Bond University

DOCTORAL THESIS

Gait performance and the benefits of exercise in adults living in residential aged care.

Fien, Samantha

Award date:
2018

PhD Thesis

by

Samantha Fien

Gait Performance and the Benefits of Exercise in Adults Living in Residential Aged Care

Submitted in total fulfilment of the requirements of the degree of Doctor of Philosophy by Research

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Faculty of Health Sciences and Medicine

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Dr. Justin Keogh

Dr. Mike Climstein

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ABSTRACT

Despite significant advances in our understanding of the biomechanical factors influencing gait performance in community-dwelling older adults, very little of this type of research has been conducted in residential aged care (RAC) adults. A similar view can be taken regarding our understanding regarding the benefits and feasibility of progressive resistance and balance training exercise programmes, particularly within the RAC setting.

The primary purpose of this *Thesis* was to characterise and describe the spatio-temporal parameters of gait performance and benefits of exercise for Australian adults living in RAC. This was completed through a systematic programme of literature reviews, and clinical studies that accounted for the limitations of the extant literature and current gaps in the knowledge.

The first study (1) (**Chapter Four**) investigated gait speed characteristics and spatio-temporal parameters in the RAC setting and gained insight into whether these parameters may predict gait performance. This study revealed step time, stride length and support base as highly predictive of gait speed in adults living within RAC.

The second study (2) (**Chapter Five**) prospectively investigated the incidence of adverse events in 100 adults living in RAC over a period of six-months. The secondary aim was to determine if gait speed thresholds could predict the frequency of falls in adults living in RAC. A total of 226 falls, 243 wounds, 65 hospital admissions and 29 deaths occurred during the six-month period. The following variables were identified as increasing the risk of falling among adults living in RAC: hospital admissions, wounds, handgrip strength, female residents and scoring a positive (increased) impairment on the Mini-Cog. None of the gait speed thresholds predicted falls in adults living in RAC.

In the third study (3) (**Chapter Six**), the feasibility of a 12-week exercise programme (GrACE) was assessed in a RAC setting with the secondary objective of measuring the programme's benefits on gait speed, sit to stand performance and handgrip strength. The pre-existing community-dwelling programme, which was modified for adults living in RAC, consisted of progressive weight-bearing exercise combined with resistance training. Results indicated that it was feasible, safe and effective in improving muscle function, including gait speed in adults living in RAC.

The final study (**Chapter Seven**) was a 24-week exercise programme (GrACE+GAIT) that assessed the benefits and determined if the programme would be feasible and sustainable in the RAC setting. This exercise programme was a combination of progressive resistance and specific gait exercises. Total adherence rate was 79.3% with 65% of exercise participants attending ≥70% sessions, 100% of those originally enrolled completed the programme and strongly agreed with the programme acceptability. Zero adverse events relating to the exercise programme were reported.

In summary, the results of this thesis demonstrated that: 1) Adults living in RAC have spatio-temporal parameters associated with low gait speed and the associated risk of falling for residents; and 2) that progressive resistance training is safe and feasible, and results in significant improvements in muscle function, including gait speed.

Future studies should explore gait performance and exercise programmes in a wider variety of adults living in RAC and assess the feasibility and benefits of a range of exercise programmes in this setting.

KEYWORDS

Age, Ageing, Acceptability, Adverse events, Feasibility, Muscle function, Physical activity, Sustainability, Walking

DECLARATION

This thesis is submitted to Bond University in fulfilment of the requirements of the degree of Doctor of Philosophy by Research.

I declare that the research presented within this thesis is a product of my own original ideas and work, and contains no material which has previously been submitted for a degree at this university or any other institution, except where due acknowledgement has been made.

Name: Samantha Fien

Signature: 

Date: 02/03/2018

ACKNOWLEDGEMENTS

While my name may be on the front cover of this PhD Thesis, I am by no means its only contributor. I wish to express my sincere appreciation to those who have contributed to this thesis and supported me in one way or other during this amazing rollercoaster ride.

I would like to thank my supervisors – Associate Professor Justin Keogh, Dr. Mike Climstein and Dr. Timothy Henwood – for their patience, guidance, encouragement and advice provided throughout my time as their student. I remain amazed that despite busy schedules, you were all able to respond to my questions and queries so promptly as well as provide invaluable insights and suggestions. In addition, you have all generously shared your passion for ageing as well as given me insights that have helped me at various stages of my research, which are to the great benefit of this thesis. I have been extremely lucky to have supervisors who cared so much about my work and me as a researcher. Thank you for making me more than what I thought I would be. As a team, you have all worked tirelessly to instil great confidence in both my work and myself. I am very proud of what we have achieved together, thank you sincerely.

I would also like to thank all members of the Bond University community who helped me during my degree, especially the friends I have made along the way. Completing this work would have been all the more difficult were it not for the support provided by Bond University. I am indebted to them for their help. In particular, I would like to thank Evelyne Rathbone for teaching me statistical analysis.

A heartfelt thanks to the aged care facilities, in particular the aged care residents who are truly inspirational, for allowing data collection and exercise interventions to be conducted. It has been an absolute privilege to research such a fascinating and exciting area.

I would also like to take this opportunity to thank the Cardiac Centre, for allowing me to pursue further education and being supportive and flexible with university.

Special thanks are also due to my Surf Life Saving family for their amazing support but for also being there when I needed assistance.

To all the wonderful people whom I have not mentioned there is not enough paper or words to say how truly thankful I am.

Finally, I would like to acknowledge the most important people in my life. My family. Words cannot express the feelings I have for my parents – Ray and Donna and my sisters – Taylor, Claudia and Olivia, for their constant unconditional love and support. To my Grandma and Nana, thank you for helping me keep things in perspective and showing me that love always prevail.

In loving memory of my Grandpa and Pop.

Publications

(i) Published - journal

1. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (2017). Gait speed characteristics and its spatio-temporal determinants in nursing home residents: a cross-sectional study. Journal of Geriatric Physical Therapy. Impact factor = 1.8, ranked 39th of 49 in Geriatrics & Gerontology and 31st of 65 in Rehabilitation. DOI: 10.1519/JPT.0000000000000160.

2. Fien, S., Climstein M., Henwood, T., Rathbone, E., & Keogh, J. W. L. (2017). Gait speed and adverse events in nursing home residents: a prospective cohort study. The Journal of Nursing Home Research Sciences (JHRS), 3: 81-87. DOI: 10.14283/jnhrs.2017.13.

3. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (2016). Feasibility and benefits of group-based exercise in residential aged care adults: a pilot study for the GrACE programme. PeerJ, 4, e2018. Impact factor = 2.2, ranked 14th of 63 in Multidisciplinary Sciences. DOI: 10.7717/peerj.2018.

4. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (2016). Clinical importance of assessing walking speed of older adults in general practice. Australian Family Physician, 45(4), 250-251. Impact factor = 0.759, ranked 106th of 151 in Medicine General & Internal.

5. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (2015). Pumping iron in residential aged adults: Why isn't this more commonly available? Australasian Journal on Ageing, 34(3), 201-202. Impact factor = 0.667, ranked 25th of 32 in Geriatrics and Gerontology.

(ii) Submitted for publication

1. Fien, S., Climstein M., Henwood, T., Rathbone, E., & Keogh, J. W. L. (Submitted). Exploring the feasibility and benefits of the GrACE+GAIT exercise programme in the nursing home setting. Archives of Physical Medicine and Rehabilitation.

(III) PUBLISHED - CONFERENCE

(III. A) PODIUM

1. Fien, S., Climstein, M., Henwood, T., Rathbone, E., & Keogh, J.W.L. (28-30th November 2017). The number game of adverse events in residential aged care facilities. Oral presentation at the Gold Coast Health Research Week Conference, Gold Coast, (Queensland, Australia).

2. Fien, S., Henwood, T., Climstein, M., Rathbone, E., & Keogh, J.W.L. (8-10th November 2017). How falls, wounds and hospitalisation are affecting nursing home residents. Rapid fire presentation at the 50th Annual Australian Association of Gerontology Conference Crown, Perth, (Western Australia, Australia).

3. Fien, S., Climstein, M., Henwood, T., Rathbone, E., & Keogh, J.W.L. (8-10th November 2017). The Golden Opportunity: Walking. Tabletop conversation at the 50th Annual Australian Association of Gerontology Conference Crown, Perth, (Western Australia, Australia).

4. Fien, S., Climstein, M., Henwood, T., Rathbone, E., & Keogh, J. W. L. (6-7th November 2017). Adverse events and gait speed in nursing home residents. Oral presentation at the 16th National Conference of Emerging Researchers in Ageing Conference Perth, (Western Australia, Australia).

5. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (31st-1st October/November 2016). Making strides in aged care. Rapid fire presentation at the 15th National Conference of Emerging Researchers in Ageing Conference Canberra, (Australian Capital Territory, Australia).

6. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (31st-1st October/November 2016). You're never too old to walk. Oral presentation at the 15th National Conference of Emerging Researchers in Ageing Conference Canberra, (Australian Capital Territory, Australia).

7. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (12th October 2016). You are never too old to walk. Oral presentation at the 2nd Bond University HDR Student Led Conference Gold Coast, (Queensland, Australia).

8. Fien, S., Climstein, M., Henwood, T., Grigg, J., & Keogh, J. W.L. (23rd November 2015). Feasibility and benefits of pumping iron for residential aged care adults. Oral presentation at the AAG Student and Early Career Researchers Brisbane, (Queensland, Australia).

9. Fien, S., Keogh, J. W. L., Henwood, T., & Climstein, M. (3rd-4th December 2015). Gait Characteristics and Muscle Function in Residential Aged Care Adults Oral presentation at the 2015 Gold Coast Health and Medical Research Conference Gold Coast, (Queensland, Australia).

10. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (18th November 2015). Feasibility and benefits of pumping iron for residential aged care adults. Oral presentation at the Inaugural Bond University HDR Student Led Conference Gold Coast, (Queensland, Australia).

(III. B) POSTER

1. Fien, S., Henwood, T., Climstein, M., Rathbone, E., & Keogh, J.W.L. (8-10th November 2017). How falls, wounds and hospitalisation are affecting nursing home residents. Poster presented at the 50th Annual Australian Association of Gerontology Conference Crown, Perth, (Western Australia, Australia).

2. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (27-29th April 2017). Gait characteristics and physical outcomes in nursing home residents. Poster presented at the International Conference on Frailty and Sarcopenia Research (Barcelona, Spain).

3. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (27-29th April 2017). Gait speed and the spatio-temporal determinants of residents in nursing homes. Poster presented at the International Conference on Frailty and Sarcopenia Research (Barcelona, Spain).

4. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (27-29th April 2017). Gait speed and sarcopenia. Poster presented at the International Conference on Frailty and Sarcopenia Research (Barcelona, Spain).

5. Keogh, J. W. L., Henwood, T., Senior, H., & **Fien, S.** (11-12th November 2016). Prevalence, predictors and benefits of resistance training for improving gait speed in aged care. Poster presented at the 1st Australia and New Zealand Conference on Sarcopenia and Frailty Research Melbourne, (Victoria, Australia).

6. Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (31st-1st October/November 2016). Making strides in aged care. Poster presented at the 15th National Conference of Emerging Researchers in Ageing Conference Canberra, (Australian Capital Territory, Australia).

7. Keogh, J.W.L., **Fien, S.,** Climstein, M., & Henwood, T. (28th-1st June/July 2016). Prediction of gait speed by spatio-temporal parameters in residential aged care residents. Poster presented at the World Congress Active Ageing Conference Melbourne, (Victoria, Australia).

8. Fien, S., Keogh, J. W. L., Henwood, T., & Climstein, M. (4-6th November 2015). Pumping iron in residential aged care: feasibility and preliminary efficacy. Poster presented at the 48th Annual Australian Association of Gerontology Conference Alice Springs Convention Centre, Alice Springs (Northern Territory, Australia).

(IV) INVITED PRESENTATIONS

Bond University Sports and Exercise Science Faculty Seminar Series (20th September 2017) – Guest speaker whereby I presented research on the topics "Adverse Events in Residential Aged Care" and an "International Research Exchange to Ireland".

(V) Relevant prizes and awards

- ERA Travel Exchange 2017

I was awarded the International Travel Exchange scholarship from the Emerging Researchers in Ageing (ERA) initiative "ERA Exchange" with additional support of the Australian Research Council - Centre of Excellence in Population Ageing Research (CEPAR).

I travelled to Barcelona (Appendix 7) where I presented three posters at the International Conference on Sarcopenia and Frailty Research. I continued onto Dublin (Ireland) where I attended University College Dublin (UCD) for seven weeks in a research exchange under the supervision of Dr. Catherine Blake. Further information about the experience is included in Appendix 7.

(VI) Media

I was granted the opportunity in 2015 by Bond University Learning and Teaching Department to develop a short film clip about my research topic. I was able to describe my research and give an insight into what area I would be focusing on. This clip can be viewed on the following link:

https://www.youtube.com/watch?v=Y5GpmFc9s-I.

(VII) CONTRIBUTION TO THESIS

Paper 1 - Gait speed characteristics and its spatio-temporal determinants in nursing home residents: a cross-sectional study (CHAPTER 4)					
Authors	Concept & Design	Data Collection	Data Analysis	Drafting of Manuscript	Critical Revision
Samantha Fien	55	100	90	70	10
Justin Keogh	25	-	-	10	40
Mike Climstein	10	-	-	10	20
Timothy Henwood	10	-	-	5	20
Evelyne Rathbone	-	-	10	5	10

Paper 2 - Gait speed and adverse events in nursing home residents: a prospective cohort study (CHAPTER 5)					
Authors	Concept & Design	Data Collection	Data Analysis	Drafting of Manuscript	Critical Revision
Samantha Fien	60	100	80	70	40
Justin Keogh	20	-	-	10	15
Mike Climstein	10	-	-	5	15
Timothy Henwood	10	-	-	5	15
Evelyne Rathbone	-	-	20	10	15

Paper 3 - Feasibility and benefits of group-based exercise in residential aged care adults: a pilot study for the GrACE programme (CHAPTER 6)					
Authors	Concept & Design	Data Collection	Data Analysis	Drafting of Manuscript	Critical Revision
Samantha Fien	55	100	95	70	10
Justin Keogh	15	-	-	5	30
Mike Climstein	5	-	-	5	25
Timothy Henwood	25	-	-	15	40
Evelyne Rathbone	-	-	5	5	5

Paper 4 – Exploring the feasibility and benefits of the GrACE+GAIT exercise programme in the nursing home setting (CHAPTER 7)					
Authors	Concept & Design	Data Collection	Data Analysis	Drafting of Manuscript	Critical Revision
Samantha Fien	65	100	80	70	10
Justin Keogh	15	-	-	10	25
Mike Climstein	5	-	-	5	25
Timothy Henwood	15	-	-	5	25
Evelyne Rathbone	-	-	20	10	15

ETHICS DECLARATION

The research associated with this thesis received ethics approval from Bond University Human Research Ethics Committee, under reference number RO 1823 and the relevant gatekeepers in the residential aged care facilities involved in the research studies.

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ABBREVIATIONS

Abbreviations included in this thesis are listed below.

3D: Three-Dimensional

ADL: Activities of Daily Living

ANCOVA: Analysis of covariance

ANOVA: Analysis of variance

BIA: Bioelectrical Impedance Analysis

BMI: Body mass index

CI: Confidence interval

EWGSOP: European Working Group on Sarcopenia in Older People

Ft: feet

GrACE: Group Aged Care Exercise

GS: Gait speed

ICC: Intraclass Correlation Coefficient

IRR: Incidence Rate Ratio

Kg: kilogram

m: metres

Mini-Cog: Mini-Cognitive test

MMSE: Mini-Mental State Examination

m/s: metres/second

no.: number

OR: Odds Ratio

RAC: Residential Aged Care

RCOF: Required Coefficient of Friction

RCT: Randomised Controlled Trial

s: seconds

SARC-F: Sarcopenia Five-Item Questionnaire

SD: Standard Deviation

yrs: years

Chapter 1

Introduction

1.1 Rationale

Ageing is associated with a general decline in physical and cognitive wellbeing that often leads to poor health, increased dependency and decreased quality of life (4, 5). The number of adults using aged care services has increased over the last 10 years in Australia. Whilst home care has seen the greatest growth in users, permanent residential aged care (RAC) still accounts for the highest percentage of adults requiring care (6). This can also be seen in Figure 1-1, where the purple represents the number of Australian adults accessing permanent residential aged care and the green represents home care. As of 30th June 2017, 178,713 adults were using permanent residential aged care services in Australia (7). RAC in Australia is defined by the Commonwealth Government under the "Aged Care Act 1997" as providing a range of care options and accommodation for older people who are unable to continue living independently in their own homes (6). The target population for aged care services are older adults aged 65 years and over (Indigenous adults aged 50 years and older) with the use of aged care (48 per 1,000 older adults) being much higher than that of home care (17 per 1,000 older adults) (7). Due to population ageing and the associated increase in complex health care needs, the demand for aged care placement in Australia is predicted to treble by 2050 (8). Consequently, the impending care needs and health care expenditure will also increase dramatically (9).

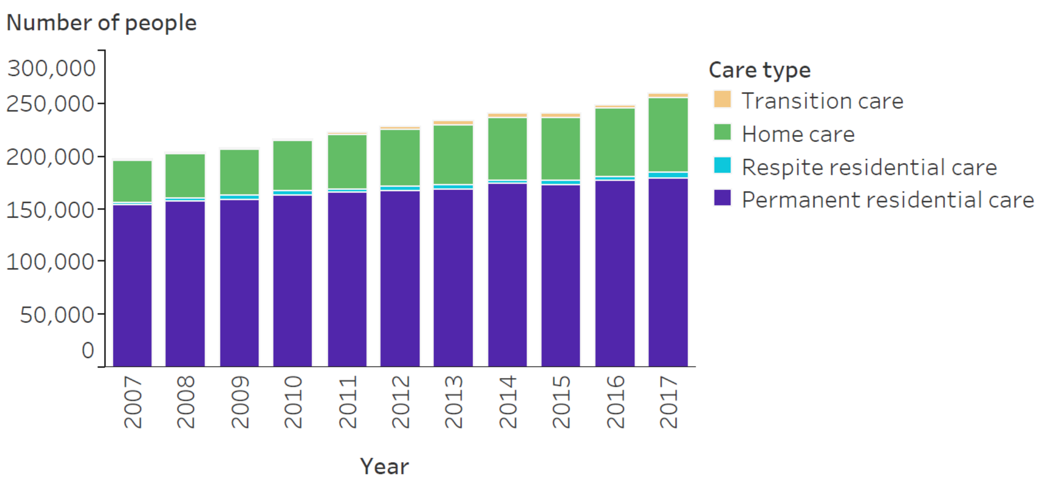

Figure 1-1. People using aged care services, by care type, 30 June 2007-2017 (6).

The physical decline of gait speed in adults living in RAC may reflect the process of sarcopenia, which is defined by the European Working Group Sarcopenia in Older People (EWGSOP) as '"the progressive and generalised loss of skeletal muscle mass, muscle strength and muscle function" (5). Sarcopenia is a significant precursor to RAC transition due to a decrease in muscle strength, loss of stamina and low gait speed (10). Moreover, RAC entry itself is assumed to significantly slow the gait speed of older adults (11, 12). Gait speed can be defined as the distance walked (metres) divided by the time taken (seconds) (13). Spatio-temporal gait parameters contain the following key variables: step length, step rate, step width (referred to as support base within this thesis), ground contact time, double support time and swing time *(14)*.

Admission into a RAC facility is also related to many adverse events including falls, wounds and hospitalisation that may result in reduced quality of life, and contribute to higher risks of disability and death in RAC facilities (15). These adverse events are often very costly, with falls being one of the leading causes of injury-related hospitalisation in older adults (16). As a result of the population ageing, the higher number of older adults living in RAC and the increasing trend in sarcopenia, the cost of falls is expected to rise to $1.4 billion in Australia by 2051 (6).

Health professionals are increasingly viewing regular exercise as a key behavioural ingredient in reducing the risk of illness, but most importantly, increasing mobility and reducing disability in older adults (17). Many health promotion advocates also emphasize the economic benefits of exercise, with resistance and balance training becoming apparent for older adults at risk of sarcopenia and adverse events (18, 19).

Ironically, residents of RAC facilities are among the least researched older adult group even though they have the highest rates for falls and hospital admissions and are among the highest consumers for prescribed medications (20). Although research has been reported in community-dwelling older adults (21-23) (22, 24), to the author's knowledge, little research has investigated the incidence of adverse events specific to falls, wounds and hospital admissions in Australian adults living in RAC, or whether spatio-temporal gait characteristics predict gait speed in this population.

This thesis hypothesises that a range of spatio-temporal parameters may predict gait speed in adults living in RAC. For this population, the identification of specific spatio-temporal parameters that determine gait speed, could then inform targeted exercise programmes to promote gait performance.

Exercise, in particular, resistance combined with weight-bearing training programmes appear to show promise in reducing entry into, and the adverse events associated with residing in RAC (25). To the author's knowledge, there is a relative lack of research quantifying the feasibility of this form of exercise in this setting (26). To create a robust research translation culture in aged care facilities, more studies investigating the feasibility (in particular, acceptability and sustainability) of exercise programmes need to be conducted for findings to become practice and influence the aged care sector.

A possible exception to the lack of demonstrated feasibility and research translation is an exercise programme which was targeted at respite care older adults in Australia (27). Older adults accessing respite care are unable to completely care for themselves due to the adverse effects of ageing, chronic disease, physical and/or cognitive disability (27). The programme consisted of seated progressive resistance and weight-bearing exercises twice a week, focusing on non-resisted upper- and lower-body dynamic and reaching movements. The value of the programme was acknowledged by the provider who supplied the trial respite site, resulting in the programme being rolled out across the state to over 40 respite centres (27). However, it is yet to be trialled amongst adults living in RAC. Given the demonstrated uptake of this exercise programme by a low functioning older adult population at risk of entry into RAC, it was hypothesised that the Group Aged Care Exercise (GrACE) programme would exhibit similar levels of feasibility and benefits in the RAC setting (27). In order to counteract the effects of reduced gait speed and altered spatio-temporal parameters, progressive resistance exercise programmes was investigated in adults living in RAC. The outlook of feasibility (acceptability and sustainability) was examined through the adoption of long-term regular exercise programmes (12 and 24 weeks) for residents of RAC to maintain physical performance.

In summary, this thesis addresses an understudied population cohort with the aim to accurately identify the spatio-temporal parameters of gait speed in a RAC setting; determine if gait speed and the spatio-temporal parameters may predict adverse events; and examine how exercise may influence these gait parameters.

1.2 STRUCTURE OF THESIS

A series of studies were designed and conducted to address some of the gaps in literature identified in the previous section. The overall structure of the thesis is shown in Figure 1-1. The first section comprises two literature reviews, which provide background on gait performance and adverse events in RAC (**Chapter Two**) and the benefits and feasibility of exercise in this setting (**Chapter Three**). These reviews were followed by a cross-sectional study conducted to characterise gait speed and spatio-temporal parameters of gait (**Chapter Four**) and a prospective cohort design used to estimate the incidence and types of adverse events including falls, hospital admissions, wounds and deaths (**Chapter Five**). Building on the findings of the first four chapters, the first intervention study (**Chapter Six**) examined the feasibility and acceptability of a 12-week exercise intervention in the aged care setting. The second intervention study (**Chapter Seven**) assessed the benefits of a 24-week supervised exercise intervention. As well as the sustainability of an intervention that was designed to further improve the positive transfer of training to improving gait speed in the RAC setting. Finally, **Chapter Eight** includes a summary of the thesis, practical applications, limitations and future directions for research in this field.

Figure 1-2. Thesis overview.

1.3 COMPLEXITY OF CONDUCTING RESEARCH IN RAC SETTINGS

The complexity of conducting research in RAC settings is due to a variety of factors and requires a certain degree of knowledge, a greater understanding and a high level of care and communication when collecting data with older adults (28). The process from development through to implementation may take a wide range of different forms (28). Figure 1-3 summarises the main stages and key functions/activities that occur at each stage.

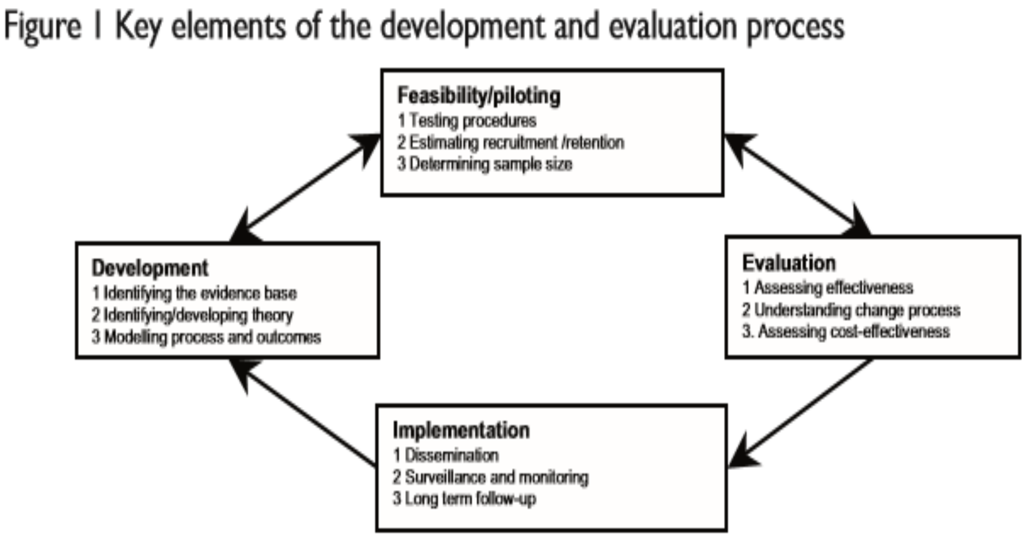

Figure 1-3. Key elements of the development and evaluation process (28).

There are specific features and variables that are important for research to be effective for adults residing in RAC settings. These can be classified, but are not limited to, the following which have been adapted from The Royal Australian College of General Practitioners Curriculum 2011 Statement (29):

- The complexity of diagnosing and managing adults living in RAC (Table 1-1)
- Requirements of health care professionals when working in RAC (Table 1-2)

Providing care for older adults living in a RAC setting is complex and challenging as each resident faces a different kind of risk, management level and requirement of professional health care (29), which can change at any time. It is a process that needs to be considered carefully to ensure the highest level of care and service is delivered.

Table 1-1. The complexity of diagnosing and managing adults living in RAC (29).

Variables featured when diagnosing and managing adults living in RAC	
• Symptom with no clearly identifiable aetiology	• Impact of ageing on people with pre-existing conditions, particularly intellectual impairment, mental illness or physical disabilities
• Altered patient presentations	• Difficulties in cognition and communication
• Multiple pathologies	• Multisystem disease that often involves chronic disease management
• Problems of polypharmacy	• Decreased reserves (physiological, psychological, financial)
• The importance of functional assessment and support (e.g. walking stick/assisted devices)	• Sensory deficits such as impaired vision, hearing and balance
• Nutrition, physical activity, continence and pain	• Relationship with guardians, relatives and other health professionals

Table 1-2. Requirements of health care professionals when working in RAC settings (29).

Requirements of health care professionals working in RAC settings	
• Positive attitudes toward empowering elderly patients to take an active part in maintaining their health	• The ability to deal with and prioritise the numerous comorbidities or challenging behaviours of the older client
• Feeling comfortable when working with the aged, their families, carers, healthcare teams and friends	• The ability to work within multidisciplinary healthcare teams
• The need to be aware of resources	• Continuity of care
• A certain level of education and training	

In addition to Table 1-1 and Table 1-2, there are also many other complex factors affecting adults living in RAC that need to be addressed. The following have been adapted from (29):

- Cultural and linguistic diversity, socioeconomic status, gender, family and community supports, and geographical location may affect the needs, acceptance and availability of services and activities for the aged.
- Cultural differences, perceptions and expectations of ageing may affect levels of carer responsibility and involvement.
- Informed consent may be impaired due to cognitive impairments and the care of adults living in RAC may involve multiple carers, issues of power of attorney and regulatory administrative bodies such as guardianship boards. This includes discussing, formulating and documenting advanced care plans and decisions concerning the end-of-life.
- Older adults are especially at risk of adverse patient safety outcomes, especially in relation to the inappropriate use of physical or medication

induced restraint, missed diagnoses due to failure to evaluate vague or unclearly expressed symptoms, and failure to understand instructions.

