hayley Rice	✓	✓	✓	✓	✓	28%
Co-Author 1 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Co-Author 2: Kylie Hill	✓	✓	✓	✓	✓	20%
Co-Author 2 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Co-Author 3: Robin Fowler	✓				✓	17%
Co-Author 3 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Co-Author 4: Carol Watson	✓				✓	10%
Co-Author 4 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Co-Author 5: Grant Waterer	✓				✓	10%
Co-Author 5 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Co-Author 6: Meg Harrold	✓	✓			✓	15%
Co-Author 6 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Total %						**100%**

Rice H, Harrold M, Fowler R, Watson C, Waterer G, Hill K. Exercise training for adults hospitalized with an acute respiratory condition: a systematic scoping review. *Clin Rehabil* 2020; 34(1): 45-55.

Conception and Design	**Acquisition of Data and Method**	**Data Conditioning/ Manipulation**	**Analysis and Statistical Method**	**Interpretation and Discussion**	**Final Approval**	**Total % contribution**
Co-Author 1: Hayley Rice	✓	✓	✓	✓	✓	29%
Co-Author 1 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Co-Author 2: Meg Harrold	✓	✓		✓	✓	15%
Co-Author 2 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Co-Author 3: Robin Fowler	✓	✓			✓	16%
Co-Author 3 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Co-Author 4: Carol Watson		✓			✓	10%
Co-Author 4 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Co-Author 5: Grant Waterer					✓	10%
Co-Author 5 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Co-Author 6: Kylie Hill	✓	✓	✓	✓	✓	20%
Co-Author 6 Acknowledgment: I acknowledge that these represent my contribution to the above research output Signed:						
Total %						**100%**