- Special issues, such as those relating to sexuality and discrimination, may affect the needs, acceptance and availability of services and activities for the aged.

Failure to address these features, variables and factors could result in that a range of adverse events occur at any stage or time (30). These include, but are not limited to:

- Incident of falls
- Hospital admission
- Wounds/skin tears
- Death
- Drug errors
- Treatment errors
- Misdiagnosis
- Epidemics
- Staff injuries

Due to the complexity involved in collecting data and the limited research currently being conducted, the importance of valid and reliable data collection is pivotal in the translation care of adults living in RAC facilities (30)and as such the research must be objective, valid and reliable. Consequently, the research conducted for this thesis attempted to maximise the validity and reliability of the research findings, while also navigating many of the challenges of research in the RAC sector that may make it difficult to always utilise ideal research designs such as randomised controlled trials due to perceptions that the facility manager and staff may have of their residents. The stages of research can be seen in Figure 1-4.

1.4 Research conducted

Stage 1

Data collected in two Northern NSW and two Queensland RAC facilities from 2014-2015

N = 100 older adults living in RAC

Chapter Four (Study One)

Gait speed characteristics and its spatio-temporal determinants in nursing home residents: a cross-sectional study

Stage 2

Based on data collected from Stage 1 a prospective cohort study was conducted in the same RAC facilities involved in Chapter Four (Study One) for six months between 2014-2016

N = 100 older adults living in RAC

Chapter Five (Study Two)

Stage 3

12-week exercise intervention in one Queensland RAC facility in 2015

N = 37 older adults living in RAC

Chapter Six (Study Three)

Feasibility and benefits of group-based exercise in residential aged care adults: a pilot study for the GrACE programme

Stage 4

24-week exercise intervention in two Northern NSW RAC facilities in 2016-2017

N = 42 older adults living in RAC

Chapter Seven (Study Four)

Exploring the feasibility and the benefits of the GrACE+GAIT exercise programme in the nursing home setting

Figure 1-4. Research conducted.

1.5 PURPOSE OF RESEARCH

The thesis had two major aims. The first was to characterise gait speed and spatio-temporal gait parameters of older adults living in RAC and to determine if spatio-temporal gait parameters could predict gait speed and adverse age-related events in adults living in RAC. The second aim focused on a general 12-week and a progressively more specific 24-week exercise intervention to determine if such programmes would be feasible and improve the gait speed and spatio-temporal parameters of the adults living in RAC.

The specific objectives for the thesis were to:

- Quantify the spatio-temporal parameters and gait speed of adults living in RAC (Study One).
- Gain insight into whether these spatio-temporal parameters predicted gait speed in this population (Study One).
- Quantify incidence of adverse events in Australian adults living in RAC over a period of six-months (Study Two).
- Determine if gait speed thresholds could predict the frequency of falls and other adverse events in adults living in RAC (Study Two).
- Determine the feasibility of the GrACE programme in RAC (Study Three).
- Gain some preliminary insight into the feasibility programme benefits on gait speed, sit to stand and handgrip strength (Study Three).
- Assess the benefits and feasibility of a 24-week targeted GrACE+GAIT progressive resistance and weight-bearing exercise programme in the RAC setting (Study Four).

Chapter 2

Literature Review One

Gait Performance

2.1 INTRODUCTION

In order to determine the current state of knowledge and existing gaps within the literature, the thesis literature was split into two sub-sections: gait and exercise. The aims of the first section (gait) was to:

1) Provide an overview of gait performance in adults living in RAC,

2) Gain a better understanding of how adults' walk living in a RAC setting and

3) Describe how gait performance may affect older adult's overall health, adverse events and well-being and why assessment is important in the RAC setting.

The aims of the second section (exercise) was to:

1) Provide an overview of the importance of exercise programmes for adults living in RAC,

2) Gain a better understanding on progressive resistance training for adults living in RAC and,

3) Examine what is known regarding the feasibility of exercise in the RAC setting.

2.2 Gait speed

Gait speed, also termed walking speed, has been shown to be associated with survival among older adults (predominantly in community-dwelling) in epidemiological cohort studies and to reflect health and functional status (31). Gait speed has also been recommended as a clinical indicator of well-being among older adults (31). Walking is an essential motor skill that all individuals, regardless of age, need to be able to do if they wish to remain independently mobile and perform activities of daily living (ADLs) including bathing, toileting, dressing and eating (32). The remainder of this literature review chapter will therefore focus on older adults living in RAC where such data was available. When there was insufficient evidence available for older adults living in RAC, the wider older adult literature was also summarised and synthesised.

A decline in gait speed, physical performance and ADLs has been shown to lead to a higher risk of falling and entry into RAC (32, 33). RAC in Australia is defined by the Commonwealth Government under the "Aged Care Act 1997" as providing a range of care options and accommodation for older people who are unable to continue living independently in their own homes (6). The type of care provided ranges from personal care to supported activities of daily living through to end-stage, palliative nursing care (34). While remaining physically active with age is essential to maintain health and quality of life, there is an age-related loss of physical activity (often measured as the number of steps taken per day) as well as an expected annual decline in gait speed of 0.03–0.05 m/s per year (35, 36), with adults living in RAC appearing more sedentary than other older age groups (37).

2.3 BIOMECHANICS OF GAIT

The biomechanical approach to assessing gait have involved three-dimensional (3D) motion capture, ground reaction force and/or surface electromyography for gait stability and are commonly performed in research studies (38-41) in community-dwelling older adults.

It is however possible to gain clinically relevant insight into aspects of the biomechanics of adults living in RAC gait by assessing their spatio-temporal parameters with a variety of pressure mat or inertial sensor systems that can be easily transported to the RAC facility. Gait speed, step length, step rate, step width (referred to as support base within this thesis), ground contact time, double support time and swing time are examples of spatio-temporal parameters that may influence gait performance and falls risk in a range of older adult groups (22, 42) that could be examined in the RAC context. Definitions of a number of these gait spatio-temporal parameters are provided in Table 2-1. It has been proposed that at least some of these variables should be monitored in older adult populations due to their relationship with falls, disability and mortality (4). However, they are rarely employed and remain underutilised in a clinical setting involving adults living in RAC due to their high financial costs and relative inability for adults to be transported to research facilities having such equipment (39, 43).

Table 2-1. Gait parameters and their definitions (14).

Gait parameters	Definition
Gait speed	A particular manner of walking (speed= length x rate) and has been suggested as the “sixth vital sign” in assessing older adults (13). More simply, gait speed can be defined as the distance walked (m) divided by the time taken (s).
Step length	The distance between one heel contact point and that of the other subsequent foot (14).
Step rate	The number of heel contacts made by both feet in one minute (14).
Ground contact time	The amount of time one foot or both feet remain on the ground (14).
Step width	The lateral distance between consecutive centres of pressure for the time sample immediately before heel-strike (14).
Single support time	The amount of time one foot is on the ground during the gait cycle (14).
Double support time	The amount of time both feet are on the ground concurrently during the gait cycle (14).

A deterministic model of gait speed and the variables that directly influence gait speed and stability is outlined in Figure 2-1. This model has been adapted from a previous study, which investigated the running stride of a 100 metre race (44).

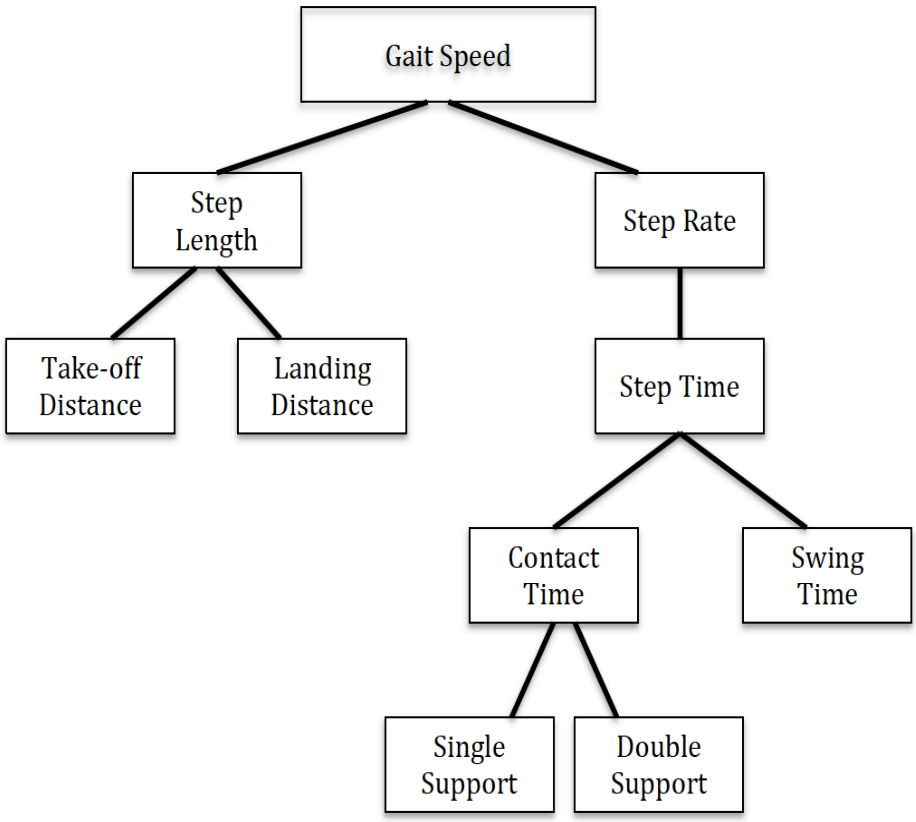

Figure 2-1. Deterministic model of gait speed outlining the direct relationships between the spatio-temporal parameters and gait speed (31, 44).

2.4 GAIT SPEED IN RESIDENTIAL AGED CARE

A low gait speed has also been reported to represent an independent predictor of muscle function and sarcopenia in community-dwelling older adults (4). Whereby muscle function is defined as muscle strength and physical performance, where gait speed (velocity) is one of the primary measures of physical performance (5). A number of muscular and neurological factors have been associated with the age-related decline in gait speed. Muscular factors may include a decrease in motor units, impaired muscular activation, substitution of type II by type I fibers and therefore diminished contraction speed. Neurological factors may include diminished cutaneuos sensitivity, decreased nerve conduction velocity and reaction time, decreased grey matter volume with functional brain impairment, and the presence of white matter lesions.

The degree of low mobility experienced by older adults in long-term RAC may be measured by gait speed (13). Using this approach, a number of studies and systematic reviews have sought to identify gait speed thresholds that are predictive of poor health in a range of older adult groups. For example, a systematic review revealed a gait speed of 0.8 m/s as a predictor for poor clinical health and adverse outcomes, and a gait speed of 0.6 m/s as a threshold of additional decreases in physical function in older adults (4). Further, a systematic review containing "well-functioning", "free from disability" and "cognitively intact" community-dwelling older adults (4) reported "extremely low mobility" status as corresponding to a gait speed less than 0.2 m/s and "requiring long term residential aged care" status corresponding to a gait speed of 0.15 m/s. It has also been demonstrated that every 0.1 m/s reduction in gait speed equates to a 10% decrease in older adult's ability to perform ADLs (4). These findings are alarming and suggest a greater emphasis should be placed on gait and its spatio-temporal parameters in older adults at risk of entry or already residing in RAC in order to reduce negative outcomes.

Studenski et al. (2011) predicted survival rate from gait speed in older men and women (Figure 2-2). Using an accelerated failure time model with Weibull distribution and age as the continuous variable, survival rate estimated as the median years of life remaining in older adults, based on the following variables: sex, age and gait speed. For example, a woman who is 85 years old and has a gait speed of 1.0 m/s is estimated to have ~ ten years median survival rate (31). Compared to a woman of the same age who has a gait speed of 0.5 m/s is estimated to have ~ seven years' median survival rate. Furthermore, the lower the gait speed, the worse the health outcomes will be for an older adult.

A meta-analysis found that being in the lowest quartile of gait speed compared with the highest quartile was associated with a threefold increased risk of mortality (31). Moreover, the association between slow gait speed and mortality seems consistent across several ethnic groups (31). As a result, gait speed may be considered a primary assessment for analysing mobility in older adults as it reflects ADL function and predicts survival in numerous studies (45, 46).

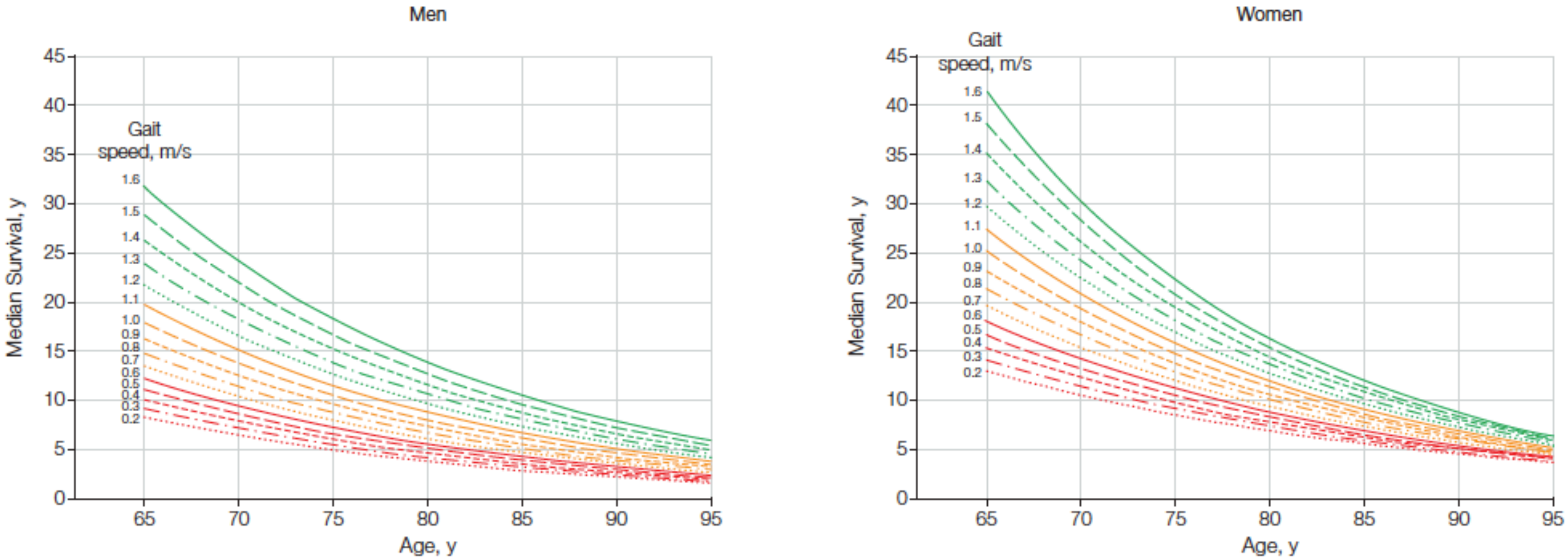

Figure 2-2. Predicted survival rate in older men and women by correlating age with gait speed to estimate median survival rate (31).

Gait speeds this low suggest that most RAC older adults are limited in independence and have decreased stability and mobility (13). Stanaway et al. (47) and Cruz-Jentoft et al. (5) reported that older adults who walk faster than 0.82 m/s are 1.23 times less likely to encounter death within the next two years than their peers who walk slower than the threshold. In addition, older adults walking at speeds of 1.36 m/s or above had added protection to mortality than those moving at or below 0.82 m/s. This supports numerous studies proposing fast walking speeds as a protective mechanism against mortality (4, 48-50).

Kuys et al. (13) performed a systematic review and Crocker et al. (51) wrote a Cochrane review (51) of gait speed in ambulant older adults in long term care, including RAC. Eleven of the studies reviewed were as well as a standalone paper Keogh et al.(52) and were selected due to their large cohort sizes and participants being adults living in RAC (Table 2-2). Within these 12 studies, gait speed was measured over distances of 2.4 m to 20 m. Seven studies reported using a static start and two reported a moving start. The remaining two studies did not report the type of start used. Reported mean habitual gait speeds in these studies were highly variable, ranging from 0.22 m/s to 0.92 m/s, with a mean habitual pace gait speed of 0.48 m/s and a mean maximal pace gait speed of 0.69 m/s.

It was however interesting that data from a more recent Australian study by our group (52) reported a mean habitual walking speed (±SD) of 0.37 (0.26) m/s from a randomly selected sample of 102 adults in 11 RAC facilities in South East Queensland. Such a finding may be indicative of Australian adults living in RAC walking slower than international cohorts or may reflect the fact that the sample recruited to the study was randomly selected (52), whereas a previous systematic review and meta analysis revealed that out of the 34 studies containing 2,888 participants, 14 of these studies clearly stipulated that they were randomised control trials that recruited participants who were more mobile (13).

Table 2-2. Summary of 12 studies of RAC older adults including 100 or more participants.

First Author, Year	Study Design	Participants	Mean Age (yrs) (+SD)	Sex	Gait Distance (m)	Gait Start	Gait Speed	Mean Gait Speed (m/s) (+SD)
Fiatarone, 1994 (53)	Intervention RCT	N=100	87.1 (0.6)	63% female	6.1	Not specified	Habitual	0.50 (0.20)
Brill, 1998 (54)	Intervention RCT	N=113 (84 with GS)	81.9 (8.4)	85.7% female	6	Static	Maximal	0.42 (0.54)
Markides, 1999 (55)	Longitudinal	N=5801	72.8*	57.5% female	4.8	Static	Maximal	0.22*

Studenski, 2003 (56)	Prospective	N=491	74.1 (5.7)	43.9% female	4	Static	Habitual	0.88 (0.22)
Faber, 2006 (57)	Reliability/ Validity	N=245	84.9 (6.0)	78% female	6	Moving	Maximal	0.76 (0.31)
Rosendahl, 2006 (58)	Intervention RCT	N=191 (n=188 with GS)	84.7 (6.5)	72.8% female	2.4	Static	Habitual Maximal	0.36 (0.20) 0.55 (0.31)
Gillespie, 2007 (59)	Prospective	N=112 (n=97 with GS)	75.6 (10.9)	66.1% female	4	Static	Habitual	0.22 (0.24)
Rolland, 2007 (60)	Intervention RCT	N=191	82.8 (7.8)	75.4% female	6	Static	Habitual	0.33 (0.14)

Bogaerts, 2011 (61)	Intervention RCT	N=113	79.8 (5.3)	100% female	10	Static	Habitual Maximal	0.92 (0.22) 1.12 (0.27)
Park, 2012 (62)	Cross-sectional	N=273	79.4 (7.9)	100% female	10	Not specified	Not specified	0.59 (0.27)
Schwesig, 2012 (63)	Prospective	N=146 (n=131 with GS)	82.7+	77.4% female	20	Moving	Habitual	0.76 (0.25)
Keogh, 2015 (52)	Observational/cross-sectional	N=102	84.5 (8.2)	69.6% female	3.2	Moving	Habitual	0.37 (0.23)

*Standard Deviations for mean age and gait speed were not stated; + Standard Deviations for mean age were not stated.

N = Numbers; GS = Gait Speed; RCT = Randomised Controlled Trial; SD = Standard Deviation; Yrs = years.

The literature reports older adults typical gait patterns differ to young adults; whereby increasing age is associated with differences in a range of gait spatio-temporal and stability parameters that may underlie the age-related change in gait speed and increased risk of adverse events. Some of these changes can be seen in Figure 2-3. Older adults' slower gait may be related to their shorter step (stride) length, which tends to be associated with increased contact time and double support time, an approach that might aid balance during the gait cycle (42, 64). This is important as a loss in balance may be linked to an increased risk of illness, dependency and falling (65). The ability to stand, walk or perform activities of daily living (ADLs) in a safe manner is essential for an adult to move and function independently (66). However, balance control declines with age, and impaired or reduced balance is a high risk for falls, which may result in severe injuries, such as, fractures, disability, and even death (66). Falling is attracting an increasing amount of attention in a clinical and research setting for a wide range of older adult populations. Unfortunately, the assessment methods designed to identify and differentiate high-risk fallers from low risk fallers' remains challenging to implement on a large scale, especially for older adults in RAC. Balance training during dual-task conditions appears to be important in order to improve balance under situations when their attention is divided (real-life situations), as balance training with single-task exercises does not maximise the transfer to dual-task conditions (66). There is limited research on exercise programmes involving gait, balance, coordination, and functional tasks and further research is required in this area (66).

Older adults may also have a similar or even higher step frequency than younger adults due to their reduced step length (45, 46). This higher step frequency may be accomplished by reducing swing time, which again may be a strategy used to improve gait stability as it minimises the time during which only one foot is in contact with the ground (Figure 2-3) (64, 67).

A number of studies have also shown that horizontal shear force (at the foot during heel contact phase of gait cycle) becomes altered as heel contact velocity, step length, and walking velocity change (68-72). Previous studies suggest that heel contact velocity, walking velocity, and step length are directly proportional to horizontal force and vertical force at the contacting heel (69, 72). As such, decreases in heel contact velocity, walking velocity, and step length should reduce friction demand (i.e., RCOF) among older adults. However, Lockhart et al. (2009), found gait parameter measures were significantly lower in adults with dementia than healthy older adults, and friction demand (RCOF) was higher (68). In other words, participants with dementia walked more cautiously yet had a higher tendency to slip at the time of heel contact. Lockhart and colleagues (2003) indicated a negative relationship between RCOF and transitional accelerations of the whole body center of mass (COM) (i.e., the slower the transition, the higher the RCOF) (68). Furthermore, studies suggest that age-related alterations found in heel contact velocity, step length, and walking velocity play a significant role in altering RCOF among older adults (68).

Collectively, the study suggests that lower functioning older adults who are characterised by walking at lower gait speed and having shorter step lengths may have altered heel contact velocity and RCOF that may predispose them to a loss of balance and falls (68). Further research investigating these relationships with that of other spatio-temporal parameters such as cadence, stance time and may be used to develop targeted interventions to improve gait in adults living in RAC.

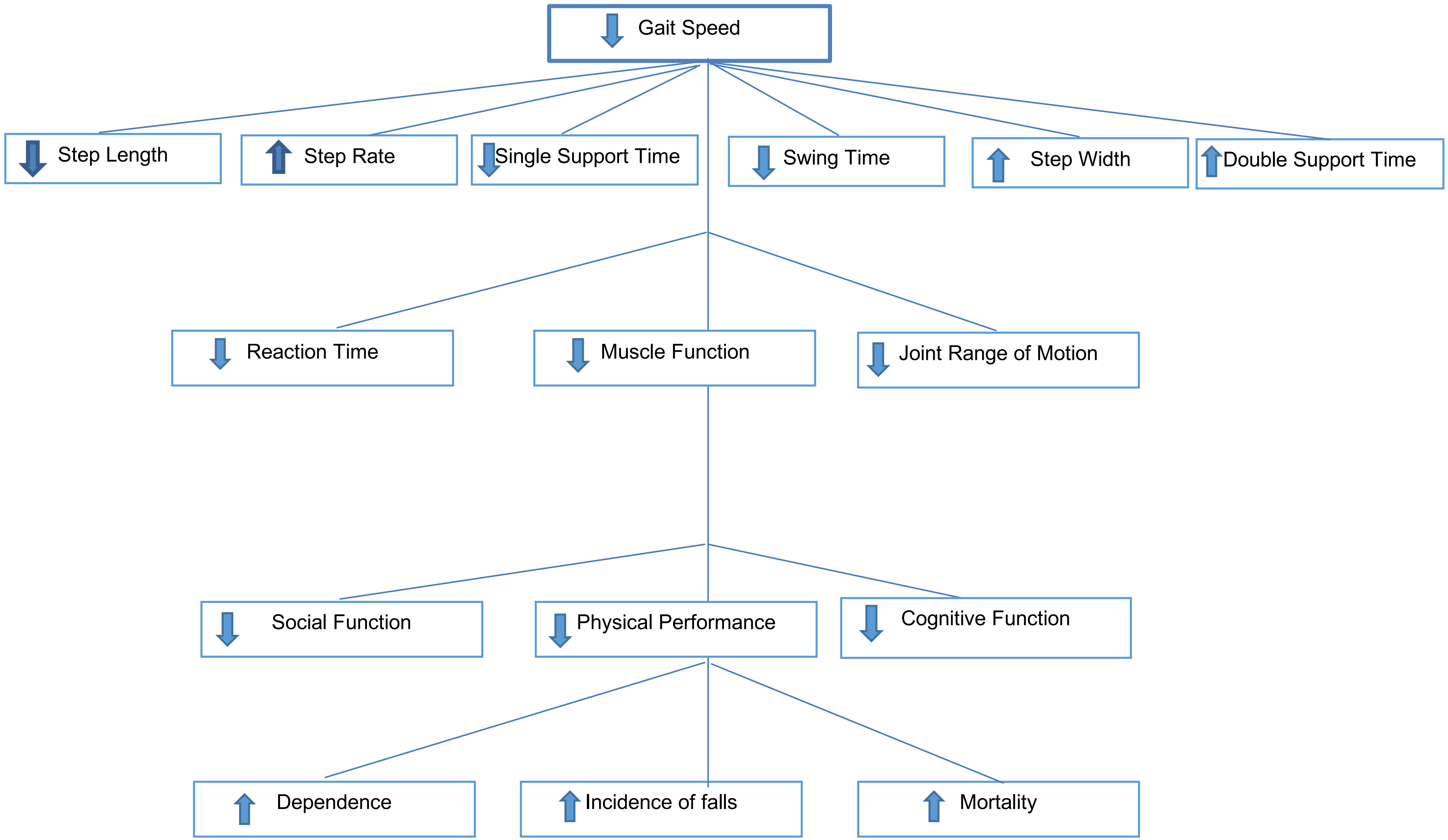

Figure 2-3. Flow chart of gait speed and the spatio-temporal parameters and the effect ageing has on the body (64).

While alterations in a number of spatio-temporal parameters have been found in older adults who walk at a slower speed (22), relatively little research has been conducted to determine how changes in spatio-temporal parameters may correlate or predict changes in gait speed or adverse events like falls in older adults, especially those in RAC (39). A longitudinal study in a RAC setting (which is explained in more detail in Section 2.6) found that a decreased walking speed predicted falls in older adults with dementia (42). A prior study involving 597 community-dwelling participants (mean age (±SD) 80.5 ±5.4 years) showed that a decrease in gait speed increases the risk of falls (OR = 1.069, 95% CI 1.001-1.142) (73). An increased falls risk was also found to be associated with negative changes in swing time, double support time, swing time variability and stride length variability (74).

Whilst two studies have shown stride-to-stride variability increases fall risk in community-dwelling older adults (75, 76), a finding that was confirmed by another study in community-dwelling older adults showed stride-to-stride fluctuations, stride variability and swing time variability increasing falls risk (23). If future studies examine the spatio-temporal parameters in adults living in RAC, then potentially, the parameters could predict decline in gait speed and adverse events in this sector. This knowledge may allow the development of exercise interventions focusing on particular spatio-temporal parameters, which may prove more effective in improving gait speed of adults living in RAC.

Gait speed may be viewed as a fascinating and complex task that depends on multiple systems working and maintaining a normal function in a highly coordinated and integrated manner (77). This can be seen in Figure 2-4, which demonstrates the percentage and time of the gait cycle for each spatio-temporal parameter (64). Whilst this model shows the gait parameter of a healthy adult, research is still required into the RAC context and how this may differ to community-dwelling older adults.

Initiating gait requires a stable upright body position. Functioning postural reflexes are necessary to assume and sustain a stable body position (78). To start walking, one leg is raised and directed forward by flexing the hips and knee. Activation of the supporting contralateral leg and trunk muscles moves the body's center of gravity over the weight-bearing leg and forward. The heel of the swinging leg is then placed on the ground, with the majority of the body weight supported by activation of the quadricep muscles and the control of the foot and ankle joint initially by the dorsiflexors (primarily tibialis anterior) and plantar flexors (gastrocnemius and soleus). The body weight is gradually shifted to the sole and then onwards to the toes, as the gluteus maximus and bilateral hamstring muscles act to extend the hip. During mid-stance, the opposite leg is lifted and moves forward until the heel strikes the ground. Meanwhile, the body is held upright, the shoulders and pelvis remain relatively level and each arm swings in the direction opposite to that of its ipsilateral leg (78). The gait cycle (seen on Figure 2-4) is divided into the stance and swing phase. The stance phase constitutes approximately 60 % of the gait cycle and is subdivided into initial contact (heel strike), loading response, mid-stance, terminal stance and pre-swing. Both feet are on the ground at the beginning and end of the stance phase. Each of these two double support periods lasts for approximately 10–12 % of the gait cycle. The swing phase takes up about 40 % of the gait cycle and is subdivided into initial swing (toe-off), mid-swing (tibia vertical) and terminal swing, terminated by the heel striking the ground (78-80).

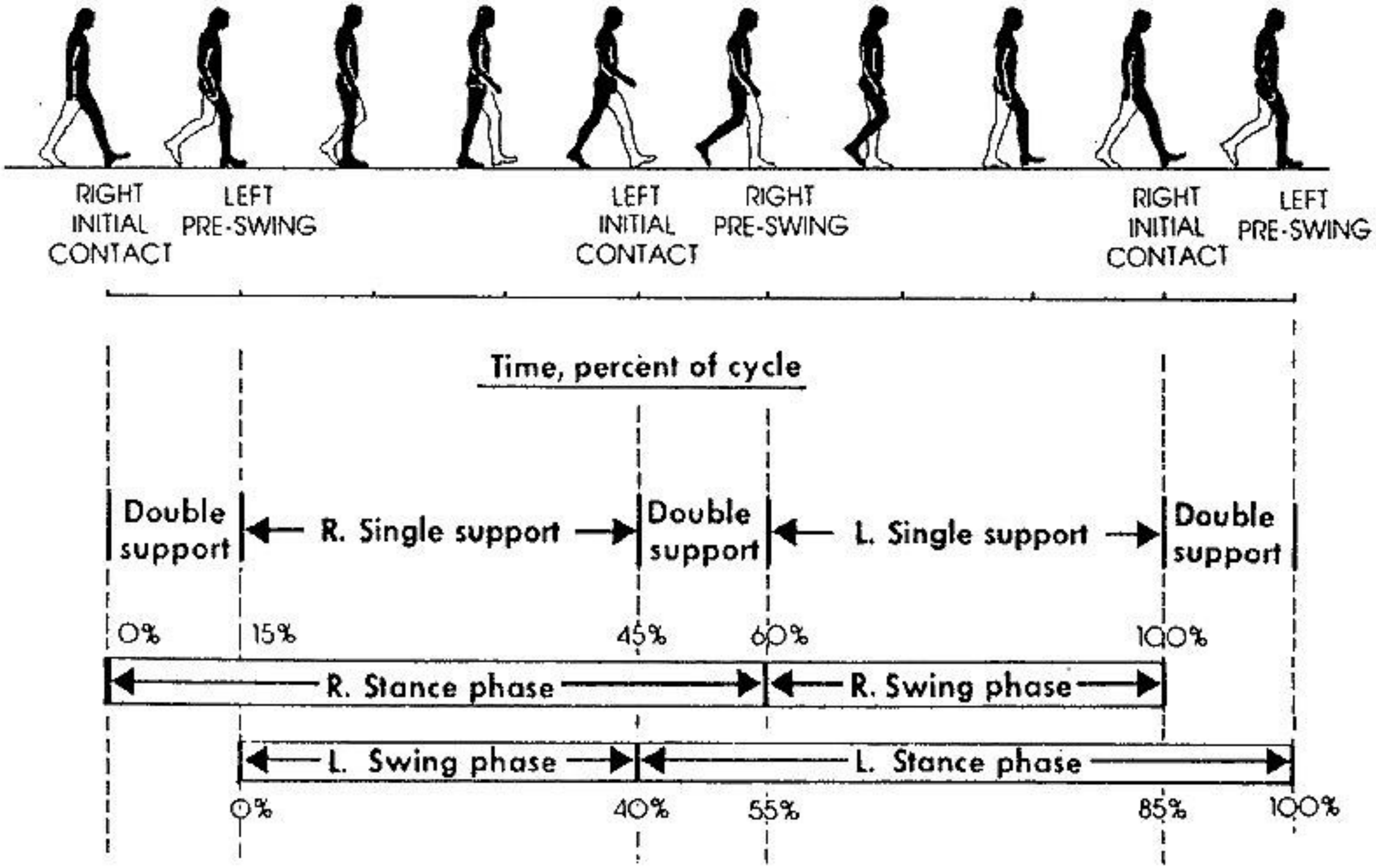

Figure 2-4. Gait parameters (64).

2.5 GAIT BIOMECHANICS DATA COLLECTION CHALLENGES

The major challenge with assessing the biomechanics of gait in older adults with poor physical and/or cognitive function such as those residing in RAC is the relative inability of these individuals to access sophisticated biomechanics laboratories (39). These laboratories are typically only found in universities and some major hospitals. As a result, clinicians who have assessed gait speed and spatio-temporal parameters of adults living in RAC have typically used a stopwatch and timed known distances to calculate gait speed and simple spatio-temporal parameters including average step rate, length and width (81-83). These methods were somewhat crude, time-intensive and relatively ineffective for collecting reliable and valid gait data.

An example, the paper and pencil test involves a 10 m long and 1.3 m wide (transparent plastic) mat, a stopwatch, two different coloured water-soluble felt-tipped pens and measuring tape. Painted lines on the mat enable the measurement of when a participant begins and ends walking with felt-tipped pens fastened to the heels of the participants' shoes. Step length and width is then measured using a measuring tape from the marks left on the plastic mat (83). Alternatively, older adults who participated in research studies or were referred to hospital-based biomechanics laboratories may have had a gait analysis including 3D motion capture, force plate and even electromyography data. While such an approach provides the gold standard in quantifying the kinematics, kinetics and muscle activation patterns relating to the gait cycle, such analyses are exceedingly time-consuming, require expensive equipment, are labour-intensive and come at considerable cost to the individual (39) with this especially true of the RAC resident who would have to rely upon someone providing them transport to the laboratory.

One of the most common tools used to collect gait data in research studies involving these types of clinical populations, are pressure mat systems like the GAITRite and Gait Mat II systems (84-88). Pressure mat systems including the GAITRite and the Gait Mat II system have allowed efficient recording of gait and its spatio-temporal variables by using a walkway with grids of embedded, pressure-sensitive sensors connected to a laptop computer. These portable systems can be taken to hospitals, clinics and RAC facilities and allow the measurement of many spatio-temporal gait variables, including gait speed, step length, step rate, ground contact time, double support time, swing time and step width on a step-by-step basis (42), this can be viewed in Figure 2-5 which is a screenshot from a laptop containing data analysed from a resident walking across the Gait Mat II. Many of these gait variables are clinically relevant, as they are highly related to adverse events such as falls, morbidity and losses of mobility within older adults (4).

These pressure mat systems automatically calculate and display real time spatio-temporal parameters, whilst a participant walks across the pressure mat platform. They were among the first type of devices to provide valid and reliable clinically relevant spatio-temporal gait data without the need to visit biomechanics laboratories. These pressure mat systems have high test-retest reliability and show a strong concurrent validity to the gold-standard measure of high-speed three-dimensional motion capture (as performed in sophisticated biomechanics laboratories) (39).

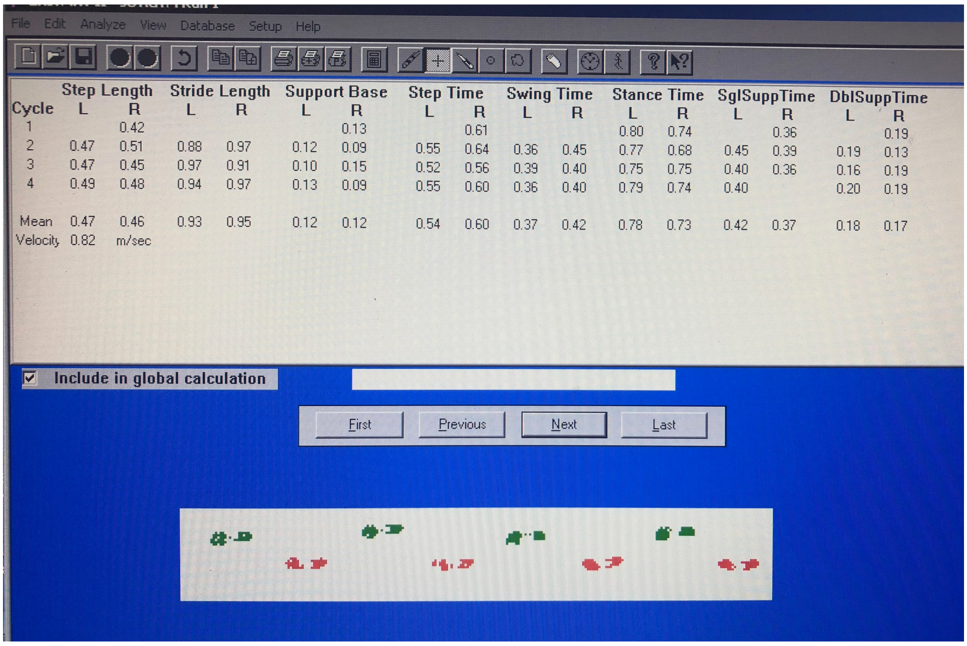

Figure 2-5. Screenshot of an older adult walking across the Gait Mat II platform.

In addition to being quite portable, they are a relatively simple to use clinical tools for the assessment of older adult's gait (39, 89). For spatio-temporal measures, McDonough et al. (39) revealed excellent correlation between the GAITRite system and paper and pencil assessment (intraclass correlation coefficient [ICC] > 0.95), as well as between the GAITRite system and video-based (stop action videocassette recorder) analysis (ICC > 0.93) for temporal measures. The GAITRite system was also found to produce reliable measurements of step length and times (in both walk-way centre and left-of-centre) (39). While slightly less commonly utilised than the GAITRite, the Gait Mat II has also been demonstrated to be highly valid when compared to the Vicon system, especially for the temporal measures (90). While the spatial parameters were not as valid, the mean difference between the Gait Mat II and the Vicon was deemed to be non-clinically significant by the authors (90).

Other difficulties that may arise or constrain when collecting data within the population of adults living in RAC are cognitive and physical function issues. Prior to a participant walking across the Gait Mat II platform, they were shown what to do and a demonstration was completed. In relation to cognitive issues, if a participant had a cognitive impairment, such as dementia or Alzheimer's, a nurse or staff member walked alongside the adult for assistance whilst data was being collected along the platform system.

Participants with the inability to mobilise independently walked with an assistive device, such as a walking frame/stick or rollator frame, across the Gait Mat II platform. This can be seen in Figure 2-6 (A), which in the bottom of the screenshot shows a resident with a rollator frame. The rollator frame or any other assisted device, did not interfere with data collection as the Gait Mat II has two operating modes – (1) collection of data, and (2) analysis of already collected data. This allowed for time in a RAC setting to solely on the task of collecting data. Whereas the analysis of the data was completed external to the RAC setting. The data was then exported into an external database (e.g. excel spreadsheet), which allowed for easier analysis of the data, especially for statistical analysis.

Sometimes the automatic identification of footprints was not successful due to the system measuring unusual gait and the automatic algorithms not selecting the correct footprints. However, when analysing the results, the program has a set of graphical editing tools that can be used to clean up the data. For example, the system allows artefact from assistive devices (use of walking frames or sticks) to be deleted from the gait sequence prior to analysis. The first tool is a "point erase" tool, which allows the circles from a walking stick to be removed from the gait sequence. The second tool is "block erase" which the user can positions over the shape the walking frame has created for a rectangle to appear around the area to be erased. This can be seen in Figure 2-6 (B), which shows the block erase has removed the top section where beforehand in (A) the rollator frame was previously in the picture. Then the user right clicks to remove the section highlighted. At this point, the user can click to analyse the data, which allows the gait sequence to be cleaned up, and the footprints from the resident to be analysed. This can be seen in Figure 2-6 (C), which shows the footsteps of the resident who was walked across the platform with the rollator (with the rollator device removed from the analysis), thus allowing the data to be analysed.

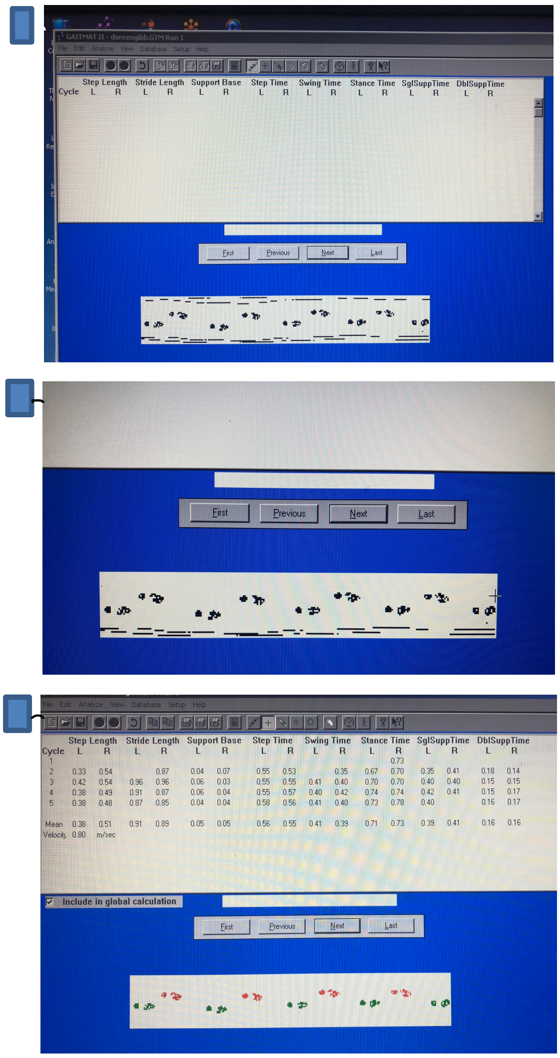

Figure 2-6. (A) Footprints with rollator frame; (B) Block erase tool removing rollator frame; (C) Data analysed by the removal of rollator frame.

Table 2-3 displays five studies (22, 42, 74, 91, 92) that investigated gait and its spatio-temporal parameters using the GAITRite system for older adults living in or at considerable risk of entry into RAC. In regards to the participants and the settings, four studies involved community-dwelling older adults (22, 74, 91, 92), whilst one included adults living in RAC (42).

Taylor et al. (22) focused on community-dwelling older adults with mild to moderate cognitive impairment, measuring simple task, functional and cognitive dual task gait performance. The findings from Taylor et al. (22) indicated that a range of spatio-temporal gait parameters discriminated between multiple and non-multiple fallers. Individuals who were classified as multiple fallers walked slower, had shorter stride lengths, spent more time in double support time, had a wider support width and showed more variability in stride length and swing time compared to those individuals classified as non-multiple fallers (22).

Thaler-Kall et al. (74) investigated the association between certain spatio-temporal parameter and falls history in 890 community-dwelling older adults. Surprisingly, no association between decreasing gait speed and falls was found. However, gait spatio-temporal parameters differences were associated with frailty, multi-morbidity, disability, multiple medication, age (cut point 75 years) and gender. In particular, a decreased stride length was revealed to be independently associated with falls in men aged 74 years and older (Odds Ratio [OR] 1.34 (CI: 1.05-1.70 per 10 cm decrease) (74).

Guedes et al. (91) assigned community-dwelling subjects into three categories: frail, pre-frail and non-frail. Results revealed that spatio-temporal parameters were more affected by dual task when compared to single task, especially in the frail group, who demonstrated a greater reduction in speed, cadence and stride length and increase in stride time in the dual task condition compared to pre-frail and non-frail adults.

Based on results for 518 community-dwelling subjects, Schoon et al. (92) stated that gait speed may be an appropriate self-test for monitoring frailty. The study was performed in an outpatient clinic whereby maximum step length, gait speed and chair rise test was investigated to identify which test would be the most useful for self-monitoring frailty. Gait speed was measured via the GAITRite whereby subjects walked across a 4-metre platform. In comparison to the other assessments, gait speed had the strongest correlation with frailty, the highest diagnostic value, and was the simplest single measurement to monitor frailty at home. This may be a valuable tool for empowering older adults, however the feasibility of a large older adults' sample size needs to be investigated to gain a greater understanding of the GAITRite data.

Sterke et al. (42) was the only study utilising participants living in a RAC setting and found the best gait predictor of a fall within the next three months was reduced gait speed and step length. The gait measurements were completed by residents walking independently over a 10 m GAITRite platform a maximum of five times per testing occasion, once at the commencement of the study and then after three, six, nine and twelve months. They recommended future studies use a system to measure gait spatio-temporal parameters that would create the opportunity for efficient and individualised treatment and prevention of falls (42).

Table 2-3. Summary of five studies involving the GAITRite system and older adults.

First Author, Year	Study Design	Participants	Mean age (yrs) (+SD)	Female (%)	Gait speed (m/s) (+SD)	Cadence (steps/min) (+SD)	Stride Length (cm) (+SD)	Double Support Time (s) (+SD)
Sterke, 2012 (42)	Prospective cohort	N=57 RAC adults	81.7 (7.0)	22.9	0.63 (24.6)	99.2 (16.0)	76.3 (26.2)	0.50 (0.40)
Taylor, 2013 (22)	Not specified	N=64 Community-dwelling older adults NMF: 41 MF: 22	NMF: 80.7 (6.8) MF: 82.5 (6.9)	NMF: 46.3 MF: 45.5	NMF Simple: 0.94 (23.6) NMF Functional dual task: 0.85 (23.3) NMF Cognitive dual task: 0.79 (27.2) MF Simple: 0.79 (29.7) MF Functional task: 0.69 (28.6) MF Cognitive dual task: 0.62 (28.4)	NMF Simple: 101.3 (12.5) NMF Functional dual task: 98.1 (12.3) NMF Cognitive dual task: 88.7 (17.4) MF Simple: 96.0 (15.7) MF Functional task: 93.0 (16.6) MF Cognitive dual task: 82.5 (20.7)	NMF Simple: 111.2 (22.5) NMF Functional dual task: 103.1 (22.5) NMF Cognitive dual task: 104.5 (24.6) MF Simple: 97.1 (25.6) MF Functional task: 86 (25.5) MF Cognitive dual task: 87.2 (25.3)	NMF Simple: 0.29 (0.07) NMF Functional dual task: 0.34 (0.11) NMF Cognitive dual task: 0.39 (0.22) MF Simple: 0.37 (0.15) MF Functional task: 0.43 (0.17) MF Cognitive dual task: 0.55 (0.32)

Thaler-Kall, 2015 [74]	Epidemiological	N = 890 Community-dwelling older adults	75.4 (6.3)	48.2	Male: 1.10 (2.3) Female: 1.07 (2.32)	Male: 102.6 (11.7) Female: 108.7 (13.5)	Male: 128.7 (19.1) Female: 117.6 (15.9)	N/A But did report time (s), stride duration (s) and step width (cm)
Guedes, 2014 [91]	Not specified	N = 81 Outpatient clinic	71.7 (6.6)	77.8	ST Frail: 0.79 (0.13) ST Pre-frail: 1.10 (0.0) ST Non-frail: 1.28 (0.07) DT Frail: 0.62 (0.10) DT Pre-frail: 0.95 (0.08) DT Non-frail: 1.16 (0.06)	ST Frail: 105.4 (13.4) ST Pre-frail: 112.9 (7.1) ST Non-frail: 114.9 (6.4) DT Frail: 96.3 (11.9) DT Pre-frail: 105.7 (9.1) DT Non-frail: 108.6 (13.9)	ST Frail: 96.0 (0.16) ST Pre-frail: 119 (0.10) ST Non-frail: 135 (0.09) DT Frail: 88 (0.15) DT Pre-frail: 112 (0.09) DT Non-frail: 128 (0.09)	N/A
Schoon, 2014 [92]	Observational cross-sectional	N = 518 Outpatient clinic	76.8 (4.8)	56	Total group: 1.01 (0.26) 95%CI 0.99-1.04	N/A	N/A	N/A

Data presented in the table above as mean (SD) unless indicated otherwise.

DT = Dual Task; MF = Multiple fallers; N = Numbers; NMF = Non-Multiple Fallers; SD = Standard Deviation; ST = Single Task; Yrs = years.

2.6 ADVERSE EVENTS

Adverse events are defined by the World Health Organisation (12) as an injury caused by medical management or complication rather than by the underlying disease itself, and one that results in either prolonged healthcare, or disability at the time of discharge from care, or both (12). Adverse events (falls, wounds, hospital admissions and deaths) information is routinely collected by the RAC staff, meaning researchers can gain insight and evaluate a residents' risk of adverse events occurring by tracking their health records within a RAC facility.

There have been numerous adverse events associated with reduced walking speed in community-dwelling older adults (77), although little research has investigated the incidence of adverse events and/or the relationship between adverse events and gait speed or spatio-temporal parameters in adults living in RAC. Examples of studies that have investigated adverse events in RAC facilities include two retrospective studies conducted in Sweden.

Andersson et al. (93) examined adverse events in RAC, hospital care, psychiatric care and primary health care settings. Out of the 242 reported adverse events during a two-year national sample, 127 (52%) occurred in RAC settings. The most common adverse events were found in the following categories in relation to lack of: participation (26%), clinical judgement (26%) essential care (26%) and nursing intervention (22%) (93). Andersson et al. (2017) included a sample of 173 residents in RAC and identified the most common adverse events that occurred and their most frequent contributing factors (16). The most common adverse events being medication error (37%), falls (24%) and delayed or inappropriate intervention (16%). A total of 693 factors were identified as being possible contributing factors for adverse events. The main reasons for adverse events occurring (89%) were the following: medication errors (n=141), delayed or inappropriate intervention (n=70), falls (n=62), missed nursing care (n=54) and suicide (n=10) (16).

To the author's knowledge, there are no studies that investigated the incidence of adverse events in Australian RAC facilities, nor predicting the likelihood of falls from the number of adverse events that occur in an Australian RAC setting. Adverse events are of high concern to the RAC setting and of high importance for residents, carers, staff and management. The following sections will focus on a particular subset of adverse events in RAC settings, namely falls, wounds, hospitalisation and deaths (mortality) due to their potential link to poor mobility and overall gait function.

2.6.1 FALLS

A fall is defined as unintentionally coming to rest on the ground, floor, or other lower level (13). Falls often lead to serious injuries and are the leading cause of death among older adults, with ~30-40% of community-dwelling older adults falling at least once a year (94, 95). These falls rate are even higher in RAC, with some data suggesting that 50% of those living in RAC experience at least one fall each year (96). Depending on whether the adult is living in the Australian community or RAC, 10-15% of older adults suffer serious injuries, 2-6% suffer fractures and 0.2-1.5% suffer hip fractures from each fall (96).

A study published in 2013 which investigated the coronial records of 3,289 Australian RAC deaths between 1 July 2000 and 30 June 2013, revealed that 81.5% of deaths were related to falls (2,679 cases) (97). Almost 96% of these adverse events occurred within the RAC facility, although 67.1% of deaths occurred externally to the RAC facility (97). The most common injuries that required hospitalisation comprised femoral neck fractures, other fractures of the leg, fractures of radius, ulna and other bones in the arm and fractures of the neck and trunk. Hip fractures resulted in death for ~25% of these older adults and of those who survived; around one third of them never regained complete mobility (96) (REF).

2.6.2 WOUNDS

A wound is defined as the result of tissue damaged by trauma (98, 99). This may be deliberate, as in surgical wounds of procedures, or due to accidents caused by blunt force trauma as may occur from a fall, projectiles, heat, electricity, chemicals or friction (14).

In Australia, Everett and Powell (25) found skin tears constituted 41% of known wounds in a RAC setting that contained 347 residents (with an average age of 80 years), with an average of 22 skin tears occurring each month. Wounds in RAC settings are a major concern due to the associated pain, risk of infection, decreased functional ability and poor quality of life (26). Thus, wounds need to be recognised as a major health issue in RAC due to residents having a high risk of suffering from wounds such as skin tears, pressure ulcers and chronic leg ulcers and the increased morbidity that they produce (27).

2.6.3 HOSPITALISATION

Hospital admission is defined as an individual who met the criteria for admission to the hospital category, care type, and underwent a hospital's admission process (documented) to receive treatment and/or care for a minimum of four hours for medical admissions (4). In regards to hospital admissions, older adults accounted for 41% of Australian patients admitted into hospital in 2014-15 (4). In particular, a growing concern is that the number of older adults aged 85 years and older admitted into hospital each year (5.8%) is higher than the population growth for this age group (4.1%) (4). It has also been highlighted that adverse events such as falls and wounds may lead to longer hospital stays and may even contribute to in-hospital deaths (28).

2.6.4 MORTALITY

While falls, wounds and hospitalisation can be serious adverse events for many older adults in RAC, the ultimate adverse event is obviously death. Older adults with slow habitual gait are at higher risk for functional or cognitive decline, institutionalisation, and mortality than those who walk faster (4). Specifically, a gait speed threshold of 1.0 m/s has been shown to be predictive of short-term mortality (death and hospitalisation within a year) (4, 100), with Guralnik et al. (100) reporting that older adults who walk faster than 1.0 m/s generally have a lower risk of negative health events and better survival rate. More recently, a gait speed threshold of 0.8 m/s has been adopted to define below normal physical performance as a component of sarcopenia, refer to Table 2-5 (101, 102).

Table 2-4. Studies investigating adverse events in RAC settings.

First Author, Year	Study Design	Participants	Mean age (yrs) (±SD)	Female (%)	Adverse Events
Andersson, 2015 (93)	Retrospective study in RAC in Sweden	N=242	N/A	60	lack of: participation (26%), clinical judgement (26%) essential care (26%) and nursing intervention (22%) resulted in adverse events in RAC
Andersson, 2017 (16)	Retrospective study in RAC in Sweden	N=173	N/A	N/A	89% adverse events – medication errors 37%, falls 24%, delayed or inappropriate intervention 16%, missed nursing care 12%, suicide or attempted suicide 6%

N = Numbers; N/A = Not Available; RAC = Residential Aged Care; SD = Standard Deviation; yrs = Years, % = Percentage.

Table 2-5. Overview of cut-off criteria for the diagnosis of sarcopenia (102).

Cut-off criteria	Value
Lean Muscle Mass Men Women	 7.26 kg/m^2 5.5 kg/m^2
Muscle strength (handgrip) Men Women	 <30 kg <20 kg
Gait speed	<0.8 m/s

The gait speed threshold of 0.8 m/s appears to be more appropriate for adverse ageing health outcomes as it predicts mobility and ADL disability at a two year follow up and premature mortality at two, three and eight years (4, 13, 47, 101). Interesting to note, is that the gait speed associated with 2-year mortality (~0.82 m/s) is virtually identical to the gait speed (0.80 m/s) associated with median life expectancy at most ages and for both sexes (31, 47, 101).

2.7 CLINICAL BENEFITS OF MAPPING GAIT SPEED

Accurate assessment of key outcomes helps to improve the thoroughness of evaluations, determine appropriate plans of care, better monitor progress, motivate patients, and enhance communication between the RAC staff team (whether it be general practitioners (GPs), physiotherapists or exercise physiologists) and the resident (including the resident's family/guardian) (103). Therefore, determining valid, reliable, and responsive measures for assessing function in older adults, especially those residing in RAC is imperative. We suggest that the regular assessment of gait speed and spatio-temporal parameters may better allow health professionals to use evidence-based approaches to improve gait and reduce the risk of falls (104-106). Such an approach may allow RAC staff teams and GPs to substantially improve patients' physical performance outcomes, ease care burden and reduce healthcare costs.

Based on the established population gait speed data, the RAC staff team could categorise the individual and provide appropriate management, where required (Figure 2-7). Such an approach is consistent with a recent paper that strongly encourages RAC staff to routinely assess their older residents' gait speed (at least on an annual basis) and develop referral pathways to provide evidence-based interventions for those individuals identified with low and/or declining gait speed. For allied health professionals working closely with RAC facilities, they may improve resident outcomes if they can convince the facility providers and managers to why routinely monitoring a resident's gait speed and perhaps spatio-temporal parameters is important. Allied health professionals may also assist facilities to develop pathways whereby those identified with poor gait speed can access appropriate interventions such as progressive resistance and weight-bearing exercise. Regular monitoring of gait speed and intervening (where appropriate) will likely produce clinically relevant and measurable positive changes to the RAC older adult that will transfer to improved outcomes for the resident and a reduction in healthcare expenditure (107).

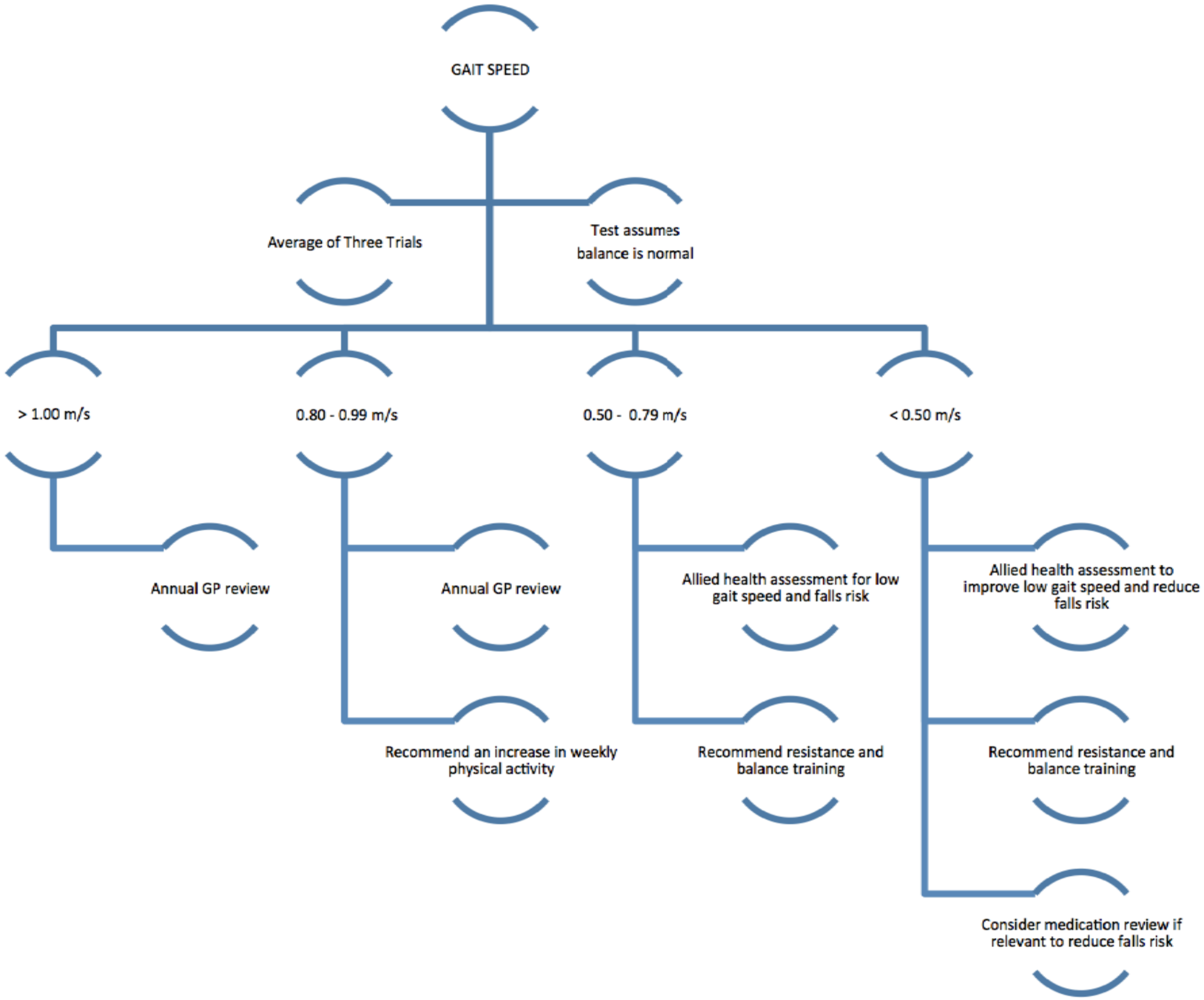

Figure 2-7. Gait speed flow chart (108)

2.8 EXERCISE

In the literature, the term “exercise” is used to distinguish structured programmes from incidental day-to-day physical activity, for example, housework (109). Whether physical activity is defined as incidental or exercise is of less importance than the type, amount, frequency and intensity of the exercise. In this thesis, the term exercise will be used quite generally to refer to “any activity that is structured, time limited and prescribes repetitive activity” (110).

2.8.1 IMPORTANCE OF MAINTAINING MOBILITY FOR OLDER ADULTS

The World Health Organisation reported that approximately 3.2 million deaths per year can be attributed to physical inactivity (19). An ageing population with an increasing life expectancy has led to an increase in the number and severity of medical conditions and a decrease in the levels of habitual physical activity (110). Alongside the increasing incidence of risk factors attributed to ageing, there is also a decline in many physiological systems linked to the geriatric condition, sarcopenia including; a loss of muscle mass, a decline in balance ability, a reduction in physical performance and a decline in cognitive performance, all of which effect an older adult’s independence (110-112). A review by Paterson et al. (113) suggested that increasing physical activity levels was the most important intervention to improve health in populations, particularly for older adults. This was also supported by the 1996 United States Department of Health and Human Service report that also stated exercise did not need to be vigorous to provide health benefits, the amount of health benefit was directly related to the amount of regular physical activity an adult performed (114). The maintenance of physical performance, extending life, quality of life and health resources are all of high importance for an older adult residing in a RAC facility (110).

The mechanisms underpinning sarcopenia and its associated loss of gait speed and physical function are complex and multi-factorial, but are reported to include sedentary lifestyle, an alteration in the endocrine function, loss of neuromuscular function, an imbalance between protein synthesis and breakdown, an inadequate dietary protein intake, and genetic factors (115-117). Prevalence of sarcopenia is even greater among adults living in RAC when compared to community-dwelling adults, with recent studies reporting prevalence rates in adults over 80 years ranging from 50-66.7% (118, 119). Australian data suggests that many of these adults living in RAC have poor muscular function, with physical limitations greatly impacting mobility, independence and health status (4, 52).

As seen in Figure 2-8, there is an unexplained range for variation in muscle mass and muscle strength in individuals as they age (120). Sarcopenia risk factors include age, gender, size, physical activity level and heritability (120). Typically, as an adult ages their muscle mass, strength and gait speed decreases and during the phase of “older life”, the range increases dramatically with older adults with lower muscle mass and strength reaching the disability threshold quicker than those older adults who have a higher muscle mass and strength. The importance of maintaining mobility for adults living in RAC is to ensure they remain above the disability threshold for quality of life (120).

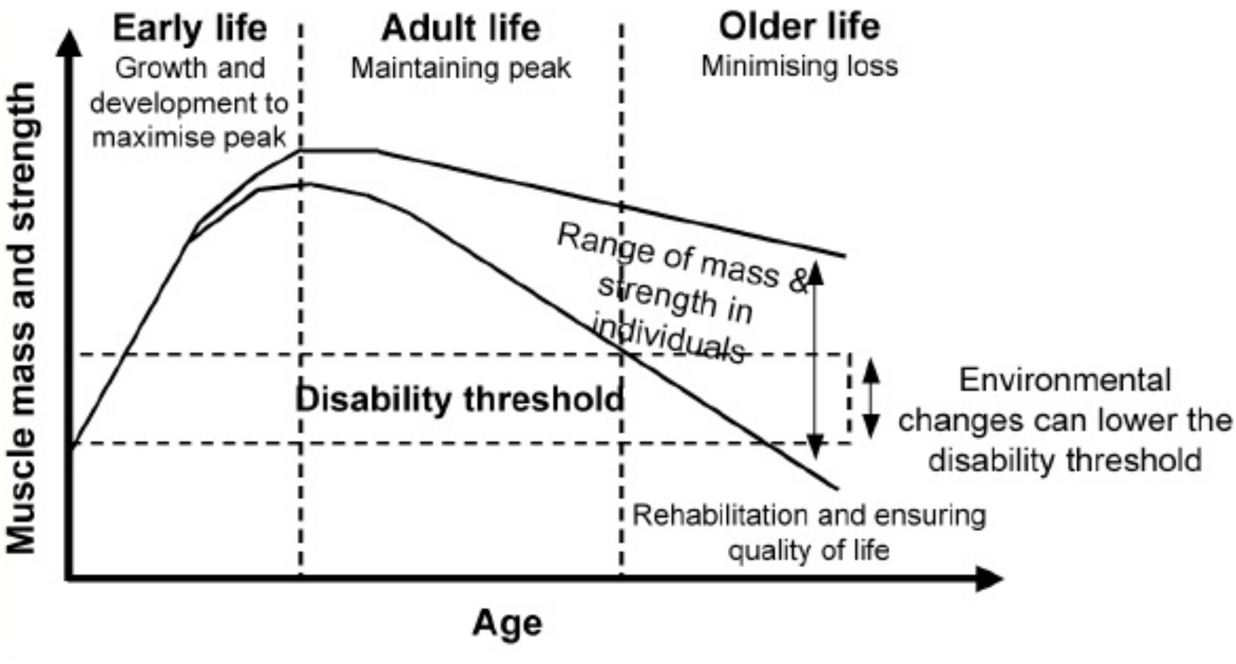

Figure 2-8. A life course model of disability (120).

In order to reduce the implications of sarcopenia and improve quality of life for adults living in RAC, effective interventions are required to counter the age associated loss of skeletal muscle mass and function (121). Exercise, particularly progressive resistance training, can improve or maintain skeletal muscle mass and function which helps greatly with independence, ADLs, balance and gait (120). A number of reviews supporting these benefits across varied populations of older adults, including community-dwelling and adults living in RAC have reported resistance exercise to be safe and effective in counteracting many of these age-related declines (104, 116, 122, 123). However, whilst evidence appears to show that resistance training can directly benefit the components of sarcopenia, debates continue concerning the impact, appropriateness and feasibility of resistance training among adults living in RAC (124).

Australian data suggests that adults living in RAC have very poor muscular function (52), with such physical limitations impacting on their mobility, independence and health status (4). Additional research on how to maintain or even improve gait speed in the RAC context is essential to maximise end of life quality of life, independence and end of life mobility. The remainder of this literature review chapter focuses on older adults living in RAC where such data were available. Where there was insufficient evidence available for older adults living in RAC, the wider older adult literature were summarised and synthesised.

2.8.2 HEALTH AND FUNCTION IN OLDER ADULTS

Adults with sarcopenia status and/or with low physical performance such as low gait speed may offset many of these limitations via progressive resistance training. Muscle strength can be improved if their muscles are overloaded during training, with it recommended this exercise is performed under the supervision of a qualified health professional to maximise the benefits but also to ensure the client’s safety (104).

If exercise is likely to improve gait speed in older adults living in residential aged care, Exercise prescription needs to take into account a range of factors influencing gait speed in this population. Gait speed, be it assessed during walking or running can be described by the impulse-momentum relationship, where impulse is the product of force and time and momentum is a product of mass and velocity. This relationship states that the velocity cannot exceed the body mass normalised impulse (i.e.

impulse divided by body mass). As a resistance training has been demonstrated to increase strength (maximum force capacity) and the rate at which force can be produced (rate of force development) in older adults (104, 122, 123, 125, 126), it appears to have the potential to improve the gait speed of older adults. The general age-related reduction in force production ability means that a greater stance time is required to produce a given impulse, with this reduced impulse likely resulting in a shorter stride length, increased step time and ultimately a reduction in habitual gait speed.

It also needs to be remembered that the total impulse produced reflects the contribution of muscles crossing multiple joints of the lower body. For example, poor stride length may reflect a shuffling gait pattern that is indicative of low plantar flexor and hip flexor strength (127). It also must be remembered that the primary muscles of the lower body a sequential activation pattern that may involve varying proportions of eccentric, isometric and concentric work. This suggests that exercise programs for older adults may require a variety of different exercises to strengthen a variety of muscles and muscle actions (eccentric, isometric and concentric function). Further, as walking gait is a complex multi-factorial total body activity requiring the integration of sensory information from a variety of sources to maintain balance, simply strengthening these lower body muscles without also improving balance is unlikely to translate to improve gait speed. Therefore, the exercise programs included in this study involved a mixture of progressive resistance and balance training exercises that targeted a range of muscle groups and types of muscle actions.

While an increased range of motion has potential to increase running speed and stride length, it appears unlikely that the main range of motion determinant of step length (i.e. hip flexion range of motion) in walking approaches the hip flexion range of motion of even older adults living in residential aged care. It is however acknowledged that some limitation of hip extension range may limit step length and that stretches for the hip flexors may therefore be important.

A review of exercise studies indicated that exercise, specifically resistance strength and weight-bearing exercise training, significantly improved gait performance in community-dwelling older adults (104). In addition, in many groups of older adults, exercise was shown to decrease falls risk and improve muscle strength and physical function, which may transfer to improved mobility, mobility capacity and general health (128-131). Importantly, gains in muscle strength and function occurred independent of age, chronic disease, level of sedentary behaviour and functional disabilities (13), with a number of studies described in the review demonstrating significant benefit for those in RAC (104). An example of one of these studies is Krist et al. (132), which recruited older adults in RAC with impaired mobility. It was reported that among those with impaired mobility at baseline, twice a weekly progressive resistance training over two months significantly improved mobility and muscle strength (132). However, one of the main issues this thesis wishes to address is to examine some of the feasibility issues that may be contributing to the lack of safe and effective progressive resistance and weight-bearing programs being offered in the RAC context in Australia and overseas.

The Blue Care Exercise Programme, which was developed in Australia for community-dwelling older adults at risk of entry into RAC is therefore of considerable interest to this thesis. Results of a study examining the Blue Care Exercise Programme demonstrated high feasibility for translating this programme into usual respite care practice and that one hour per week of training for 20 weeks significantly improved functional capacity and balance in respite day care adults (27). Specifically, Henwood et al. (27) recruited 23 participants (mean age of 78.35 ± 7.32 years), with 12 of the participants cared for by a family member and 11 who lived in an independent unit that catered to older adults. All participants required assistance, this varied from individual, some were unable to perform ADLs, while others managed ADLs but fatigued quickly. Before the end of the intervention, all participants had progressed from no resistance to using dumbbells in their resistance training exercises. All physical performance measures (30 second sit to stand performance, 6 metre fast walk time and hand grip strength) increased significantly (27).

Effective in a disabled community-dwelling population, the Blue Care Exercise programme is yet to be trialled among adults living in RAC. However, the documented success of the programme in respite care has led to two thirds of all Blue Care Respite Centres across Queensland undertaking and implementing the programme since December 2010. Further demonstrating the long-term feasibility of an exercise programme for respite care participants, over 170 staff and volunteers across the Blue Care community and RAC services having received training to deliver the exercise programme to their clients. Given the high uptake of this exercise programme in Blue Care respite day care centres, it is hypothesised that the GrACE exercise programme (a modified version of the Blue Care Exercise Programme) that was developed for Study Three will exhibit similar levels of feasibility and effectiveness in RAC centres (27).

The benefits of exercise for the promotion of health and function in older adults are widely accepted (133, 134). However, research is still in its infancy as to what forms of exercise may optimise the benefits, while also being safe and feasible for adults living in RAC. The issue of feasibility is particularly important to investigate, as there seem to be so little ongoing progressive resistance and balance training programmes currently available to older adults living in RAC in Australia or many other parts of the world. Consistent with the aims of the overall thesis, an improvement in physical performance and function (components of sarcopenia) with a focus on gait speed will be used as the primary outcome to determine the effectiveness of the exercise programme in the RAC context (135).

2.8.3 Exercise to improve gait

Whist the literature demonstrates widespread improvements in physical function as a result of progressive exercise in community-dwelling older adults (130, 131); little research has been conducted on exercise, gait and the spatio-temporal parameters in the RAC setting. Although spatio-temporal parameters were not measured, a systematic review reporting data from several resistance exercise programmes in this setting found an increase in the resident's habitual walking speed by up to 0.04-0.12 m/s (104). Based on the exercise programmes performed in the studies, it is likely these gains are mediated by improved lower body strength and/or balance.

In addition, two reviews have examined exercise to improve muscle function, including gait speed, in frail older adults (136). In the first of these, Chou, Hwang & Wu (136) reported that exercise produced a significant 0.07 m/s (CI 0.02–0.11) increase in gait speed compared to the control group (−6% change). The second review, Valenzuela (104) examined specifically progressive resistance training and/or weight-bearing exercise programmes. This review also reported significant improvements in muscle strength and functional performance outcomes (sit to stand, stair climbing, gait speed, balance and functional capacity) post progressive resistance exercise programmes in adults living in RAC (104).

Table 2-6 summarises key aspects of the methodology and results of six studies that investigated changes in gait speed as an outcome of resistance training programmes in the RAC setting. Programmes ranged from 10 weeks to 12 months, frequency and duration varied from 15-20 minutes of strength training with an additional 10-minute walking period for three months (137) to 45 minutes five times every two weeks for three months (58) to 90 minutes twice a week for 10 weeks (138). One study (35) also compared the effects of two exercise programmes conducted over a two-month period in an attempt to determine the effect of different exercise prescriptions on the outcome. In this study, the first exercise programme consisted of lower limb strengthening and balance training, with the exercises progressed to advanced exercises in the 10th session and performed in the upright position to challenge balance. The second exercise programme involved a series of light exercises performed in a seated position with no progression; similar to what often constitutes exercise programmes for adults living in the real world.

2.8.4 GAIT SPEED OUTCOMES

Across these six exercise studies, changes in gait speed were assessed over distances of 2.4-10 m and walking speed from self-paced to maximal effort. None of the studies measured gait speed using an electronic walkway, such as the Gait Mat II or GAITRite, employing the less reliable method of using human-eye with digital stopwatch and measuring tape to measure resident's gait (58, 60, 137-140). Gait was also assessed by a performance-oriented mobility assessment with the gait score ranging from 0 (worst) to 12 (best) points (141). Post intervention, four of the six studies found a significant improvement in gait speed (60, 125, 142) or gait score (143). Whilst two studies failed to show a significant improvement in gait speed (144, 145), this may be due to small sample size (144) or low attendance rates (145).

Table 2-6. Table summary of papers (2007-2017) investigating gait speed changes from exercise trials in RAC facilities.

First Author, Year	Study Design and Intervention	Demographic Details Mean Age (±SD) % Females	Gait Speed Post intervention Change
Rolland, 2007 (60)	Collective exercise program (1 hour, twice weekly of walk, strength, balance, and flexibility training) or routine medical care for 12 months.	N=134 in 5 RAC in France (n=67 in both EX and CON groups) Age: EX group - 82.8 (7.8) 71.7% female CON group 83.1 (7.0) 79.1% female	+0.04 m/s*
Bossers, 2014 (142)	Pilot study - 6-week combined aerobic and strength training program, five times per week, 30 minutes per session, in an individually supervised format	N=33 with dementia in 1 RAC facility Netherlands Age: EX - 86.1 (.38) 76.5% female Con – 84.1 (5.7) 75.0% female	+0.03m/s*
Sievänen, 2014 (144)	Pilot study- 10-wks, twice-a-week progressive vibration training with slight exercises done on a side-alternating device or similar sham training without vibration	N=15 Finland RAC facility Age: WBV - 84 (6.3) Sham - 83.6 (8.9)	WBV 0.00m/s Sham +0.05m/s

Henwood, 2015 (145)	Participated twice weekly for 12-wks in a dementia specific, aquatic exercise program	N=10 moderate to severe dementia in Australian RAC facility Age: 88.4	-0.1m/s
Hassan, 2016 (125)	Pilot study – 6mos twice weekly progressive resistance and balance training by air-pneumatic equipment	N=42 4 different Australian RAC facilities With n=21 in EX group Age: 85.9 (7.5)	+0.02m/s*
Pereira, 2017 (143)	Pilot study - 10-week multimodal exercise program – 70mins per session, twice a week with exercises promoting simultaneous motor and cognitive simulation	N = 34 Living in 4 RAC facilities in Portugal Age: 82.4 (6.3)	+0.02m/s*

* = statistically significant increase in gait speed

CON = Control Group; EX = Exercise Group; N = Numbers; RAC = Residential Aged Care; SD = Standard Deviation; WBV = Whole Body Vibration.

2.9 Feasibility, acceptability and sustainability

As healthcare systems face enormous challenges, sustainability is crucial for the implementation of new interventions including exercise programmes however; there is no consensus with regard to definition and variables that characterise a sustainable healthcare system (146). Successful implementation depends on a number of variables, which include but are not limited to, a scientific understanding of the behaviours required to change, the factors maintaining current behaviours and barriers, the process and implementation to develop change based on achieving a sustainable healthcare system (28). Further, research may assist in the process of implementing a sustainable healthcare system. While it is important to demonstrate the effectiveness and success of a new intervention, it is equally important to determine the implementation outcomes especially within a specific health care context. These implementation outcomes include – acceptability, adoption, appropriateness, feasibility, fidelity, implementation cost, coverage and sustainability (147). For the purpose of this PhD thesis, the two exercise studies that included some feasibility outcomes attempted to gain some insight into: feasibility, acceptability and sustainability of the training interventions developed within this thesis.

Research within this area of RAC can provide insight into the impact an exercise intervention could influence an older adult's health status. The following can be defined as:

Feasibility – the extent to which an intervention can be carried out in a particular setting or organisation (147).

Acceptability – the perception among stakeholders (e.g. consumers, managers, policy makers) that an intervention is agreeable (147).

Sustainability – the extent to which an intervention is maintained or institutionalised in a given setting (147).

Even in the most resource constrained environments, the following variables: measuring change, informing stakeholders (e.g. RAC staff and management), and using information to guide decision making have been found to be critical to successful implementation of an exercise programme (147).

Ultimately, research in this area needs to focus on providing a sound theoretical and practical understanding of all the issues that may impact on the sustainability of a beneficial healthcare intervention or alteration to usual care practice. One common approach to gain some insight into the sustainability of a healthcare intervention is the three sphere approach of Aminuddin & Nawari (2015). The first of the three spheres contains the environmental factor which is the setting of the RAC and the impact of the efficiency and resources within the environment. The economic sphere focuses on concepts including profit and cost savings, with the importance of this perhaps being quite different between public and private RAC facilities. The last of the spheres being social contains the standard of activities of daily living and the community lifetysle within the RAC setting. The three spheres interlap together and signify that the environment, econoy and social variables impact the sustainability of a healthcare system (148).

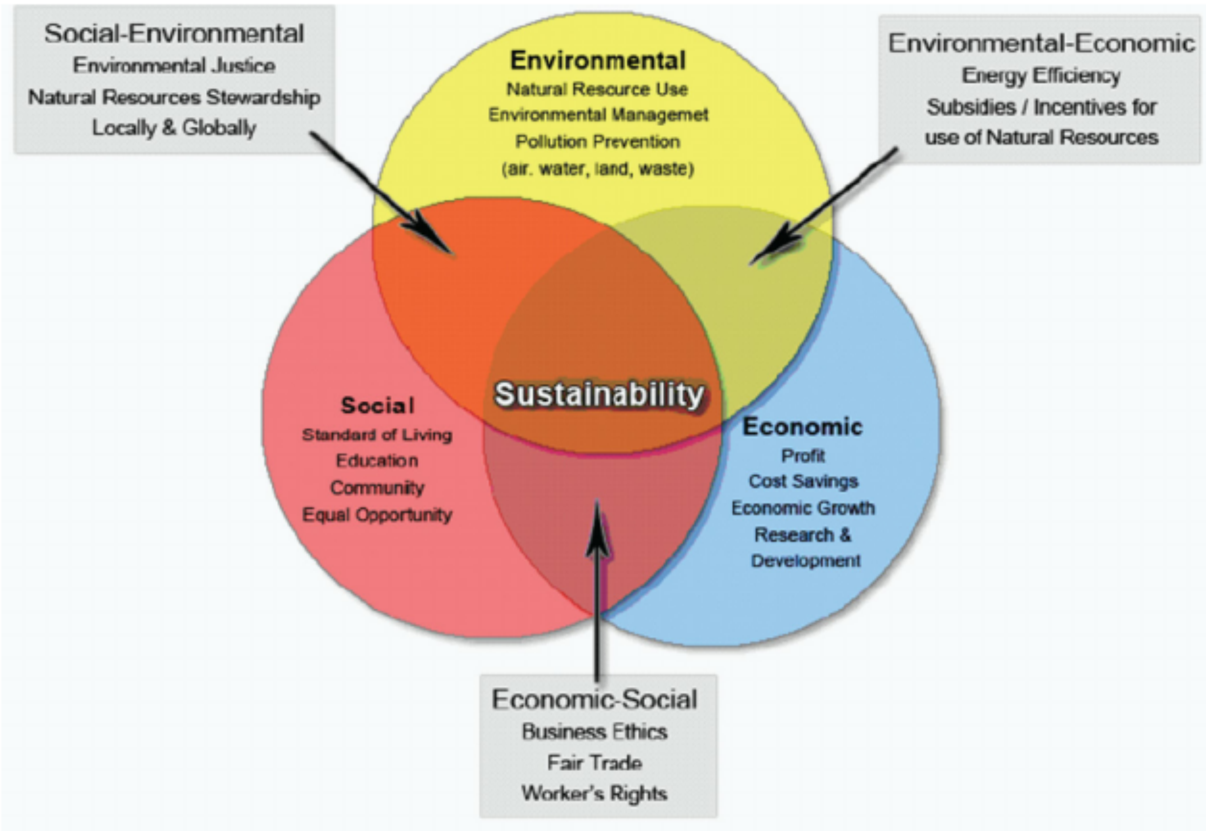

Figure 2-9. The three spheres of sustainability (148).

While the conceptual framework proposed by (148) has a number of applications to this PhD thesis, another model postulates that five major dimensions may need to be considered for the sustainability of an intervention in healthcare (147). The five distinct dimensions that were deemed to be the most important for a sustainable healthcare system are: long-term strategic perspective and innovativeness, disease prevention and health promotion, quality, institutionalization of environmental concerns and institutional accountability and individual responsibility. This is described pictorially in Figure 2-10.

Figure 2-10. Relevant dimensions of health care systems sustainability (147).

Due to the high degree of complexity within RAC facilities, the approach to creating a sustainable exercise programme must take into account a potentially large number of variables within and between the different categories to measure sustainability. Building on this sustainable healthcare system framework, the adapted model (Figure 2-11) provides an overview of sustainability model for the RAC facilities in Northern

NSW and QLD region in which the research was conducted for this PhD thesis. For an intervention to demonstrate resident benefit and sustainability within the RAC healthcare system, the following variables may need to be considered: social lifestyle, RAC staff and management, funding available, type of RAC facility, resident's perspectives, quality care, life and safety, economic value and environment. Each variable summarised in the outer petals of Figure 2-11 has the potential to interact and influence the other variables and the overall outcome for the resident living in a RAC facility. The following variables in the petals overlap each other and the inner circle because each variable impacts greatly on an adult living in a RAC facility and each other.

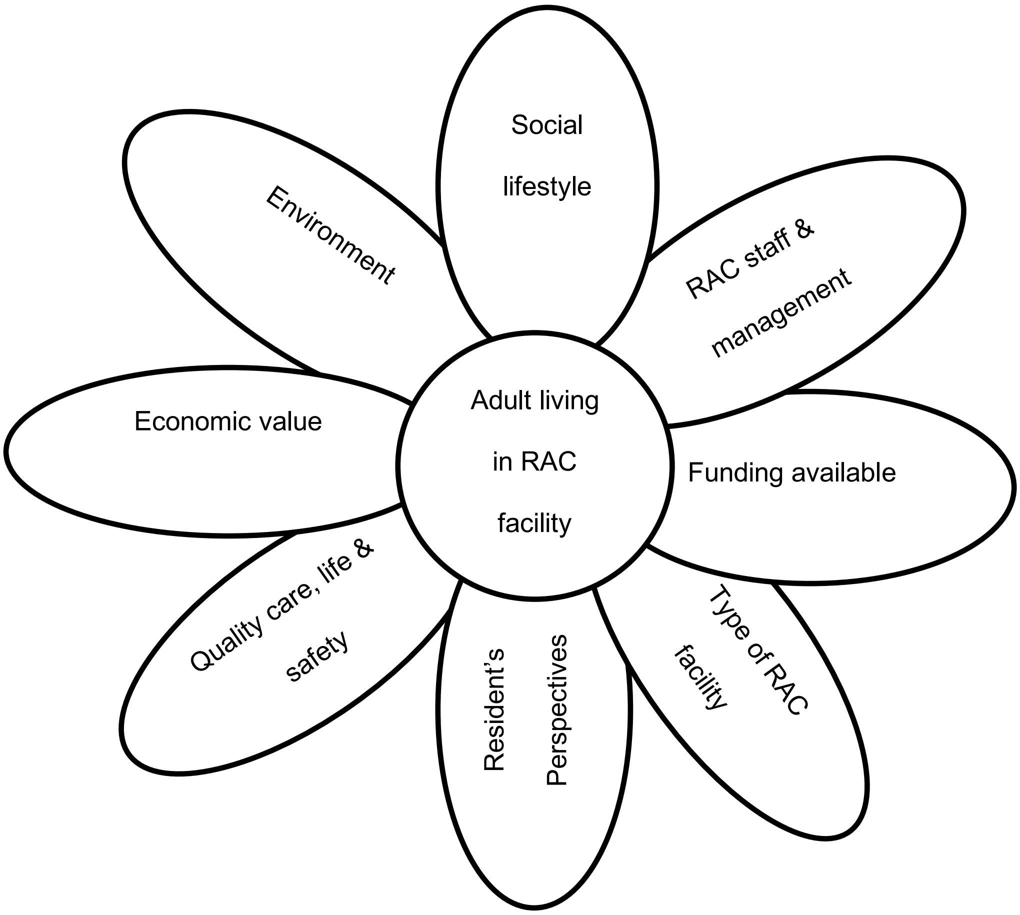

Figure 2-11. Adapted model of sustainability.

Overall, Figure 2-11 was not designed to replace former concepts of sustainability but rather utilise the strengths and address the relative limitations of these previous models so to provide a greater context to the RAC healthcare setting in terms of how exercise professionals as well as RAC management and care staff may look to develop and implement such programmes. I. As such, this new approach combines existing sustainability approaches and future-oriented thinking that may offset some of the challenges of improving usual care practices in the RAC setting. Due to the complexities of conducting research in RAC and the high work demands placed on management and care staff, getting the staff actively involved in providing insight into the feasibility can be challenging as they may already be actively involved in assisting the intervention take place. On this basis, the focus of the feasibility chapter and thesis will be on the factors identified by the older adults living in RAC.

In a variety of health contexts, the assessment of feasibility for interventions, including exercise, are typically defined by the following variables (142, 145, 149-153):

- Recruitment rate is defined as the number of potential participants recruited from those invited (142).
- Measurement completion rate is defined as the number of participants able to complete each outcome measure at baseline and follow-up (142).
- Loss to follow-up is defined as participants who withdrew or dropped out and did not consent to a follow up assessment (142).
- Exercise session adherence is measured by the percentage of sessions attended out of the total available exercise sessions. Previous exercise studies involving low functioning older adults have also quantified the proportion of participants who completed 75 and 100% of the total exercise sessions due to the likelihood that many participants will miss at least one session due to a variety of health complications not related to the exercise programme including their advanced age and relatively poor health (27, 142, 149, 154).
- Adverse events (intervention) is defined as incidents in which harm or damage including but not limited to, falls and fall-related injuries musculoskeletal or cardiovascular incidents and problems with medication and medical devices (152) as a result of their involvement in the exercise programme.

  Acceptability is often measured via a programme satisfaction survey completed post-training that will typically assess the burden of training and testing, as well as how participants felt about the intervention/trial (142).Sustainability is measured by determining the impact of the cost to a facility, the exercise programme and the benefits of physical performance achieved for older adults (153).

Table 2-7 summarised the feasibility outcomes of the exercise programmes that were previously mentioned in Table 2-6 for their effect on gait speed. Recruitment rate ranged from 14.0% to 53.3% in the six studies, which is not uncommon for RAC research. The low rate of 14% with Hassan et al. (125) is perhaps due to this being a sub-study to a parent study that recruited 300 residents across 20 RAC facilities in Australia (155).

Measurement completion from 42% to 100% with three studies (125, 142, 145) having a low completion rate due to illness, death, hospital admission, fluctuating psychological symptoms with dementia residents and/or facility capacity to transport residents to the exercise intervention. The challenges mentioned are not uncommon in RAC research (124, 156). Meanwhile the other three studies had high attendance rates with Pereira et al. (143) having 100% completion rate, although three participants were replaced in the intervention period.

Previous feasibility exercise programmes involving adults living in RAC facilities reported relatively high mean adherence rates with results suggesting that exercise classes may be well attended by residents living in RAC facilities (125, 142, 144, 145, 157). The adherence rate for Bossers et al. (142) study was 84% compared to Hassan's and Rolland's studies which had attendance rates of 50% or less for the majority of their training sessions. Whilst poor levels of attendance and adherence are not uncommon in RAC research studies (145, 156), Bossers' adherence rate was 31% higher than the mean adherence in a 12-month group walking exercise programme using adults with mild cognitive impairment (158) and 9% higher than the individualised 12-week home based combined exercise programme in a similar group (159). A factor that may have contributed to the high adherence rate of Bossers was that all residents started the training programme at a generally low-intensity, working their way up to higher intensity levels as the programme progressed (142). Such an approach may have also contributed to the lack of exercise-related adverse events programme drop outs in this study (142).

The most common reasons for loss to follow up in the studies were the following: death, unwilling to participate, changed RAC facility, family withdrawal and medical conditions, such as a stroke. The reasons mentioned are not uncommon in RAC research.

In Table 2-7, adverse events were also included in the reporting of the studies. None of the studies defined adverse events within their research but all reported whether adverse events occurred. No adverse events were reported during the exercise sessions in three studies (125, 144, 145). Whilst three studies reported adverse events with Bossers et al. (142) reporting sore leg muscles and a sense of exertion; none resulting in a drop out of the intervention. Pereira et al. (143) stated two falls (without fractures) occurred during the exercise intervention and Rolland et al. (60) reported a total of five falls during the exercise intervention period, with one fall causing a head injury.

None of the studies summarised in Table 2-7 appeared to assess acceptability and/or sustainability. However, the methodology employed in these studies suggest a number of major challenges to long-term sustainability in this setting. Bossers et al. (2014) delivered individualised, supervised walking and strength training programmes five days per week. Sievänen et al. (2014) delivered the intervention using relatively expensive whole body vibration devices, with Hassan et al. (2016) also using large, expensive resistance training machines. Due to the size and cost of these exercise devices, both these studies also required a separate room dedicated to housing the exercise equipment (125, 144). Henwood et al. (2015) trialled aquatic exercise that required participants to be transported by shuttle bus to and from a community pool and change in and out of swimming attire in the public changing rooms, which may pose a falls risk due to the potentially wet and slippery surfaces.

Based on the intensive staffing or equipment costs of many of the studies in this area, it could be proposed that RAC exercise programmes should be developed and trialled that utilise group-based weight-bearing and progressive resistance training equipment that require relatively little equipment and can easily been conducted in the RAC facility. This lack of translation may also reflect the many barriers to the sustainability of resistance combined with weight-bearing training programmes in

RAC (25) and to our knowledge, a complete lack of research quantifying the acceptability and sustainability of this form of exercise in this setting.

Table 2-7. Table summary of papers (2007-2017) investigating feasibility outcome from exercise trials in RAC facilities.

First Author, Year	Recruitment Rate	Measurement Completion	Adherence to Exercise Programme	Most Common Reasons for loss to follow-up	Adverse Events	Acceptability	Sustainability
Rolland, 2007 (60)	31.2%	82%	33.2%	Died; changed RAC facility; refused to continue	N=5 falls during the exercise sessions with n=1 caused head injury	N/A	N/A
Bossers, 2014 (142)	46.2%	52%	86.3%.	Unwilling to participate	No adverse events reported	N/A	N/A
Sievänen, 2014 (144)	37.5%	87%	WBV 74 % Sham 73 %	Died	No adverse events reported	N/A	N/A
Henwood, 2015 (145)	53.3%	42%	70% completed 12–18 EC 30% completed 5 – 7 EC	Left RAC facility; family withdrawal; declined to participate	No adverse events reported	N/A	N/A

Hassan, 2016 (125)	14.0%	43%	52.4% completed 10%-50% 28.4% completed more than 75%	Did not attend or assent to follow-up assessment; died	No adverse events reported	N/A	N/A
Pereira,,2017 (143)	40.5%	100%	65 - 95%.	Declined to participate; stroke	EX group n=2 falls without fracture	N/A	N/A

CON = Control Group; EC = Exercise Class; EX = Exercise Group; N = Number; N/A = Not Available; RAC = Residential Aged Care; WBV = Whole Body Vibration.

2.10 SUMMARY OF BOTH LITERATURE REVIEWS

From the literature reviews described in this thesis, a number of gaps in the literature were identified that resulted in the specific objectives for this thesis.

The specific objectives for the thesis were to:

- Quantify the spatio-temporal parameters and gait speed of adults living in RAC (Study One).
- Gain insight into whether these spatio-temporal parameters predicted gait speed in this population. (Study One).
- Quantify incidence of adverse events in Australian adults living in RAC over a period of six-months (Study Two).
- Determine if gait speed thresholds could predict the frequency of falls and other adverse events in adults living in RAC (Study Two).
- Determine the feasibility of the GrACE programme in RAC (Study Three).
- Gain some preliminary insight into the feasibility programme benefits on gait speed, sit to stand and handgrip strength (Study Three).
- Assess the benefits and feasibility of a 24-week targeted GrACE+GAIT progressive resistance and weight-bearing exercise programme in the RAC setting (Study Four).

Chapter 3

Methodology Overview

A residential aged care (RAC) facility can be defined as permanent accommodation with the provision of facility-specific nursing services in addition to personal care services (160). It can also be referred to as a nursing home, extended care facility and skilled nursing facility (160).

Due to the complexity involved in collecting data within the setting of RAC the methodology for each chapter was different due to the following variables:

- Size
- Location
- Organisation
- Services provided
- Building type
- Allied health provided
- Social activities offered
- Location of exercise class

Consequently, the four RAC facilities that conducted research can be seen in Figure 3-1.

Table 3-1. Contextualisation of the RAC facilities that data collection occurred in for the thesis.

Variables	***RAC #1***	***RAC #2***	***RAC #3***	***RAC #4***
Chapter in thesis	*4,5, 7*	*4,5*	*4,5,6*	*7*
Control group	*N/A*	*N/A*	✓	✓
Exercise group	*N/A*	*N/A*	✓	✓
Size	*90 beds*	*137 beds*	*151 beds*	*40 beds*
Location	*Northern NSW*	*QLD*	*QLD*	*Northern NSW*
Organisation	*Not for Profit*	*Not for Profit*	*Private*	*Not for Profit*
Services provided:				
RAC	✓	✓	✓	✓
Respite care	✓	✓	✓	✓

Retirement living	✓	*N/A*	*N/A*	*N/A*
Palliative care	✓	✓	*N/A*	✓
Dementia wards	✓	✓	*N/A*	*N/A*
Building type	*Multi-story*	*Ground level*	*Multi-storey*	*Ground level*
Chapel/church within RAC facility	✓	✓	*N/A*	*N/A*
Allied health provided	*Physiotherapists, general practitioner, podiatrists, dietitians, and hairdresser*	*Physiotherapists, psychologists, podiatrists, dietitians, speech pathologists, dentist, optometrist and hairdresser*	*Physiotherapists, general practitioner, podiatrists, dietitians, and hairdresser*	*Physiotherapists, general practitioner, podiatrists, dietitians, and hairdresser*
Social activities offered	*Art and crafts; Bingo; regular outings and trips;*	*Art and crafts; regular outings and trips; Visiting entertainers;*	*Art, craft and mosaics; Zumba; Yoga and Tai Chi;*	*Art and crafts; Bingo, Visiting entertainers; Concerts; Movie*

	Visiting entertainers; Concerts Movie nights and exercise programs	*Movie nights and exercise programs*	*Bingo, Trivia, Games, Quizzes; regular outings and trips; Visiting entertainers; Concerts and sing-a-longs; Movie nights and exercise programs*	*nights and exercise programs*
Location of exercise class	*Multi-purpose room*	*Multi-purpose room*	*Multi-purpose room (exercise intervention occurred in dining room)*	*Multi-purpose room*

Chapter 4

Gait speed characteristics and its spatio-temporal determinants in nursing home residents: a cross sectional study

4.1 PREFACE

Before the publication of this manuscript, to the student's knowledge, there had been no research to investigate the spatio-temporal parameters of gait in adults living in RAC. This Chapter describes the gait speed and the spatio-temporal parameters of adults living in RAC via a cross-sectional study.

This manuscript was published in the Journal of Geriatric Physical Therapy (2017 Impact Factor: 1.51). The paper formatting has been modified in accordance with a consistent thesis-style and minor amendments suggested by thesis reviewers. The references (in-text and bibliography) are included at the end of the thesis. However, the grammar, headings, and terms are unaltered in accordance with the journal's publishing guidelines (US English). Thus, for consistency the terms "nursing home" and "spatio-temporal determinants" have been replaced with the word "RAC" and "spatio-temporal parameters", respectively.

In addition, portions of the data from this manuscript were presented at the following conferences:

Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (27-29th April 2017). Gait speed and the spatio-temporal determinants of residents in nursing homes. Poster presented at the International Conference on Frailty and Sarcopenia Research (Barcelona, Spain).

Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (31st-1st October/November 2016). You're never too old to walk. Oral presentation at the 15th National Conference of Emerging Researchers in Ageing Conference Canberra, (Australian Capital Territory, Australia).

Fien, S., Keogh, J. W. L., Henwood, T., & Climstein, M. (3rd-4th December 2015). Gait Characteristics and Muscle Function in Residential Aged Care Adults Oral presentation at the 2015 Gold Coast Health and Medical Research Conference Gold Coast, (Queensland, Australia).

<u>Citation:</u>

Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (2017). Gait speed characteristics and its spatio-temporal determinants in nursing home residents: a cross-sectional study. Journal of Geriatric Physical Therapy. DOI: 10.1519/JPT.0000000000000160.

4.2 Abstract

Low and slowing gait speeds among residential aged care residents are linked to a higher risk of disability, cognitive impairment, falls, and mortality. A better understanding of the spatio-temporal parameters of gait that influence declining mobility could lead to effective rehabilitation and preventative intervention. This study aims were to objectively quantify the spatio-temporal characteristics of gait in the residential aged care setting and define the relationship between these parameters and gait speed. One hundred residential aged care residents were enrolled into the study and completed three habitual gait speed trials over a distance of 3.66 m. Trials were performed using an instrumented gait analysis. The manner in which the spatio-temporal parameters predicted gait speed was examined by univariate and multivariable regression modelling. The residential aged care residents had a habitual gait speed of 0.63 ± 0.19 m/s, a stride length of 0.83 ± 0.15 m, a support base of 0.15 ± 0.06 m and step time of 0.66 ± 0.12 s. Multivariable linear regression revealed stride length, support base and step time predicted gait speed (R^2 = 0.89, $p<0.05$). Step time had the greatest influence on gait speed with each 0.1 s decrease in step time resulting in a 0.09 m/s (95% CI 0.08 - 0.10) increase in habitual gait speed. This study revealed step time, stride length and support base are the strongest predictors of gait speed among residential aged care adults. Given the impact of low and slowing gait speed in this population, future research should concentrate on developing and evaluating intervention programs that were specifically designed to focus on improving step time, stride length and support base in residential aged care adults. As gait speed has been shown to be predictive of many adverse events in older adults, we would also suggest that routine assessments of gait speed, and if possible their spatio-temporal characteristics be done on all residential aged care adults in an attempt to identify residents with low or slowing gait speed.

Keywords: *health professionals; gait speed; nursing home; spatio-temporal determinants*

4.3 INTRODUCTION

Walking is a key physical performance task for people of all ages, including older adults. The majority of older adults, especially those living in residential aged care settings have decreased physical activity (37) and poor physical function as indicated by their reduced gait speed, muscle strength and balance (13). Older adults with slower gait speeds are at higher risk of disability, cognitive impairment, institutionalization, falls, and mortality (4). While a variety of gait speed thresholds exist, healthy community-dwelling older adults tend to experience poorer health when their habitual gait speed is < 0.8 m/s, (4, 5) whereas for nursing home residents > 80 years of age, a threshold of < 0.5 m/s has been proposed (5, 161). A recent systematic review which included 34 studies quantifying the gait speed of residents living in nursing homes reported a mean habitual pace gait speed of 0.48 m/s (95% confidence interval (CI) 0.40-0.55) (162). Gait speeds this low suggest that most nursing home residents are limited in mobility and independence, have decreased stability and are at increased risk for many other age-related conditions (162).

Currently, little is known in relation to the physical determinants or risk factors for low gait speed in low-functioning older adults and those living in nursing home facilities. While McGough et al. (163) and Keogh et al. (52) have reported that measures of physical function, balance, lifetime physical activity levels and sitting time correlate with gait speed in these less functioning older cohorts, no studies have quantified the spatio-temporal parameters (e.g. step length, step rate) that determine gait speed in a nursing home population (164). Figure 4-1 presents a pictorial representation of the relationship between selected spatio-temporal parameters and gait speed. When compared to younger adults, older adults walk more slowly; have a shorter step length and a broader support base than their younger counterparts, with these differences more pronounced in older adults living in nursing homes and/or with a high risk of falls (21, 38, 42, 75).

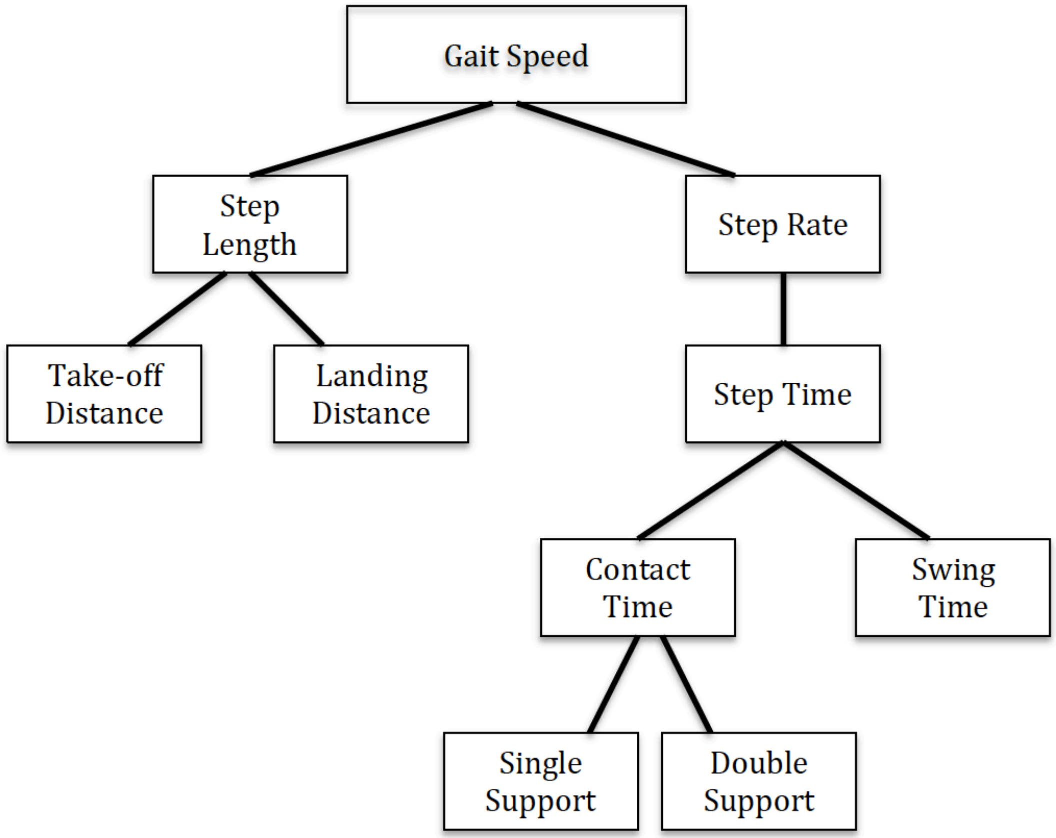

Figure 4-1. ***Deterministic model of gait speed outlining the direct relationships between the spatio-temporals parameters and gait speed.***

A greater understanding of nursing home residents' gait speed and spatio-temporal parameters may assist health professionals to identify nursing home residents at high risk of adverse events and allow for a more specific-tailored physical therapy and rehabilitation program for each individual (42). We would argue this is very important as indicated by a systematic review that found exercise-related improvements in older adults' gait speed are typically smaller in magnitude and more variable than the improvements in muscular strength (104).

Specifically, semi-regular monitoring of gait speed and spatio-temporal parameters could assist appropriate health professionals to prescribe resistance, balance and gait exercises that target their clients' major spatio-temporal limitations. The collection of this gait spatio-temporal data may also allow the exercise therapist to provide their client task-relevant augmented feedback (e.g. visual cues, instant or delayed feedback) during these exercises to improve the transfer of training to their habitual walking performance (165, 166).

4.3.1 Aims

This study aims were to objectively quantify the spatio-temporal parameters and gait speed of nursing home residents and to gain some insight into whether these spatio-temporal parameters may predict their gait speed.

4.4 Materials and methods

4.4.1 Recruitment and study design

The study employed a cross-sectional design, with data collected over an eight-month period across three nursing home facilities in South East Queensland, Australia. The facilities were from different providers that were either part of a small chain of nursing home facilities or a not for profit organisation. The flow of recruitment to assessment is represented in Figure 4-2. Facilities were approached via email and telephone follow-up seeking an expression of interest for participation. Following an expression of interest, nursing home facilities were visited and the study explained to the Service Manager.

Once the Service Manager approved the participation of their nursing home in the project, eligible participants were identified at a meeting between the project lead researcher and the Service Manager, head Registered Nurse and head Diversional Therapist. Ethical approval for this study was attained from the University Human Ethics Research Committee (RO 1823) and gatekeeper's approval obtained through the RAC facilities.

Based on study's eligibility, participants were eligible for inclusion if they were: a) aged 65 years and over, b) residing in a nursing home facility, c) ambulate independently or without a walking aid and d) could provide informed consent. The exclusion criteria included: a) end-stage terminal and/or life expectancy <6-months (ethical reasons), b) two person transfer or increased falls risk during ambulation (as assessed by the nursing home staff), c) unable to communicate or follow instructions (personal needs beyond the scope of this project) and d) behaviors that would endanger the participant or research staff.

All participants were approached personally about participation and given the opportunity to ask questions or raise concerns about the study. A total of 43 out of 166 participants discontinued on to the next stage with 19 not meeting the inclusion criteria and 24 declining to participate. Following this discussion and reading of the participant information sheet, participants provided their informed consent if they wished to participate. Twenty-three participants discontinued at this stage of the process due to, but not limited to, the following reasons: sick/unwell on the testing days, decided they did not want to participate, medical appointments, in hospital and family visiting/outings. A total of 100 participants took part in the study, with the primary investigator responsible for observing and administering all of the assessments.

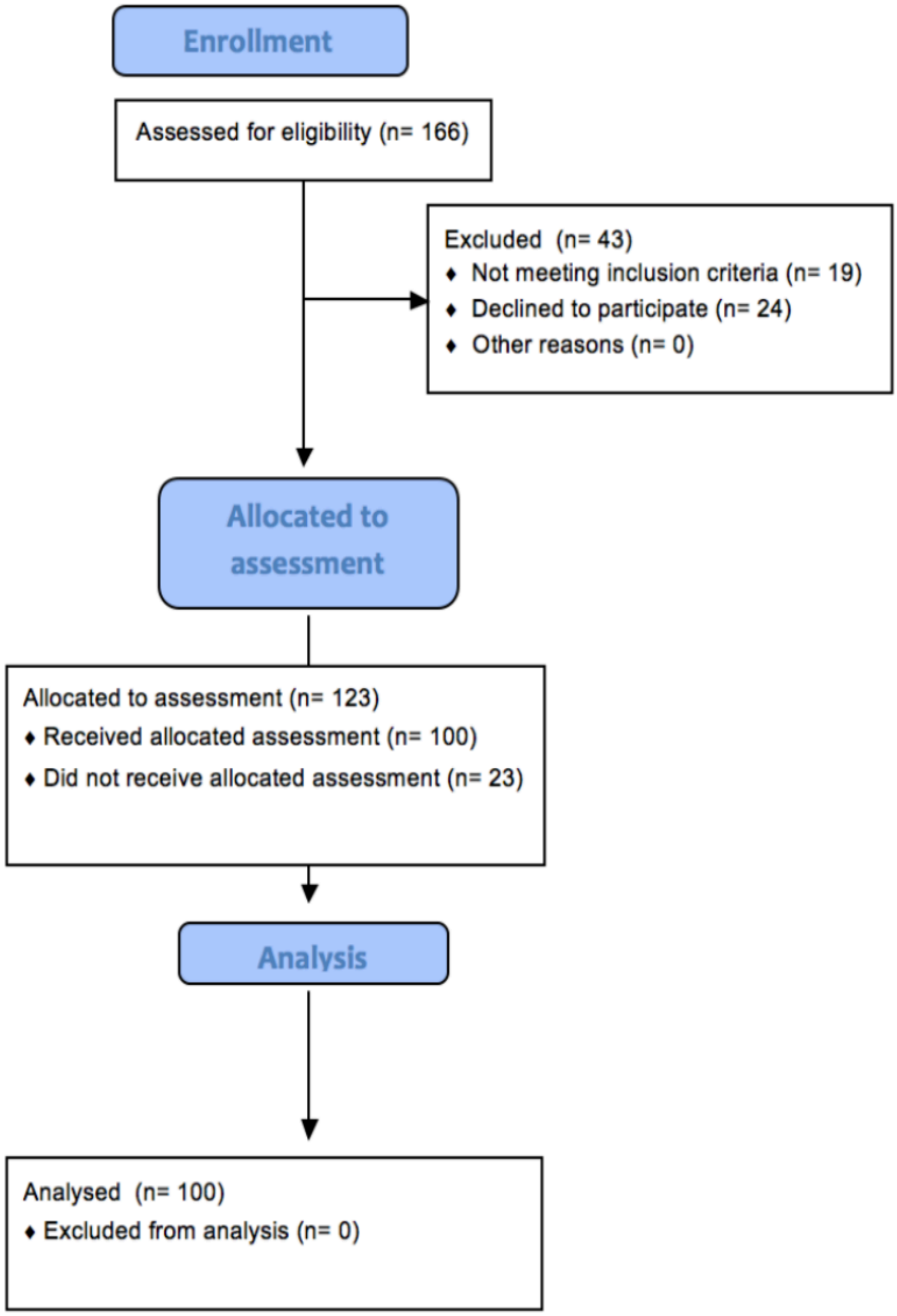

Figure 4-2. CONSORT flow diagram of the recruitment process within the nursing home settings.

4.4.2 Primary outcome measures: gait speed

Gait speed was assessed using a computer interfaced electronic system (model GaitMat II, EQInc, USA), which required participants to walk across a level pressure mat system that was 3.66 m (11.91 ft.) long (39). The concurrent validity of the spatio-temporal parameters of gait recorded with the GaitMat II is extremely high when compared to the criterion method of 3-D motion capture (R =.99) (27, 31). The Gait Mat II was chosen due to it being much more feasible to use in nursing home facilities and 3-D motion capture. The GaitMat II system automatically measured gait speed and spatio-temporal parameters, with this data automatically stored in a Microsoft Excel spreadsheet.

Participants completed the trials at their habitual gait speed in their regular footwear. The following instructions were provided, "Walk towards the end of the room in the centre of the mat at a pace that is comfortable for you". All measures were initiated from a standing start 2 m (6.56 ft.) from the GaitMat II platform in order to reduce the effect that acceleration or deceleration may have on the outcomes (3, 167). The average gait speed (m/s) from three attempts was used for data analysis. Participants were allowed as much rest as required between attempts, with rest periods typically being up to one minute.

4.4.3 Secondary outcome measures

A full spectrum of spatio-temporal gait parameters outputted were recorded. These spatio-temporal gait parameters included step length, stride length, support base, step time, swing time, stance time, single support time and double support time and are defined by the GaitMat II manual found in Table 4-1.

In addition, handgrip strength, the Mini-Cog test (168) and a simple five-item questionnaire (SARC-F) (169, 170) were collected for the purpose of cohort characteristics description. Residential aged care facility records provided other relevant descriptors including the number of medical conditions and medications.

4.4.4 Data management and statistical analysis

All data were initially checked for normality prior to analysis. As data were normally distributed, descriptive statistics are presented as mean and standard deviations for continuous variables. Descriptive statistics were provided on the total group (n=100), females (n=67) and males (n=33) as it was thought prudent to see if there were any significant differences between males and females in variables that may impact on their gait speed. A one-way ANOVA and post-hoc Tukey and Scheffe tests were performed to investigate between nursing home differences. Linear regression analyses were performed to gain insight into the potential determinants of gait speed (i.e. gait spatio-temporal parameters) in residents. Univariate analyses of all gait spatio-temporal parameters were employed to identify possible determinants of gait speed (two-tailed). Factors with a significance $p \leq 0.10$ determined from simple linear regression analyses were included in the multiple linear regression model. This multivariable model determined which combination of variables best-predicted gait speed in residents. The 95% confidence interval (95% CI) was included for the coefficients in the multivariable model. All data were analysed using SPSS statistic software (version 22) with statistical significance set at $p<0.05$ a priori.

Table 4-1. Spatio-temporal gait parameters and definitions as defined by the GaitMat II manual.

Spatio-temporal gait parameters	Definitions
Step length	The distance from the first switch closure of one footprint to that of the footprint on the contralateral side (14).
Stride length	The distance from the first switch closure of one footprint to the next footprint on the ipsilateral side (14).
Support base	The medial lateral distance across the mat to the innermost switch closure for one footprint from the innermost switch closure of the previous footprint on the contralateral side (14).
Step time	The time to the earliest switch closure of a footfall from the earliest switch closure of the previous footfall on the contralateral side (14).
Swing time	The time to the earliest switch closure of a footfall from the latest switch opening of the previous footfall on the ipsilateral side (14).
Stance time	The time to the latest switch opening of a footfall from the earliest switch closure of the same footfall (14).
Single support time	The time to the earliest switch closure of the next footfall on the contralateral side from the latest switch opening of the previous footfall on the contralateral side (14).
Double support time	The time to the latest switch opening of the previous footfall on the contralateral side from the earliest switch closure of a footfall (14).

4.5 RESULTS

4.5.1 Participants

One hundred of 166 (60.24%) invited, eligible residents were recruited to the study. There were no significant differences between all variables for nursing home cohorts in this study (p>0.05), thus data were combined into one group for analysis. Cohort data are presented in Table 4-2. The average age of the 100 residents was 85.7 (7.1) years with a mean gait speed of 0.63 (0.19) m/s, an average of 11.0 (4.9) medical conditions and 14.0 (5.8) prescribed medications. There were no significant differences with gait speed and spatio-temporal parameters, handgrips strength, sarcopenia status and medications and chronic diseases across males and females. However, males were significantly younger (p = 0.038) and had a lower Mini-Cog assessment (p = 0.002) in comparison to females.

Table 4-2. Characteristics of the cohort of 100 nursing home residents.

Parameter	Group Mean (SD)	Females (n=67) Mean (SD)	Males (n=33) Mean (SD)
Age, yrs	85.7 (7.1)	86.1 (6.6)*	85.0 (8.1)
Handgrip Strength, kg	11.1 (4.9)	10.7 (4.2)	11.7 (6.2)
Mini COG, #	1.3 (0.4)	1.3 (0.4)*	1.3 (0.5)
SARC-F, #	5.5 (3.3)	4.9 (3.3)	6.6 (3.1)
Medical Conditions, #	11.0 (4.9)	11.4 (4.9)	10.2 (4.9)
Medications, #	14.0 (5.8)	13.8 (6.1)	14.4 (5.3)
Gait speed, m/s	0.63 (0.19)	0.65 (0.20)	0.58 (0.16)
Step length, m	0.41 (0.08)	0.42 (0.07)	0.41 (0.07)
Stride length, m	0.83 (0.15)	0.84 (0.16)	0.81 (0.14)

Support base, m	0.15 (0.06)	0.16 (0.06)	0.15 (0.07)
Step time, s	0.66 (0.12)	0.64 (0.12)	0.70 (0.12)
Swing time, s	0.42 (0.07)	0.41 (0.07)	0.44 (0.08)
Stance time, s	0.91 (0.20)	0.88 (0.19)	0.98 (0.20)
Single support Time, s	0.42 (0.07)	0.41 (0.06)	0.43 (0.08)
Double support time, s	0.24 (0.07)	0.23 (0.06)	0.27 (0.08)

= number; Mini COG = Mini Cognitive test; SARC-F = Sarcopenia Five-Item Questionnaire; yrs = years

* = Statistical significance $p<0.05$.

The majority of participants (79%, n = 79/100) presented with below normal habitual gait speeds (< 0.80 m/s), whilst 26% (n = 26/100) ambulated at below the mean reported for nursing facilities residents (< 0.48 m/s, 95% CI 0.396-0.554) (162).

Results of the univariable linear regression analyses identified three spatio-temporal factors as being predictive of gait speed: stride length (p<0.001), support base (p<0.001) and step time (p=0.002) (see Table 4-3). Of these factors, stride length contributed to the largest change in gait speed, with each 0.1 m increase in stride length resulting in an average 0.09 m/s (95% CI 0.06 – 0.13) faster habitual gait speed.

Table 4-3. Univariable and multivariable linear regression model of the spatio-temporal predictors for habitual gait speed in 100 residents living in nursing home facilities.

Factor	Univariable		Multivariable	
	Coefficient (95% CI)	***p*-value**	**Coefficient (95% CI)**	***p*-value**
Stride length, m	0.93 (0.55 – 1.31)	< 0.001	0.83 (0.74 – 0.92)	< 0.001
Support base, m	-0.51 (-0.77 to -0.26)	< 0.001	-0.44 (-0.68 to -0.21)	< 0.001
Step time, s	-0.70 (-1.13 to -0.27)	0.002	-0.92 (-1.03 to -0.81)	< 0.001

CI = Confidence Interval.
R^2 of multiple regression equals 0.892.
Note: All results significant $p<0.05$.

The multivariable linear regression model that included stride length, support base and step time predicted 89% (R^2 = 0.89) of the variation in gait speed (see Table 4-3). Specifically, step time contributed to the largest change in gait speed with every 0.1 s decrease in step time resulting in a mean increase in gait speed of 0.09 m/s (95% CI 0.08 – 0.10). A 0.1 m increase in stride length was also associated with a mean increase of 0.08 m/s (95% CI 0.07 – 0.09) in gait speed. The third determinant identified in the multivariable regression, support base appeared to have a smaller effect on gait speed, with a 0.1 m decrease in support base resulting in a mean gait speed increase of 0.04 m/s (95% CI 0.02 – 0.07).

4.6 Discussion

This study demonstrated that nursing home residents who can self-ambulate with or without a walking aid still walk at a gait speed (0.63 ± 0.19 m/s) and possess spatio-temporal parameters that place them at high risk of falls and other adverse age-related events (38, 42, 171). A total of 79 participants presented with below normal habitual gait speeds (< 0.80 m/s), which is a threshold defined to screen for sarcopenia in adults aged 80 years and older (172). A total of 27 participants also walked at a threshold below 0.48 m/s which a meta-analysis of 48 studies found to be the mean gait speed for older adults in nursing homes (162).

Results of the regression analyses also indicated that nursing home residents who ambulated at a slower habitual gait speed were more likely to have an increased step time, shorter stride length and a wider support base than their more ambulatory counterparts. While the finding that some spatio-temporal parameters do predict gait speed is not overly surprising, to our knowledge this is the first study to investigate the potential for spatio-temporal parameters to determine gait speed in the nursing home setting. The importance of the spatio-temporal parameters in determining gait speed also appear consistent with Sterke et al. (42) and Taylor et al. (38) who demonstrated that slower older walkers with increased falls risk had shorter stride lengths, longer double support times and a wider support base when compared to aged matched individuals with no falls history.

The significant ability of spatio-temporal parameters such as step time, stride length and support base to determine gait speed in the current study ($R^2 = 0.89$) and falls in previous studies (38, 42) would appear to reflect a variety of biomechanical concepts. For example, the ability of step time and stride length to determine gait speed may be explained by the impulse-momentum relationship and/or the nursing home residents' reduced ability to maintain balance during the gait cycle. It is fair to conclude that reduced lower-body muscle strength and power may mean that the nursing home residents require greater single/double support times to produce the necessary impulse (force multiplied by time) to propel their body forward during the gait cycle (127). Their reduced force production ability and greater stance time would then contribute to a reduced stride length, increased step time and ultimately a reduced habitual gait speed. Poor stride length may also be suggestive of shuffling gait and low plantar flexor and hip flexor strength (127). Therefore, certain exercises such as calf raises and leg raises coupled with gait training may need to be incorporated in resistance training programs to improve gait speed in nursing home residents (3).

The clinical significance of this study is that gait speed characteristics and spatio-temporal parameters are becoming more easily measured and analysed in nursing home settings. Health professionals can then use this individualised gait data to identify residents at risk of adverse events and intervene where appropriate by providing an individualised exercise intervention for each resident. In doing so, residents are likely to benefit more from these exercise programs as they are better tailored to the specific spatio-temporal parameters underlying the participants' poor gait speed and/or falls risk. Such an approach may also improve exercise adherence as these programs can better concentrate on improving gait performance in activities of daily living (ADL) (145).

Collectively, the manner in which the nursing home residents walk (as described by their spatio-temporal parameters) have major implications to exercise therapy and rehabilitative approaches to improving gait speed in this cohort. With the clinical implications being that if health professionals can continually monitor and assess gait speed and spatio-temporal parameters, we may be able to decrease or prolong the number of residents who are induced into the vicious cycle of reduced physical activity and decreased mobility and physical performance that have a direct effect on their health and survival.

However, it is also possible that the tendency for the slower nursing home residents to have shorter stride lengths, increased step times and wider support bases may be indicative of a compensation for their reduced strength and dynamic stability. Longer strides and a narrower support base increase the distance that the centre of mass travels outside the anterior-posterior and medial-lateral bases of support, respectively (127). Sherrington et al. (173)

reported that exercise programs that do not sufficiently challenge balance may actually increase rather than decrease the risk of falling of nursing home residents, we would recommend that nursing home residents with short strides and wide support bases focus initially on improving their static and dynamic balance. Once balance has been improved in the anterior-posterior and medial lateral directions, these residents may further prioritise resistance and gait retraining to safely improve their gait speed and overall mobility.

Given the interplay between decreasing mobility and increasing disability, the monitoring of gait speed by health professionals (and if possible the primary spatio-temporal parameters) on at least an annual basis in the nursing home setting has been recommended (108, 174). For those nursing home residents identified with poor and slowing mobility, systematic review evidence suggests that regular progressive resistance and balance training can improve their habitual gait speed by 0.07 m/s (95% CI 0.02-0.11) when compared to non-exercising controls (136). While these reported improvements in gait speed are positive, there may be two potential criticisms of the studies reviewed in this meta-analysis (and the wider literature). The first is that the studies have typically used quite generic exercise prescriptions that focus on improving muscular hypertrophy and strength in a variety of muscle groups. Based on emerging evidence that reduced gait speed in older adults is primarily a result of reduced ankle plantarflexor rather than hip or knee extensor moment and muscle power, (127) a greater focus on increasing the muscle strength and power of the plantarflexors compared to the traditional focus on the knee and hip extensors may be warranted.

In addition, the majority of studies in this area that have included balance training primarily used static balance tasks that require the older adults to hold a position for a period of 10-20 s e.g. two feet stands on unstable surface or with eyes closed or semi-tandem/tandem stance. Based on our results, we suggest that dynamic balance ability, which would appear more closely related to the balance requirements of human gait, be taught by health professionals on a weekly basis. Therefore, nursing home residents may obtain greater gait speed benefit from performing dynamic balance tasks (e.g. stepping and perturbation response) than static balance tasks (175-177).

The Gait Mat II provided a feasible, reliable and valid tool to measure gait speed and spatio-temporal parameters in nursing home adults (178-180). New equipment has been developed since the data collection of this study. One suggestion for future studies would be to use inertial sensors (181) which may be a more portable and affordable gait assessment. Such advancements in inertial sensor technology would more easily allow health professionals to routinely monitor gait speed and spatio-temporal parameters in the nursing home setting, which may further increase allow the development of targeted exercise programs for each nursing home resident.

4.6.1 Study limitations

Participation selection bias is a limitation that may have influenced our findings as the inclusion criteria deemed that a participant should have the ability to walk with or without an aid. A total of 55% of residents in the nursing home facilities were ineligible because of the inability to mobilise or because they were deemed too high a risk to participate. Because of this bias in selecting individuals who were ambulant (with or without assistive devices), the gait speed and spatio-temporal parameters obtained in this study may not be generalised to all nursing home residents. Nevertheless, the participants in the current study were still below the cut off for physical performance and at risk of further decreased disability, cognitive decline and mortality, (182) with every 0.1 m/s reduction in gait speed equating to a 10% decrease in older adult's ability to perform ADLs (4). It must also be acknowledged that static or dynamic balance ability were not directly assessed in this study. Therefore, while our proposition of poor dynamic balance contributing to the reduced gait speed of nursing home participants has some experimental support, (183, 184) we cannot explicitly state that is the case with our participants.

4.6.2 Conclusion

This is the first study to investigate gait speed characteristics and spatio-temporal parameters in the nursing home setting. While our cross-sectional study suggests that step time, stride length and support base are highly predictive of gait speed in nursing home residents, longitudinal research is required to determine if changes in these three spatio-temporal parameters may be predictive of changes in gait speed. If these longitudinal relationships between gait speed and spatio-temporal parameters can be found, health professionals may be better able to alter aspects of their exercise prescription and augmented feedback approach to improve outcomes for nursing home residents.

Chapter 5

Gait speed and adverse events in nursing home residents: a prospective cohort study

5.1 PREFACE

Before the publication of this manuscript, to the student's knowledge there had been no research to investigate the incidence of adverse events and potential relationships to gait speed and spatio-temporal parameters in Australian adults living in RAC. This chapter estimated the incidence and types of adverse events experienced by 100 residents in RAC settings for a period of six-months.

This manuscript was published in Journal of Nursing Home Research Sciences. The paper formatting has been modified in accordance with a consistent thesis-style and minor amendments suggested by thesis reviewers. The references (in-text and bibliography) are included at the end of the thesis. However, the grammar, headings, and terms are unaltered in accordance with the journal's publishing guidelines (US English). Thus, for consistency the term "nursing home" has been replaced with the word "RAC".

Some of the data from this manuscript was presented at the following conferences:

Fien, S., Henwood, T., Climstein, M., Rathbone, E., & Keogh, J.W.L. (8-10th November 2017). How falls, wounds and hospitalisation are affecting nursing home residents. Rapid fire presentation at the 50th Annual Australian Association of Gerontology Conference Crown, Perth, (Western Australia, Australia).

Fien, S., Climstein, M., Henwood, T., Rathbone, E., & Keogh, J. W. L. (6-7th November 2017). Adverse events and gait speed in nursing home residents. Paper presented at the 16th National Conference of Emerging Researchers in Ageing Conference Perth, (Western Australia, Australia).

Citation:

Fien, S., Climstein M., Henwood, T., Rathbone, E., & Keogh, J. W. L. (2017). Gait speed and adverse events in nursing home residents: a prospective cohort study. The Journal of Nursing Home Research Sciences (JNHRS), 3, 81-87. DOI: 10.14283/jnhrs.2017.13.

5.2 ABSTRACT

Falls, wounds and hospitalization are serious adverse events that may result in reduced independence and quality of life, and contribute to higher risks of disability and death in residential aged care (RAC) facilities. Objectives: To quantify the incidence of events (falls, hospital admissions and wounds) in nursing home residents and to determine if gait speed thresholds can predict falls. Design: A prospective cohort design was used to estimate the incidence and types of adverse events. Setting: Three nursing homes on the Gold Coast/ Northern New South Wales, Australia. Participants: 100 nursing home adults consented to participate in this project. Measurements: The primary outcome included the number of adverse events (falls, wounds and hospital admissions) accessed through the nursing homes records. We used negative binomial regression models adjusted for potential confounders to examine associations between gait speed group and falls suffered by residents in nursing home settings, and we reported incidence rate ratios (IRRs) with 95% CIs and the actual P-value. Results: During the six-months, there were a total of 226 falls, 243 wounds, 65 hospital admissions and 29 deaths with 12% of the residents having a fall(s), wound, admitted to hospital and dying in the 6-month period. Gait speed was not a statistically significant factor that impacted adverse events. However, for every additional hospital admission there was a 28% increased rate of falling, for every additional wound there was a 7.8% increased rate of falling and for every kilogram increase in handgrip strength there was a 4.4% increase rate of falling. Residents were also found to have an increased rate of falling if they were female (65.5%) and a decreased rate of falling with a positive impairment Mini-Cog score residents were likely to have a 52% decrease in their rate of falling when compared with negative cognitive impairment. Conclusion: The incidence of adverse events in Australian nursing homes is high, suggesting that continual refinement of assessment, education, awareness and management processes are required to improve resident outcomes. In particular, falls reduction interventions appear important, as they would likely reduce the number of hospital admissions and wounds in the nursing home setting.

Key words: *adverse events, falls, hospitalisation, nursing homes, wounds.*

5.3 Introduction

With an ageing population and rising life expectancy rates, older adults are likely to move into nursing homes as their physical and/or cognitive function declines. Falls, hospitalization and wounds are serious problems that result in higher risks of disability, loss of independence, reduced quality of life and mortality in nursing homes (15). These adverse events are also proving to become very costly with falls being the leading cause of injury-related hospitalization in adults aged 65 years or older. In those aged 85 years and over, 4% of men and 7% of women are admitted to hospital annually as result of a fall (152). As a result, the cost of falls is expected to rise to $1.4 billion in Australia by 2051.

Thus, continual improvements in fall prevention programs are required in order to reduce the falls incidence rate or additional strain on the health expenditure will incur (185). One component of the high costs of falls is the need for hospital beds. In 2010, there were 240,000 hospital bed days per year related to falls in Australia, with this expected to nearly double to 450,000 hospital bed days by 2051 (152).

To the authors' knowledge, little research has investigated the incidence of adverse events specific to falls, wounds and hospital admissions in Australian nursing home adults. A recent document on adverse events in Australian nursing home residents is a 2014-15 Australian Government report which has provided insight into older adults in hospital, however there appears to be a lack of peer-reviewed research that focuses purely upon nursing home settings (186). Residents often have multiple chronic diseases, a sarcopenic status and take multiple prescribed medications, with the interaction of these factors placing the residents at a high risk of adverse events (187, 188). Ironically, residents of nursing homes are among the least researched older adult group even though they have the highest rates for falls and hospital admissions and are among the highest consumers for prescribed medications (162).

A recent systematic review has indicated that a significant predictor of adverse events including mobility disability, cognitive decline, mortality, falls and institutionalisation for community-dwelling older adults (aged 65 and older) was low gait speeds (4). In 2012, Sterke et al. (42) sought to extrapolate the findings for community-dwelling older adults to those in nursing homes by examining whether gait speed was a significant predictor of short-term falls risk in 57 nursing home residents with moderate to severe dementia in the Netherlands. Sterke et al. (42) conducted a longitudinal study and assessed the gait performance of the nursing home residents with a computer-interfaced instrumented pressure mat every three months for a period of 15 months. A reduced gait speed (OR = 1.22; 95% CI 1.04 – 1.43) and reduced mean stride length (OR = 1.19; 95% CI 1.03 – 1.40) were the strongest gait predictors for falling within three months (42).

Knowing this, we wanted to investigate if in the Australian context gait speed could predict adverse events in six-months with nearly double the number of participants. Such a study would appear warranted as Keogh et al. (52) reported that a randomly selected sample of 100 nursing home resident's mean (SD) walking speed was 0.37 (0.26) m/s, a value substantially less than a recent meta-analyses of 34 studies that reported the nursing home residents' mean walking speeds to be 0.48 m/s (95% CI 0.40 – 0.55) (13). As very few studies have used gait speed to predict adverse events in nursing home residents, additional research utilising functional performance tasks such as gait speed to predict adverse events in Australian nursing homes appears warranted.

5.3.1 Aims

The primary aim was to quantify incidence of adverse events in Australian nursing home residents over a period of six-months. The secondary aim was to determine if gait speed thresholds could predict the frequency of falls in nursing home residents. We hypothesised that the incidence of adverse events (i.e. falls) in Australian nursing home residents would be greater than what is commonly reported for community-dwelling older adults and that gait speed thresholds could predict falls in Australian nursing home residents.

5.4 MATERIALS AND METHODS

5.4.1 Methods

A prospective cohort design was used to estimate the incidence and types of adverse events experienced by 100 residents in nursing home settings for six-months. Participants were eligible for inclusion if they were: (i) aged 65 years and over, (ii) residing in a nursing home facility, (iii) able to self-ambulate with or without a walking aid and (iv) could provide informed consent.

The exclusion criteria included: (i) end-stage terminal and/or life expectancy <6-months (ethical reasons), (ii) two person transfer or increased falls risk during ambulation, (iii) unable to communicate or follow instructions (personal needs beyond the scope of this project) and (iv) behaviours that would endanger the participant or research staff.

All participants were approached personally about participation and given the opportunity to ask questions or raise concerns about the study. A total of 100 participants supplied informed consent and took part in the study whereby the primary investigator was responsible for observing and administering all of the testing.

5.4.2 Recruitment and study design

Three nursing homes from Northern NSW/Gold Coast were approached and recruited for participation via telephone and email. A meeting was arranged with the facility Service Manager at each site; following an explanation of the procedures, purposes, benefits and associated risks of the study, potential participants were identified with the Service Manager.

The primary investigator went and visited all potential participants and explained the procedures, purposes, benefits and associated risks of the study, participants also had the opportunity to ask questions. A total of 43 out of 166 participants discontinued on to the next stage with 19 not meeting the inclusion criteria and 24 declining to participate. Following this discussion and reading of the participant information sheet, participants provided their informed consent if they wished to participate. Twenty-three participants discontinued at this stage of the process due to, but not limited to, the following reasons: sick/unwell on the testing days, decided they did not want to participate, medical appointments, in hospital and family visiting/outings. A total of 100 participants took part in the study, with the primary investigator responsible for observing and administering all of the assessments. A total of 100 residents (66 females and 34 males), aged between 66 and 99, with mean (SD) 85.5 (7.2) years, provided written informed consent for the study. The final sample obtained was a convenience sample from all three nursing homes. Participant recruitment and assessment occurred over a nine-month period whereby gait speed data was collected when the participant informed consent and the six-month commenced from the date the gait speed was completed.

The flow of recruitment to assessment is represented in Figure 5-1. Ethical approval for this study was attained from the University Human Ethics Research Committee (RO 1823) and gatekeeper's approval obtained through the nursing homes.

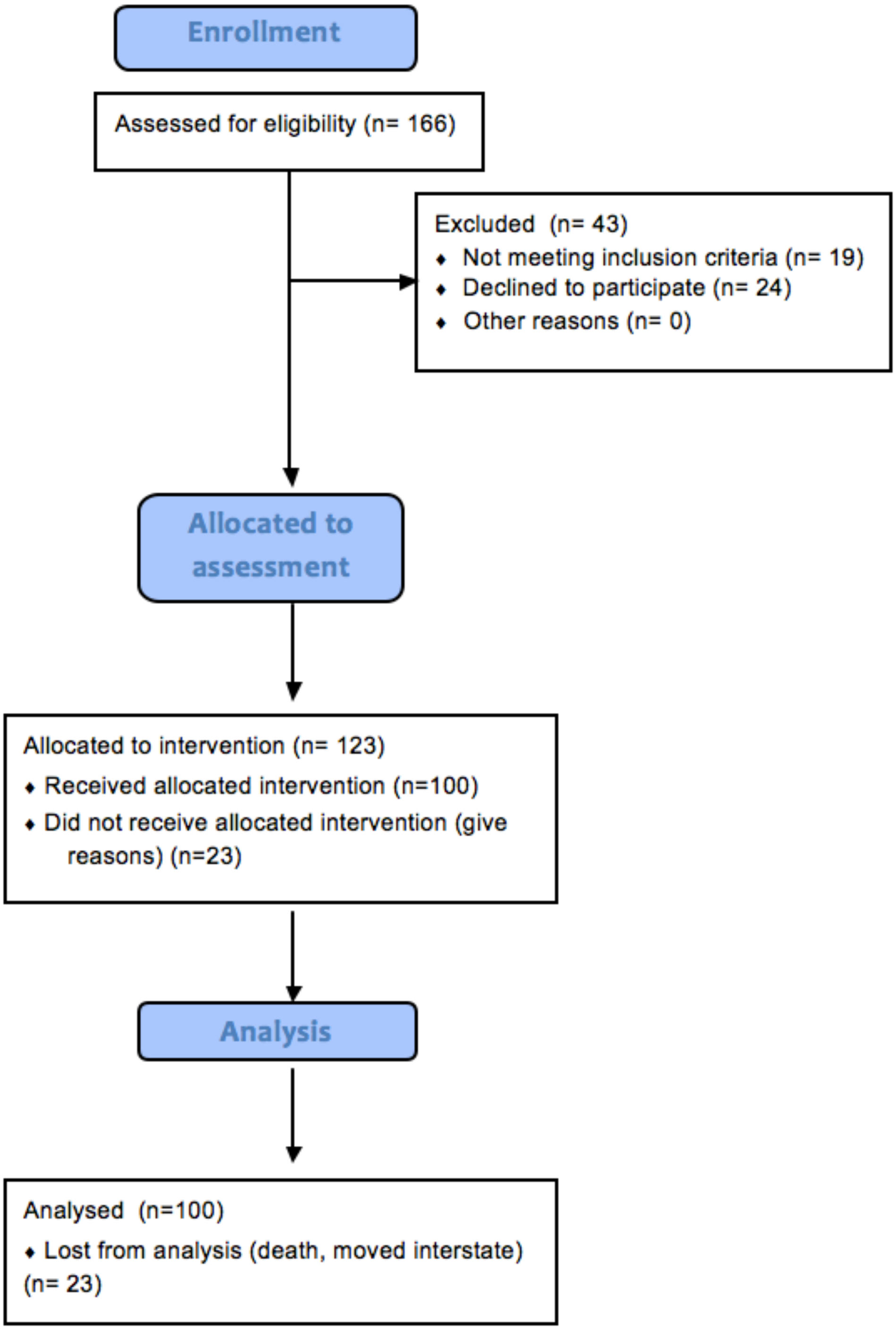

Figure 5-1. CONSORT flow chart diagram of the recruitment process within the nursing home facility.

5.4.3 Adverse events

Adverse events were defined by the World Health Organization (189) as an injury caused by medical management or complication rather than by the underlying disease itself, and one that results in either prolonged healthcare, or disability at the time of discharge from care, or both (189). Adverse events (falls, wounds, hospital admissions and deaths) information was collected by the nursing home staff and nurses, for a total of six-months' post gait speed assessment. A file audit was then completed by the investigator to record the adverse events; the information was recorded straight onto a password protective excel spreadsheet. A fall was defined as unintentionally coming to rest on the ground, floor, or other lower level (190). Hospital admission was defined as an individual who met the criteria for admission to the hospital category and care type, and underwent a hospital's admission process (documented) to receive treatment and/or care for a period of time – minimum four hours for medical admissions (186). Wounds were defined as the result of tissue damaged by trauma. This may be deliberate, as in surgical wounds of procedures, or due to accidents caused by blunt force, projectiles, heat, electricity, chemicals or friction (99).

5.4.4 Gait

The GaitMat II system measured the participants gait speed as they walked across a level pressure mat system that was 3.66 m (11.91 ft.) long (39). Three trials were completed at the participants' habitual speed, with the following instructions provided to the participants, "Walk towards the end of the room in the centre of the mat at a pace that is comfortable for you". An extra 2 m (6.56 ft.) platform was included on both ends of the GaitMat II in order to reduce the effect of acceleration or deceleration (3, 167). Participants were allowed as much rest as required between attempts, with rest periods typically being up to one minute. For safety reasons, all participants wore their own preferred footwear or walked barefoot and were spotted by the primary researcher who followed each participant with the average gait speed used for data analysis.

5.4.5 Other measures

In addition, handgrip strength, the Mini-Cog test (27) and SARC-F questionnaire (169, 170) were collected for the purpose of cohort characteristics description. Nursing home facility records provided other relevant descriptors including the number of medical conditions and prescribed medications for each resident.

5.4.6 Data management and statistical analysis

Three gait speed thresholds were defined; (i) ⩾0.8 m/s; (ii) 0.61 to 0.79 m/s; ⩽ 0.6 m/s. Baseline categorical variables like gender and gait speed group were tested using chi-square tests to determine if these characteristics were similar in the three nursing homes. Frequencies were reported for categorical variables. All continuous data were initially checked for normality prior to analysis. As data were normally distributed, descriptive statistics are presented as mean and standard deviations for continuous variables. A one-way ANOVA and post-hoc Tukey and Scheffe tests were performed to determine if statistically significant differences existed between the three nursing home facilities.

The results for falls were reported when it comes to finding a relationship between gait speed and an adverse event. Chi-square and logistic regressions were conducted to examine the relationships between gait speed and other adverse events but these did not turn out to be statistically significant. The total number of cases of adverse events were computed, as well as the incidence as reflected by the number of residents who suffered an adverse event, out of 100 residents at risk. The counts and percentages who suffered an adverse event were also calculated by gait speed group.

A Poisson regression was run to predict the number of falls in nursing home in the last six-months based on the gait speed group and the number of hospital admissions within those six-months. However, the data were over dispersed and a negative binomial regression with custom parameter was performed to correct for over dispersion. For the number of falls in the time frame of six-months, we report incidence rate ratios (IRRs) with 95% CIs and the actual P-value (191). All data were analysed using SPSS statistic software (version 22) with statistical significance set at $p<0.05$ a priori.

5.5 RESULTS

5.5.1 Participants

One hundred of the 166 (60.2%) invited, eligible adults were recruited to the study. There were no significant differences between all variables for the three RAC cohorts in this study (P>0.05), thus the data was combined into one group for analysis. Table 5-1 summarises the characteristics of study participants. The average age of study participants was 85.5 (SD: 7.2) years old. The majority of participants were female (66%) and 29 deaths (15 females) occurred during the 6-month period with the average age being 85.3 (SD: 6.5) years ranging from 79 to 97 years at the time of death. The residents took an average of 14.0 (SD: 5.8) medications and had a total of 11.0 (SD: 4.9) medical conditions.

Table 5-1. Characteristics of the 100 adults living in RAC aged 66 to 99 years.

Characteristics	Frequency
Age mean (SD)	85.5 (7.2)
Sex	
Male	34
Female	66
Number of chronic diseases	
1-5	11
6-10	46
11+	43
Total medications	
1-5	7
6-10	23
11-20	57
20+	13
Psychotropic medications	69
Falls	
Fell once	24
Fell twice	14

Fell three times	12
Fell > 3	23
Total number of residents who suffered a fall	73
Gait aids	
Ambulant	18
Walking stick/Wheelie walker	73
Wheelchair	9
Fall: time of day	
12am – 7:59am	15
8am – 3:59pm	33
4pm – 11:59pm	25
Hospital admissions	
Admitted once	27
Admitted twice	9
Admitted ≥3	4
Total number of residents placed into hospital	40
Wounds	
1-5	37
6-10	6
11+	2
Total number of residents who suffered wounds in 6 months	45
Gait speed threshold	
≥ 0.80 m/s	23
0.61 to 0.79 m/s	31
≤0.6 m/s	46
Handgrip strength (kg) mean (SD)	11.1 (4.9)
SARC-F* Score	
"Minimal risk"	33
"At risk"	67
Mini-Cog Score	

Negative cognitive impairment	25
Positive cognitive impairment	75

* SARC-F = Sarcopenia Five-Item Questionnaire

Many of the 100 participants experienced adverse events during the six-months of data collection (refer to Table 5-2). Of the 100 participants, 73 fell during the follow-up period with 24 falling once and 49 falling two or more times. One third of the residents fell between 8:00 am and 3:59 pm (33%). Forty-two residents were admitted to hospital with the majority of these individuals (29 residents, 69%) being hospitalized once in the six-month period. The numbers of days in hospital ranged from 1 to 30 days. There were 45 residents who received treatment for wounds. The majority, (79%, n = 79) of residents had a low gait speed according to European Working Group on Sarcopenia in Older People (EWGSOP) criteria (101) that was characterised as normal (< 0.80 m/s) and 26% (n = 26) ambulated below the mean reported for adults living in RAC in the local area (< 0.37 m/s) (52).

Table 5-2. Adverse events by gait speed thresholds after a period of six-months in 100 adults living in RAC.

Adverse events			Gait Speed Thresholds		
	No. of cases	**No. of Individuals**	**≤ 0.60 m/s** *n* (%)	**0.61 to 0.79 m/s** *n* (%)	**≥ 0.80 m/s** *n* (%)
Falls	226	73	33 (45.2)	26 (35.6)	14 (19.2)
Wounds	243	45	21 (46.7)	16 (35.6)	8 (17.7)
Hospital admissions	65	40	17 (42.5)	14 (35.0)	9 (22.5)
Deaths	29	29	16 (55.2)	7 (24.1)	6 (20.7)

n (%) represent the number of residents (%) who experienced any of the four adverse events (falls, wounds, hospital admissions for deaths) during the six-month period.

A negative binomial regression was run to predict the number of falls in RAC facilities in a six-month follow up based on their baseline gait speed. Specifically, the residents were categorized into one of three gait speed groups: ≤0.6 m/s, 0.61 – 0.79 m/s and ≥0.80 m/s. The gait speed threshold of ≥0.80 m/s was used as the reference group. The results of univariable regression analyses (Table 5-3) indicated that hospital admissions (IRR = 1.34, 95% CI 1.11 - 1.62, P = 0.002), wounds (IRR = 1.10, 95% CI 1.03 - 1.17, P = 0.004), SARC-F (IRR = 1.07, 95% CI 1.00 - 1.15, P = 0.062), handgrip strength (IRR = 1.07, 95% CI 1.02 - 1.12, P = 0.005) and Mini-Cog (IRR = 0.59, 95% CI 0.36 - 0.97, P = 0.037) were statistically significant predictors of falls at the 0.10 significance level. In contrast, gait speed thresholds (below or equal to 0.6 m/s and 0.61 – 0.79 m/s) were not statistically significant predictors of falls in adults living in RAC (P = 0.379 and P = 0.297, respectively).

Table 5-3. Univariable negative binomial regression model (IRRs with 95% CIs) to predict the number of falls over six-months in 100 adults living in RAC.

Parameters	IRR	95% CI	*P*-value
Number of hospital admissions*	1.34	1.11 – 1.62	.002
Number of wounds*	1.10	1.03 – 1.17	.004
Mini-Cog: positive impairment*	0.59	0.36 – 0.97	.037
Chronic diseases**	1.04	1.00 – 1.09	.053
Handgrip strength (kg)*	1.07	1.02 – 1.12	.005
SARC-F**	1.07	1.00 – 1.15	.062
Medications	1.02	0.98 – 1.06	.387
Sex: female	0.86	0.53 – 1.38	.532
Age (years)	1.00	0.97 – 1.03	.926
Gait speed threshold†			
≤0.6 m/s	1.30	0.72 – 2.35	.379
0.61 – 0.79 m/s	1.40	0.75 – 2.62	.297

* = Statistically significant $P<0.05$. ** = Statistically significant $P<0.1$.

† = Reference group is gait speed ≥0.80 m/s.

IRR = Incidence Rate Ratio; CI = Confidence Interval

Variables that were significantly associated with a fall at the 0.10 significance level (hospital admissions, wounds and Mini-Cog) were included in a multivariable regression model, and adjusted for other covariates including age, sex and gait speed group. Results of the multivariable regression are provided in Table 5-4. These results indicated that hospital admissions (IRR = 1.28, 95% CI 1.07 - 1.53, P = 0.006), wounds (IRR = 1.08, 95% CI 1.02 - 1.14, P = 0.008), handgrip strength (IRR = 1.04, 95% CI 1.00- 1.09, P = 0.040), sex: female (IRR = 1.66, 95% CI 1.03 – 2.65, P = 0.037) and Mini-Cog (IRR = 0.48, 95% CI 1.03 - 2.65, P = 0.002) were statistically significant predictors of falls.

Hence for every unit increase in previous hospital admissions, the incidence rate (or rate of falls) increases by 28%, for every unit increase in wounds; the incidence rate of falls increases by 7.8% and for every additional kilogram increase in handgrip strength the incidence rate of falls increases by 4.4%. Residents who were female had an increased risk of falling by 65.5% compared to males; residents were found to have a 51.7% decrease in the rate of falling if they scored a Mini-Cog score of positive impairment. Age, gait speed thresholds below and/or under 0.6 m/s and 0.61 – 0.79 m/s, SARC-F score, number of chronic diseases and number of medications were not statistically significant and thus did not influence the rate of falling.

Table 5-4. Multivariable negative binomial regression model (IRRs with 95% CIs) to predict the number of falls over six-months in 100 adults living in RAC.

Parameters	**IRR**	**95% CI**	***P*-value**
Handgrip strength*	1.04	1.00 – 1.09	.040
Mini-Cog: positive impairmen	0.48	1.03 – 2.65	.002
Number of hospit admissions*	1.28	1.07 – 1.53	.006
Number of wounds*	1.08	1.02 – 1.14	.008
Sex: female*	1.65	1.03 – 2.65	.037
Gait speed threshold†			
≤0.6 m/s	1.10	0.65 – 1.88	.715
0.61 – 0.79 m/s	.93	0.53 – 1.63	.792
Chronic diseases	1.00	0.97 – 1.05	.842
Medications	1.01	0.98 – 1.05	.518
SARC-F	1.06	0.99 – 1.14	.060
Age	0.99	0.96 – 1.02	.394

* = Statistically significant P<0.05. † = Reference group is gait speed ≥0.80 m/s.

IRR = Incidence Rate Ratio; CI = Confidence Interval; m/s = metres per second.

5.6 Discussion

The present study reported that over a period of six-months, a sample of 100 adults living in RAC experienced a total of 226 falls, 243 wounds, 65 hospital admissions and 29 deaths. The rate of these adverse events happening within RAC appeared substantially greater than what is reported for community-dwelling older adults (4). The frequency of these adverse events provides an ongoing challenge in the RAC setting. For example, the rate of falls in males living in RAC were seven times higher than those living in the community in 2009-10; whilst the equivalent comparison for females was five times higher (162).

The results of the current study and findings reported within the literature for older adults (192, 193) show that females may be 65.5% more likely to fall than compared to males; suggesting that females should be the focus of fall prevention programmes in RAC. In Australia, Everett and Powell (98) found skin tears constituted 41% of known wounds amongst a RAC facility that contained 347 residents (with an average age of 80 years) with an average of 22 skin tears occurring each month.

During the six-months of the current prospective study, 45% of residents experienced a wound, higher than that of Everett and Powell which had 38% of residents experiencing a skin tear in six-months (98). Wounds experienced by up to 50% of residents in RAC settings is a major concern due to the associated link of pain, risk of infection, decreased functional ability and poor quality of life (194). Thus, wounds need to be recognised as a major health issue in RAC facilities due to residents having a high risk of suffering from wounds such as skin tears, pressure ulcers and chronic leg ulcers (195).

In regards to hospital admissions, older adults accounted for 41% of Australian patients admitted into hospital in 2014 and 2015 (186). In particular, a growing concern is that the number of older adults (aged 85 years and older) admitted into hospital each year (5.8%) is higher than the population growth for this age group (4.1%) (186). It has also been highlighted that adverse events such as falls and wounds may lead to longer hospital stays and may even contribute to in-hospital deaths (196). In 2009-10, approximately one in five falls that resulted in hospitalization were reported to have occurred in a RAC setting (162). Further findings suggest that the rates of fall related injury cases in RAC facilities remain nearly six times higher than community-dwelling adults (197-199).

In contrast to findings in several other studies (200, 201), we found that those residents who were classified as having a positive cognitive impairment in the Mini- Cog score had a 51.7% reduction in falling when compared to those who scored a negative cognitive impairment score. While such a result was initially unexpected, this may reflect a fact that residents who are classified as being cognitively impaired are more closely monitored by nurses and staff and require more assistance (i.e. assisted transfer walking to dinner table) when compared to those who are not cognitively impaired. The substantially greater rate of adverse events in RAC than community-dwelling settings for older adults is not an unexpected finding.

However, it does continue to raise the question of how to minimise the incidence and severity of these events in the RAC facilities. One factor that may be implicated in this number of adverse events in RAC facilities is the age of the residents (85.7, SD: 7.1 years), number of medical conditions (11.0, SD: 4.9) and number of prescribed medications (14.0, SD: 5.8). Currently, two thirds of Australians aged over 75 years take five or more prescribed medications, an outcome referred to as “polypharmacy”. Depending upon the setting and definition used, 20-70% of older adults use at least one medication that is either harmful or unnecessary (202), with polypharmacy increasingly becoming the norm in RAC settings. Unfortunately; polypharmacy has been shown to increase the risk of medication errors, falls, confusion, frailty, loss of independence, hospitalisation and mortality (202). As age is a non-modifiable risk factor for falls, reductions in polypharmacy and/or number of medical conditions may reduce these adverse effects. Non-pharmacological approaches such as exercise programs involving progressive resistance, balance and/or cardiovascular exercise may provide such benefits (202, 203).

Another approach that may assist RAC staff reduce the severity and incidence of these adverse events is to screen their residents based on factors that are predictive of these adverse events. Prior to conducting the study, one such simple factor to screen adults living in RAC was gait speed. This approach was based on a systematic review in community-dwelling older adults (aged 65 and older) that indicated low gait speed was a significant predictor of a range of adverse events, including mobility disability, cognitive decline, mortality, falls and institutionalization in community-dwelling adults (4).

The potential use of gait speed to predict adverse events in adults living in RAC were also supported by Sterke et al. (42) who identified reduced gait speed and stride length as significant predictors of falls over the following three months for a group of 57 adults living in RAC with dementia. As a result of the over-dispersion identified in the initial Poisson analysis, the best approach according to the nature of the data was a negative binomial regression analysis to further examine the relationship between potential risk factors and falls in our sample.

Our multivariable analysis found that for every additional hospital admission, the incidence rate (or rate of falls) increases by 28%; for every additional wound, the incidence rate of falls increases by 7.8% and for every additional kilogram increase in handgrip strength the incidence rate of falls increases by 4.4%. Residents who were female had an increased risk of falling by 65.5% when compared to males. Residents who scored a positive impairment on the Mini-Cog had a reduced rate of falls by 51.7% compared with those who were negatively impaired.

The potential use of gait speed to predict adverse events in nursing home residents was also supported by Sterke et al. (42) who identified reduced gait speed and stride length as significant predictors of falls over the following three months for a group of 57 nursing home residents with dementia. While the results of the present study indicated that residents admitted to hospital who walked ≤0.6 m/s were ~1.3 times more likely to fall than residents with a faster gait speed, the data for this analysis was over dispersed due to the sample's greater variance than expected. When compared to the literature, the inability of our study to demonstrate significant relations between gait speed and adverse events was somewhat unexpected, but may reflect a variety of between study differences in gait speed, frequency of adverse events and statistical approaches. As a result of the over-dispersion of the initial analysis, we were forced to use negative binomial regression analyses to further examine the relationship between adverse events in our sample. Such results suggest that continuing improvements in fall prevention programs are required in the Australian RAC context so to minimize the high social, economic and care burden associated with falls-related hospitalisation and wound care. As suggested in a recent meta-analysis by Lee and Kim (204), to prevent these adverse outcomes from occurring programs that combine exercise and fall interventions that challenge balance should be targeted at high and low falls risk older adults in RAC facilities.

5.6.1 Study limitations

Some limitations must also be acknowledged. Due to the study being conducted in a small geographical area within Australia, the results may not be generalizable to other parts of the world. Additionally, in contrast to Sterke et al. (42) who quantified gait speed every three months over a period of 15 months, the present study only assessed gait speed at the beginning of the six-month follow-up.

5.6.2 Conclusions

This study identified the high incidence of adverse events including falls, wounds and hospital admissions in Australian adults living in RAC over a period of six-months. To reduce the frequency and/or severity of these adverse outcomes, population-based intervention programs should be targeted at the population at risk. As the number of hospital admissions, wounds and handgrip strength increases the risk of falls, with females and Mini-Cog scores classifying positive cognitive impairment with a decrease rate of falling, a combination of exercise and fall interventions that challenge balance should be targeted to reduce falls in older adults in RAC facilities. This is especially important for the residents for whom the nursing staff may consider to be at lower risk of falls (those with higher strength and cognitive function). These higher functioning residents may be more physically active and monitored less closely than those with reduced strength and cognitive function. Thus, additional research is needed to better understand the mechanisms underlying our results; with the implication being that different approaches may be needed to minimize the risk of adverse falls-related events in higher and lower functioning adults living in RAC.

Chapter 6

Feasibility and benefits of group-based exercise in residential aged care adults: a pilot study for the GrACE programme

6.1 PREFACE

Before the publication of this manuscript, to the student's knowledge there had very little research investigating the feasibility and potential benefits of progressive resistance and weight-bearing exercise in Australian adults living in RAC. In this chapter, a 12-week combined resistance and weight-bearing exercise programme within a RAC facility with the primary outcome of this study being feasibility

This manuscript was published in PeerJ (2017 Impact Factor: 2.2). The paper formatting has been modified in accordance with a consistent thesis-style and minor amendments suggested by thesis reviewers. The references (in-text and bibliography) are included at the end of the thesis. However, the appendices within this study have been included at the end of this chapter to assist the reader. The grammar, headings, and terms are unaltered in accordance with the journal's publishing guidelines (UK English). Thus, for consistency the term "resident" has been replaced with the word "adult".

Some of the data from this manuscript was presented at the following conferences:

Fien, S., Keogh, J. W. L., Henwood, T., & Climstein, M. (2015). Pumping iron in residential aged care: feasibility and preliminary efficacy. Paper presented at the 48th Annual Australian Association of Gerontology Conference Alice Springs Convention Centre, Alice Springs.

Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (2015). Feasibility and benefits of pumping iron for residential aged care adults. Oral presentation presented at the inaugural Bond University HDR Student Led Conference Gold Coast, Queensland.

Fien, S., Climstein, M., Henwood, T., Grigg, J., & Keogh, J. W.L. (2015). Feasibility and benefits of pumping iron for residential aged care adults. Paper presented at the AAG Student and Early Career Researchers Brisbane, Queensland.

Citation:

Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (2016). Feasibility and benefits of group-based exercise in residential aged care adults: a pilot study for the GrACE programme. PeerJ, 4, e2018. DOI: 10.7717/peerj.2018.

6.2 ABSTRACT

The objective of the study was to examine the feasibility and benefits of a group resistance training exercise programme for improving muscle function in institutionalised older adults. A feasibility and acceptability study was designed for a residential aged care (RAC) facility, based on the Gold Coast, Australia. Thirty-seven adults, mean age 86.8 ± 6.1 years (30 females) participated who were living in a RAC facility. Participants were allocated into an exercise (n = 20) or control (n = 17) group. The exercise group, the Group Aged Care Exercise (GrACE) programme, performed 12-weeks of twice weekly resistance exercises. Feasibility was measured via recruitment rate, measurement (physiological and surveys) completion rate, loss-to-follow-up, exercise session adherence, adverse events, and ratings of burden and acceptability. Muscle function was assessed using gait speed, sit to stand and handgrip strength assessments. All intervention participants completed pre- and post-assessments, and the exercise intervention, with 85% (n = 17) of the group attending ≥ 18 of the 24 sessions and 15% (n = 3) attending all sessions. Acceptability was 100% with exercise participants, and staff who had been involved with the programme strongly agreed that the participants "Benefited from the programme." There were no adverse events reported by any participants during the exercise sessions. When compared to the control group, the exercise group experienced significant improvements in gait speed ($F(4.078) = 8.265$, $p = 0.007$), sit to stand performance ($F(3.24) = 11.033$, $p = 0.002$) and handgrip strength ($F(3.697) = 26.359$, $p < 0.001$). Resistance training via the GrACE programme is feasible, safe and significantly improves gait speed, sit to stand performance and handgrip strength in adults living in RAC.

Keywords: *ageing, exercise, residential aged care, muscle function, feasibility*

6.3 INTRODUCTION

Ageing can lead to an impaired physical function, mobility and reduction in quality of life (132). A decrease in mobility may prompt a vicious cycle of sedentary behaviours, reduced physical activity and deconditioning, with residential aged care (RAC) adults shown to be more sedentary than their community-dwelling counterparts (37). The mobility decline may reflect the emergence of sarcopenia, which is defined as the progressive and generalised loss of skeletal muscle mass and subsequent muscle function (muscle strength and physical performance) associated with the ageing process (101). The preferred sarcopenic measure for physical performance in older adults is gait speed, which is also considered a primary precursor to age-related adverse events including disability, cognitive impairment, falls, mortality, institutionalisation and hospitalisation (4, 101, 162). The threshold to be considered as having normal or above habitual gait speeds is 0.8 m/s (13), a value almost identical to the 0.82 m/s cut-off proposed as being predictive of death within two years for older men (47).

A meta-analysis of 2,888 long-term ambulant adults living in RAC reported a mean habitual gait speed of 0.48 m/s (95% confidence interval (CI) 0.40–0.55) (13). However, it was cautioned that the true mean gait speed of adults living in RAC may be even less than 0.48 m/s as many of the reviewed studies utilised non-randomly selected samples, meaning the participants were likely to be more mobile than those who did not consent to participate. Consistent with such a view, a recent study of 102 randomly selected adults living in RAC reported a mean gait speed of 0.37 m/s (174). The widespread low gait speed documented for adults living in RAC and the link between low gait speed and many adverse age-related effects suggests that further research needs to be conducted to examine feasible and efficacious approaches to improving or at least offsetting the expected annual decline in gait speed of 0.03–0.05 m/s per year (35, 36).

Two recent reviews have examined the potential for exercise, and specifically progressive resistance training (e.g. strength) and weight-bearing exercise (e.g. balance and mobility) to improve many aspects of muscle function including gait speed in RAC/frail older adults (104, 136). In their meta-analysis of 225 participants across four studies, Chou, Hwang & Wu (2012) reported that exercise produced a significant 0.07 m/s (CI 0.02–0.11) increase in gait speed compared to the control group (−6% change) (136). However, a limitation of this literature is that the implementation of these exercise programmes in RAC is still relatively uncommon. This lack of translation may reflect the many barriers to the sustainability of resistance combined with weight-bearing training programmes in RAC (25) and to our knowledge, a complete lack of research quantifying the feasibility of this form of exercise in this setting.

A possible exception is an exercise programme, which was targeted at respite care older adults in Australia (27). Older adults accessing respite care are unable to completely care for themselves due to the adverse effects of ageing, chronic disease, physical and/or cognitive disability and are at increased risk of entry into RAC. These individuals typically access respite day care for several hours per day for one or more days per week to allow their carer the opportunity to attend to other everyday activities or to have a break from their caregiving responsibilities. An analysis of the exercise programme demonstrated a high feasibility for translation into an ongoing respite day care centre and that two hours of participation per week for 20 weeks significantly improved functional capacity and balance among participants (27).

While this programme was feasible and effective in a disabled community-dwelling population, it is yet to be trialled amongst adults living in RAC. Given the demonstrated uptake of this exercise programme by a low functioning older adult population at risk of entry into RAC, it was hypothesised that the Group Aged Care Exercise (GrACE) programme would exhibit similar levels of feasibility and benefits in adults living in RAC (27).

6.3.1 Aims

The primary aim of this study was to determine the feasibility of the GrACE programme in RAC, with the secondary objective of measuring the programme benefits on gait speed, sit to stand and handgrip strength.

6.4 Materials and methods

6.4.1 Participants

Participants were included if they were:

- Aged 65 years and over;
- Residing in a RAC;
- Able to walk with a walker and/or walking stick or could self-ambulate; and
- Could provide informed consent.

The exclusion criteria included:

- End-stage terminal and/or life expectancy < 6-months (ethical reasons);
- Two person transfer or unable to self-ambulate (due to increased falls risk);
- Unable to communicate or follow instructions (personal needs beyond the scope of this project);
- Insufficient cognitive function to provide informed consent; and
- Dangerous behaviours that would endanger the client or research staff.

6.4.2 Study design and recruitment

This study compared the delivery feasibility and outcomes of a 12-week combined resistance and weight-bearing exercise programme, which we named the GrACE programme. Participant recruitment and assessment occurred over a five-month period. The flow of recruitment to assessment is represented in Figure 6-1. A total of 25 out of 62 participants eligible for enrolment discontinued on to the next stage with 15 not meeting the inclusion criteria and 10 declining to participate. Following this discussion and reading of the participant information sheet, participants provided their informed consent if they wished to participate. There were no withdrawals from either group during the study however, three participants died in the control group. A total of 37 participants took part in the study, with the primary investigator responsible for observing and administering all of the assessments.

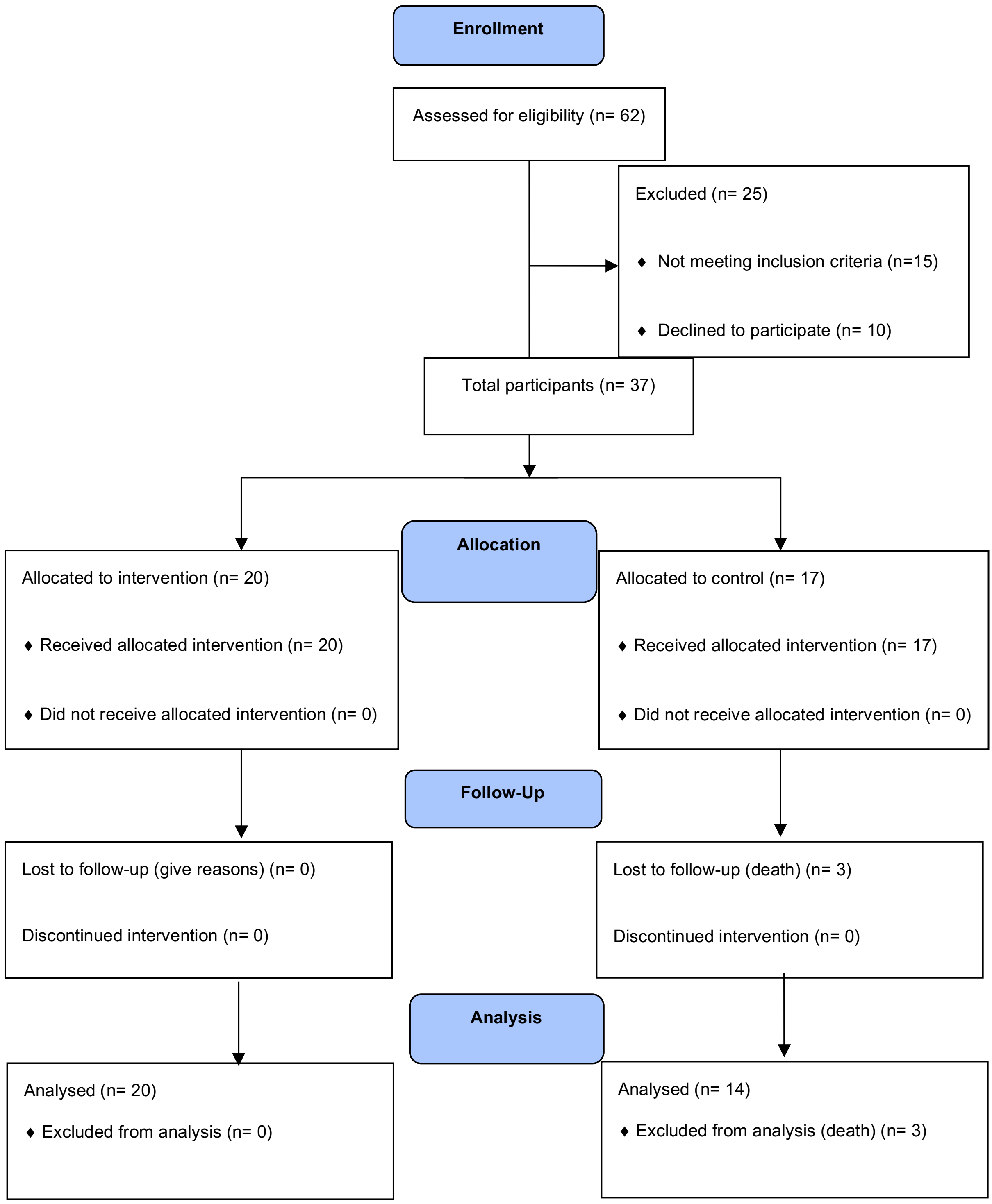

Figure 6-1. Project CONSORT diagram of recruitment and assessment of study participants. Enrollment numbers and withdrawals, or those to follow-up, are indicated in the boxes.

The RAC was approached about participation via email and telephone follow-up. Potential participants were identified at a meeting with the facility Service Manager. Participants were screened via the inclusion criteria at the meeting with the Service Manager and a Registered Nurse, whom also deemed who would be able to perform the exercises due to the inclusion and exclusion criteria. The Service Manager and a Registered Nurse created two lists from the eligible participants, one that contained the names of residents who could be recruited for the exercise group and one for the recruitment of the control group.

This group allocation was based on the location of their bedroom with respect to the training room, as the Service Manager and a Registered Nurse felt that only participants who resided on the same level as the exercise room were likely to join and adhere to the GrACE programme. As we wished to get some idea on the number of participants who would enrol in such an exercise program, the sample obtained in the current study reflected the maximum number of participants who were eligible and provided their informed consent to participate.

The final sample obtained was a convenience sample from one RAC facility. Following an explanation of the procedures, purposes, benefits and associated risks of the study, participants had the opportunity to ask questions. A total of 37 older adults living in RAC (86.8 ± 6.1 years, range 72–99 years, 30 females) provided written informed consent for the study. The exercise group contained 20 participants (86.9 ± 5.7 years, range 72–97 years, 15 females) and the control group 17 participants (86.3 ± 6.6 years, range 75–99 years, 15 females).

Ethical approval to conduct this study was attained from Bond University's Human Ethics Research Committee (RO 1823). The protocol for this trial was published at Clinical Trial Registry ID NCT02640963.

6.4.3 Intervention: the GrACE programme

Previous work by our group trialed a successful exercise programme in respite day care that could promise benefits to those in RAC (27). The GrACE programme's full outline is available in Appendix 1. In brief, the programme included a number of targeted weight-bearing exercises (using body weight and dumbbells) and a range of seated, non-resisted upper- and lower-body dynamic and reaching movements. While developed for respite care older adults, the programme was slightly modified for the RAC setting; initially using reduced range of motion and resistance, and an extended conditioning/familiarisation phase. The conditioning phase lasted for three weeks in which technique was emphasised without using any weights or additional resistance. The focus of this technique of the conditioning phase was to develop the correct technique and minimise the potential for any delayed onset muscle soreness or adverse effects. After concluding the conditioning phase, participants were able to use light dumbbells (often starting with 0.5 kg) increasing to heavier dumbbells (up to 4 kg) with their increasing capacity over the course of the programme.

Participants performed the exercises twice per week for 12-weeks, with an average of 15 of the 20 participating residents attending each exercise class. Training sessions lasted approximately 45 min, were separated by at least 48 h and were delivered by an allied health professional experienced working with older adults.

The sessions were conducted in the communal dining room, where the furniture was moved around prior and post training. The dining room was selected as the facility in which the exercise programme was performed had three levels, with the dining room located on the level having the highest number of residents. The allied health professional (exercise physiologist) was not blinded to the allocation of participants as they collected both pre- and post- outcomes for the study as well as conducting the exercise programme. The exercise physiologist was experienced working with community-dwelling older adults, but received additional training prior to the project delivery via the respite community-training package used in a previous study (27) and by RAC facility staff on issues relevant to working with adults living in RAC.

6.4.4 Control group

All subjects assigned to the control group were given the option to engage in other activities that were offered by the facility during the 12-week intervention period. Activities were conducted either in their fitness room or communal areas, and included Zumba Gold, aerobic exercise and walking. These sessions lasted for 30–45 min and conducted by their facility's leisure staff. However, no specific resistance exercises were offered in these activities.

6.4.5 Data collection

Reasons for refusal (non-consent) to participate were recorded (12). All muscle function outcome measures in this study have been previously validated for use with older adults, and their protocols reported elsewhere (27, 42). Assessments were completed one-on-one with each participant, assessing muscle function as well as a range of demographic characteristics, which are important in describing the sample. During muscle function measures assessments, participants were encouraged to rest as needed and given verbal support and encouragement to reduce any potential burden to the participant.

6.4.5 Measures

(i) Feasibility outcomes

The assessment of feasibility was defined by recruitment rate, measurement (physiological and surveys) completion rate, loss-to-follow-up, exercise session adherence, acceptability and adverse events (149-151). Recruitment rate was defined as the number of residents recruited from those invited. Measurement completion rate was defined as the number of participants able to complete each outcome measure at baseline and follow-up. Loss to follow-up was defined as participants who withdrew or dropped out and did not consent to a follow up assessment. Exercise session adherence was measured by the number of sessions attended out of the maximum 24 sessions. Consistent with previous exercise studies involving low functioning older adults (27, 142, 149), the proportion of participants who completed 75 and 100% of the required 24 sessions was recorded. Acceptability was measured via a programme satisfaction survey completed post-training (during morning tea after the last exercise session was completed) for the residents that were not there on the last day, their questionnaires were completed over that coming week. Depending on their level of ability, residents either completed the questionnaire themselves or had the questionnaire read out to them and/or had help answering the questions physically in regards to writing. The survey assessed the burden of training and testing, as well as how participants felt about the trial.

Questions included:

"Prior to commencing the exercise programme did you have any concern(s) with the GrACE programme?";

"Did you enjoy participating in the GrACE programme?";

"Do you believe the GrACE programme was well organised?";

"Whilst participating in the GrACE programme do you believe that the programme impeded on your daily routine?";

"Would you be happy to continue participating in the GrACE programme or something similar?"; and

"Overall, would you rate your current physical condition to be better than before you started the GrACE programme?"

Answers to the acceptability questions were scored on a five-point Likert Scale (1 = strongly agree, agree, neither, disagree or 5 = strongly disagree).

Adverse events were defined as incidents in which harm or damage resulted to a participant and included, but were not limited to, falls and fall-related injuries, musculoskeletal or cardiovascular incidents and problems with medication and medical devices (152). These adverse events were recorded via the facility's records. The exercise group also received a diary to record if they had any muscle soreness or complaints about the exercise class. These diaries were returned to the instructor at the end of each week. The exercise instructor also verbally confirmed the information contained in these diaries with each of the exercise group participants at the end of each week.

(ii) Muscle function measures outcomes

Gait speed

Gait speed was recorded via the GaitMat II system (Manufacturer is EQInc; Model is GaitMat II), which required participants to walk across a level pressure mat system 3.66 m (11.91 ft.) long (39). Participants completed the trials at their preferred (habitual) walking (gait) speed. The following instructions were given, "Walk towards the end of the room at a pace that is comfortable for you." Participants were allowed to walk in their own footwear. All measures were initiated from a standing start 2 m (6.56 ft.) from the GaitMat II platform as suggested by Kressig & Beauchet (167) to reduce the effect that acceleration may have on gait speed. The average gait speed (m/s) from three attempts was used for data analysis. Participants were allowed as much rest as required between attempts, with rest periods typically being up to 1 min.

Handgrip strength

Upper body muscle function was measured by isometric handgrip strength. When performing the handgrip strength assessments, participants were seated, instructed to keep their elbow at 90° and asked to squeeze a handgrip dynamometer (Sammons Preston Roylan, Bolingbrook, IL, USA) to their maximum ability for a period of up to 5 seconds (s) (205). Three trials were performed with the subject's dominant hand with one-minute rest between trials and the best result used for analysis (206).

Sit to stand performance

The sit to stand measure was performed to assess lower body muscle function of the participants. In the sit to stand measure, participants sat and stood to their full standing position from a 43 cm high chair as many times as possible in 30s whilst keeping their arms crossed against their chest (207). Timing commenced when the assessor gave the command, "go."

6.4.6 Participant demographics

All participants were assessed for Body Mass Index (BMI), body fat percentage (%) and cognitive status at pre- and post-testing. BMI was calculated based on body mass (kg) divided by the square of height (m^2). Body fat was estimated via Bioelectrical Impedance Analysis (BIA, Maltron BF-906 body fat analyser) (208). The BIA required participants to have two electrode stickers placed on their hand as well as two on their foot whilst in the supine position. The flow of electrical signals was measured through fat, lean tissue and water, which was then applied to a database of algorithms revealing the whole body analysis (209).

Cognitive status was quantified via the Mini Cog (168). The Mini Cog was scored out of three words that are recalled after drawing the face of a clock on a piece of paper to read 10 min after eleven o'clock, with scores > 1–2 recalled words and abnormal clock drawing, indicative of cognitive impairment (168).

6.4.7 Data management and statistical analysis

A total of 34 participants were required to provide an 80% statistical power based on standard deviation of 0.2 $m.s^{-1}$ found within a randomly selected RAC cohort in the same geographical location by the research team (208). A total of 37 participants were recruited; the control group consisted of 17 participants and the exercise group consisted of 20 participants that were found to have statistically similar baseline testing for gait speed.

Descriptive statistics were calculated to describe the baseline characteristics and feasibility results, with all continuous variables presented as mean and standard deviation (±SD), and for categorical variables as the total number and percentage (%) of responses. In circumstances where participants were unable to complete a physical measure, they were given the lowest score, generally zero. All data were initially checked for normality prior to analysis by investigating homogeneity of regression slopes, scatterplots for linearity, kurtosis, skewness and Levene's test of equality of error variances.

Baseline characteristics of the two groups were compared using ANCOVA and chi-square analysis for continuous and categorical variables, respectively. A one-way ANCOVA was performed to assess the between-group changes in gait speed, handgrip strength and sit to stand performance. SPSS (version 20) was used for data analysis; statistical significance was set at $p \leq 0.05$ a priori.

6.5 RESULTS

Descriptive characteristics of the sample, provided in Table 6-1, showed no significant difference between groups at baseline. Of the 62 individuals put forward for participation by the RAC Service Manager, 47 were found to be eligible and 37 consented to involvement. At follow-up, three participants in the control group had passed away, resulting from falls complications (n = 1) and pre-existing heart disease (n = 2). Apart from these three deaths, the study experienced a 100% retention rate of surviving participants and final analysis was conducted on 34 individuals (20 in the intervention and 14 in the control). Seventeen (85%) participants in the exercise group attended 18 or more exercise sessions, with three (15%) of these 17 participants attending all 24 training sessions.

Table 6-1. Descriptive data for the exercise and control group.

Variable	Exercise Group (n = 20)	Control Group (n = 17)
Age (yrs)	86.9 ± 5.7	86.3 ± 6.6
Range (yrs)	72-97	75-99
No. of females (no.%)	15 (75%)	15 (88%)
Length of stay in RAC (days)	745.1 ± 622.6	755.0 ± 492.1
Medical Conditions (no.)	15.3 ± 5.2	14.2 ± 5.3
Medications (no.)	14.3 ± 6.1	14.6 ± 5.9
Use of walking aid	11 (55%)	13 (76%)
BMI (kg/m^2)	26.5 ± 3.7	27.2 ± 4.7
Body fat %	33.2 ± 10.8	38.8 ± 5.6
Marital Status		
Married	4 (20%)	2 (12%)
Divorced	3 (15%)	0 (0%)
Widowed	13 (65%)	15 (88%)
Nationality		
European	20 (100%)	15 (88%)
Asian	0	2 (12%)
Primary Language		
English	19 (95%)	16 (94%)
German	1 (5%)	0

Russian	0	1 (6%)
Mini-COG status #		
Positive	12 (60%)	14 (82%)
Negative	8 (40%)	3 (18%)

Data are mean ± standard deviation; yrs = years; no. = number

Participant responses to the exercise programme questionnaire, measured by the Likert scale questions are summarised in Table 6-2. Acceptability of the programme was very high with 100% of exercise participants and staff who had been involved with the programme (i.e. nurses who helped bring the residents from their rooms to the GrACE programme or observed the class from the nurses' station) strongly agreeing that the participants "Benefited from the GrACE programme" and "Happy to continue participating."

Refer to Appendix 6.7.2 to see the full responses to the open-ended questions. With respect to diary completion, all diaries were returned with five partially completed (ranging from 50–80%) and 15 fully completed. There were no adverse events reported by any participants during the exercise sessions.

Table 6-2. Exercise group participant questionnaire post 12-week completion.

Question				
Did you have any concern(s) with the GrACE programme before starting exercise programme?				
SA = 0	A = 0	U = 1	D = 15	SD = 4
Did you have any concern(s) with the GrACE programme upon completing the exercise programme?				
SA = 2	A = 18	U = 0	D = 0	SD = 0
Did you enjoy participating in the GrACE programme?				
SA = 20	A = 0	U = 0	D = 0	SD = 0
Do you believe the GrACE programme was well organised?				
SA = 20	A = 0	U = 0	D = 0	SD = 0
Did you find the GrACE programme impede on your daily routine?				
SA = 3	A = 17	U = 0	D = 0	SD = 0
Would you be happy to continue participating in the GrACE programme or something similar?				
SA = 20	A = 0	U = 0	D = 0	SD = 0
Overall, would you rate your current physical condition to be better than before you started the GrACE programme?				
SA = 20	A = 0	U = 0	D = 0	SD = 0

SA = Strongly agree, A = Agree U = Unsure, D = Disagree, SD = Strongly disagree.

The exercise group had significantly greater improvements in habitual gait speed ($F(4.078) = 8.265$, $p = 0.007$), sit to stand performance ($F(3.24) = 11.033$, $p = 0.002$) and handgrip strength ($F(3.697) = 26.359$, $p < 0.001$) when compared to the control group. Pre- and post-intervention muscle function measures data are presented in Table 6-3.

Table 6-3. Changes in the muscle function outcomes for the exercise and control groups.

Muscle Function Outcome	Exercise Group			Control Group			Between- group significance
	Pre	Post	% Change	Pre	Post	% Change	
Gait speed (m/s)	0.65 ± 0.19	0.68 ± 0.17	+4.6	0.64 ± 0.16	0.60 ± 0.16	-6.0	0.007*
Sit to stand (repetitions)	0.0 ± 0.0	6.4 ± 4.5	NA	0 ± 0	1.3 ± 3.2	NA	0.002*
Handgrip strength (kg)	15.2 ± 5.3	15.9 ± 5.9	+4.6	13.2 ± 4.5	10.6 ± 4.1	-19.7	0.001*

All data were reported as mean ± standard deviation; m/s = metres per second; kg= kilogram. NA = not applicable as the pre-test score equalled zero.

* = Statistical significance ($p<0.05$).

6.6 DISCUSSION

This study demonstrated a combined weight-bearing and resistance training exercise programme, which we called the GrACE programme, designed and tested in community-dwelling respite day care older adults, is feasible, safe and effective in improving gait speed, sit to stand performance and handgrip strength in adults living in RAC. Findings from this study may assist RAC providers and care staff to develop and implement feasible, safe and effective exercise programmes for older adults. .

The recruitment rates for this exercise trial appeared similar or better than other similar trials in respite care, hospital inpatient or RAC populations (27, 149-151). Sixty-two of the 151 adults were identified by the Service Manager as being potentially eligible for the study, a proportion equating to approximately 40% of total population of the RAC facility.

The other 89 adults living in RAC were deemed ineligible due to the following: being in a wheelchair or restricted to bed duties, not being able to follow simple instructions, lack of attention or unpredictable behaviour. It is interesting to note that some adults (n = 10) refused to participate due to fear of change in their schedule, fear of never doing resistance training before and not wanting to try and after being in the RAC facility for over five years had declared they were not doing exercise anymore. Suggested ideas to overcome this were through word of mouth via adults to other adults, especially at communal times such as breakfast, where the residents remind each other of exercise class.

Of the 62 residents identified by the Service Manager as being eligible to participate, 37 (60%) provided informed consent and were placed into either the exercise or control groups. While a recruitment rate of 60% of the eligible participants may appear relatively low, this value appeared comparable (145) or slightly higher (142, 144, 157) than previous exercise trials in RAC.

The reason provided by the 25 (40%) potentially eligible participants who declined to participate included: not being interested in the study or exercise programme, lack of time: did not want to commit to the 12-weeks, did not want to try something different/that was out of the normal routine and were happy with their current lifestyle. The reasons reported by the potential participants who declined participation in this project should be taken into account by future researchers considering conducting RAC exercise RCTs if they wish to ensure maximum participant recruitment and statistical power of the resulting analyses.

For the 20 participants who were enrolled into the GrACE programme, adherence rates were high with 85% of the participants attending at least 18 (75%) of the required 24 exercise classes. This relatively high attendance rate appeared similar (142, 144, 157) or greater than (125, 145) previous feasibility exercise studies involving RAC older adults. Such results suggest that many exercise class options (if offered) may be well attended by adults living in RAC facilities.

The acceptability of the programme was further assessed by using a five-point Likert scale questionnaire that focused on the participants' perceptions of the exercise sessions. All exercise participants strongly agreed that they obtained substantial benefits from their participation and that they wished to continue being involved in the programme. These results are consistent with previous studies reporting high acceptability of RAC exercise participation (142, 144, 145, 157).

However, in contrast, our study supports the feasibility of an in-centre delivery using targeted supervision and inexpensive equipment, where previous work has employed more complicated deliveries. Specifically, Bossers et al. (142) delivered individualised, supervised walking and strength training programmes five days per week, Sievänen et al. (144) and Álvarez-Barbosa et al. (157) delivered their interventions using relatively expensive whole body vibration devices, Hassan et al. (125) used expensive resistance training machines and Henwood et al. (145) trialled aquatic exercise that required participants to be transported to and from a community pool and change in and out of swimming attire.

Our study required only one qualified trainer; the exercises were conducted at the RAC facility so there was no transport needed and delivery was not affected by busy times or school holidays such as experienced by Henwood et al. (145). Further, our study did not need to have a personalised exercise programme developed for each individual resident or require the purchase and storage of expensive equipment (125, 144, 157). The acceptability of the programme was further demonstrated by the lack of any adverse effects reported within the exercise group. This lack of adverse effects is again consistent with the literature on a variety of exercise programmes for adults living in RAC (125, 142, 144, 145, 157). Therefore, our study further supports the safety of supervised exercise in this population and demonstrates that the perception held by some care staff that exercise is dangerous for adults living in RAC is not based on the current peer-reviewed evidence.

However, it must be acknowledged that although the GrACE programme was found to be feasible for those who participated in this study, this amounted to only ~25% of the population of the RAC facility. Collectively, the results of this study suggest that further feasibility trials may need to target adults living in RAC who were ineligible for this study (210) and also examine some of the issues influencing recruitment rates from those who were eligible to participate (211).

While the primary focus of this study was to demonstrate feasibility and acceptability of the GrACE programme in RAC, we were also interested in further quantifying the benefits of exercise in this population as such data may inform future RCTs in this area. Significant between-group differences were reported for gait speed, sit to stand performance and handgrip strength, all of which favoured the exercise over the control group. Such results are impressive due to the relative simplicity of the GrACE programme performed in the current study and the importance of these outcome measures for older adults, particularly those living in RAC who wish to maintain their health and independence.

The significant between group effect for gait speed was a promising finding, with the relative 0.07 m/s improvement in gait speed for the exercise group was identical to the results of a recent meta-analysis involving exercise for adults living in RAC (136). However, results of the within-group analysis indicated that the exercise group experienced an increase in gait speed of 0.03 m/s (~5%), whereas the control group experienced a decline of 0.04 m/s (~6%). As the control group's decline of 0.04 m/s was consistent with the expected annual decline of 0.03–0.05 m/s per year for older adults (35, 36), the GrACE programme appears able to maintain or perhaps slightly increase gait speed in this population.

The significantly greater improvement in sit to stand performance for the exercise group was of considerable interest, with none of the residents being able to perform the sit to stand with their hands on the chest during baseline assessments. The ability to safely rise from a chair and sit down is a prerequisite for maintaining Activities of Daily Living (ADL) function (212). Specifically, older adults who are unable to perform the sit to stand are considered below the capacity for independence and at risk of accelerated physical deterioration associated to extended sedentary behaviours (212). The RAC participants' lack of leg strength (as demonstrated by their initial inability to perform even one sit to stand) was consistent with previous research that observed over 70% of adults living in RAC were unable to rise from a chair without assistance (213).

The exercise group's significantly greater improvement in handgrip strength was also considered important, as lower handgrip strengths have predicted an accelerated decline in ADL disability and cognition as well as functional limitation and physical disability in older adults (214-216). The exercise-related increase in handgrip strength was also consistent with a previous exercise study in RAC (217).

Such results were a little bit surprising as the control participants also experienced a considerable reduction in the handgrip strength of close to 20% over the 24-week period. A potential explanation might be some degree of learning effect, whereby these older individuals who rarely, if at all get out of a chair on their own with their hands on their chest have now practiced this task on three separate occasions over the 24-week period. It therefore may be that such practice allowed some individuals who were close or very close to being able to perform one repetition at baseline to perform some repetitions at the 24-

weeks post test. Other reasons may have been, but not limited to: some residents being reliant on their assisted devices daily for sit to stand performance and therefore didn't stand without using their wheelie walker or walking stick, many residents could get out of the chair and stand but it was not to the upright position while retaining their hands on their chest or where too scared to stand all the way for fear of falling. Thus it was more than a physical factor contributing but a mental and social/cultural problem as well.

6.6.1 Study limitations

There were several limitations in the current study. We acknowledge that 37 participants assessed represented a recruitment rate of only 59.6% of the participants initially thought to be eligible for the study and only about 25% of the facility's population. However, this rate of uptake is not uncommon in RAC, nor is the strict eligibility criteria imposed or participant safety reasons in exercise intervention. Therefore, caution is warranted if considering this GrACE programme feasibility across all RAC populations. It should also be noted that there was a risk of bias with the same allied health practitioner conducting the outcome measures and supervising the exercise programme. Future RCT should address this limitation by blinding the assessor to the participants' group allocation. The significant improvements observed in the present study for gait speed, sit to stand performance and handgrip strength also need to be replicated in RCTs due to the lack of a controlled study design and attention matching of the participants of each group.

6.6.2 Conclusions

The GrACE programme, consisting of progressive weight-bearing combined with resistance training, was shown to be feasible, safe and effective in improving muscle function in adults living in RAC. Improved muscle function measurements are valuable client outcomes, and may have significant cost saving benefits to the RAC setting, as increased muscle function could reduce the older adults' degree of disability, care needs and risk of falls (136).

This work has direct measurable benefits for adults living in RAC, staff and providers and other health professionals working with older adults. Our findings addressed a number of previously unanswered and understudied questions in relation to the feasibility, safety and benefits of exercise classes that could be offered by RAC facilities to their residents. By having a greater understanding of these issues, RAC providers can better target interventions (e.g. exercise for maintaining gait speed or to reduce falls risk) to their residents. We would therefore encourage other RAC providers to strongly consider implementing similar programmes.

6.7 Appendices

6.7.1. The GrACE programme.

The programme included weight-bearing exercises and a range of seated, non-resisted upper- and lower-body dynamic and reaching movements. Prior to performing the exercises, participants warmed up for approximately fifteen minutes using the non-resistive movements, and completed each session with a warm down of approximately ten minutes with targeted stretching. The stretches involved non-resistive movements undertaken two or three times and reaching (stretching) movements were held for 20 seconds. Between the warm up and cool down the participants performed the following-weight-bearing and resistance exercises: chair stands, chair dips, calf raises and hip flexor/abdominal lifts, trunk twists, and bicep curl and shoulder press.

The aim was to complete three sets of ten repetitions per exercise. Initially participants worked at a reduced intensity (50% of estimated 1-repetition maximum) and number of sets and repetitions, with the sets and repetitions increasing over the first four weeks to reach the GrACE programmes full delivery goal. Prior to the GrACE programme all participants were familiarised to the programme, with participants commencing with no resistance so to encourage appropriate technique and posture, whilst reducing reliance on balancing aids before progressing to resistance (dumbbells).

The programme took approximately one hour to complete and was delivered by an accredited, allied health professional. Participants were closely monitored, told to rest as needed and to not over exert themselves.

1. Starting with No Resistance

Be aware of:

- Any per-existing injuries or problems that limit range of motion
- Poor technique
- Poor posture
- Undue fatigue

Solution:

- Encourage participant to do the best they can but not aggravate problem
- Offer positive reinforcement
- Take your time with improvements
- If problem persists suggest seeing a doctor

⬇

Has the participant achieved **3 sets of 10 repetitions** using **GOOD TECHNIQUE AND POSTURE?**	If not **KEEP GOING AT THE SAME INTENSITY**

⬇

2. Increasing the time in the down phase

For example:

Chair Stands	Sitting down as slowly as possible
Chair Dips	Lowering down slowly as possible
Calf/Knee Raises	Dropping the feet back to the ground as slowly as possible
Trunk Twists	Rotating the trunk as slowly as possible
Bicep Curl/Shoulder Press	Return the hand (dumbbells) slowly to shoulder then to the waist

⬇

Has the participant achieved **3 sets of 15 repetitions** using **GOOD TECHNIQUE AND POSTURE?**	If not **KEEP GOING AT THE SAME INTENSITY**

⬇

3. Adding Resistance

Generally

- IF YOU INCREASE THE WEIGHT YOU DECREASE THE REPETITIONS
- IF YOU INCREASE THE REPETITIONS YOU DECREASE THE WEIGHTS

6.7.2. Feedback from the participants in regards to the exercise group.

Feedback Questions	**Comments**
What was the best aspect of the GrACE programme?	"Neck exercises" "Improvement" "The use of weights" "I liked all of it" "The instructor" "Enjoyable group exercise" "It kept me moving" "I liked the instructor coming to remind me exercises were on, cause I forgot most of the time" "Instructor was very concise" "Nothing was too difficult" "I enjoyed the challenge" "The group and the instructor" "I was very happy with all the programme had to offer" "Feeling of support" "Breathing exercises" "I liked that I got to push myself" "Everyone was enthusiastic" "I realised that I need to exercise more, but I have

	to be realistic" "Everybody being in a group made the exercises more enjoyable"
What aspect of the GrACE programme needs improvement?	"More time for exercises" "None" "Nothing" "None, it was all good" "I liked it all" "Needs to go for longer" "Better spacing of the days we do exercise"
Other comments/feedback.	"I like the structure, no interruptions, everyone seems to cope and it is so worthwhile" "Covered a lot of things that I liked" "A very good, organised programme – even one could say meticulous" "I would like the programme to continue" "It was wonderful" "Thank you for your organisation and commitment" "I would like to do more of it" "I find it easier to walk now after the exercise programme" "I would like more variation" "Considering I am 3 months older now than when I

	commenced, I am surprised that I now feel okay at the end of the programme, I was exhausted at the start of the programme" "It is a joy to do the exercises with our instructor"

Chapter 7

Examining the feasibility, sustainability and the benefits of the GrACE+GAIT exercise programme in the residential aged care setting

7.1 PREFACE

In this chapter, a quasi-experimental study design consisted of an extension of the “GrACE” programme now called the “GrACE+GAIT”. The second phase “GAIT” was developed based on an identified need for a greater proportion of standing rather than seated exercise and targeted spatio-temporal gait parameters to increase mobility for adults living in RAC.

This manuscript was submitted to PeerJ (2017 Impact Factor: 2.2). The paper formatting has been modified in accordance with a consistent thesis-style and minor amendments suggested by thesis reviewers. The references (in-text and bibliography) are included at the end of the thesis. Additionally, the appendices within this study have been included at the end of this chapter to assist the reader. The grammar, headings, and terms are unaltered in accordance with the journal’s publishing guidelines (UK English).

Some data from this manuscript was presented at the following conferences:

Fien, S., Climstein, M., Henwood, T., Rathbone, E., & Keogh, J.W.L. (8-10th November 2017). The Golden Opportunity: Walking. Tabletop conversation at the 50th Annual Australian Association of Gerontology Conference Crown, Perth, (Western Australia, Australia).

Citation:

Fien, S., Henwood, T., Climstein, M., & Keogh, J. W. L. (Submitted). Examining the feasibility, sustainability and the benefits of the GrACE+GAIT exercise programme in the residential aged care setting. PeerJ.

7.2 ABSTRACT

Background: The feasibility and benefits of a 24-week targeted progressive supervised resistance and weight-bearing exercise programme (GrACE+GAIT) in the residential aged care (RAC) setting were investigated as very little peer-reviewed research has investigated exercise programmes of this duration in this cohort.

Methods: A quasi-experimental study design consisting of two groups (control and exercise) explored a 24-week targeted progressive weight-bearing and mobility exercise programme (Group Aged Care Exercise + GAIT (GrACE+GAIT)) in two RAC facilities in Northern New South Wales, Australia. A total of 42 adults consented to participate from a total of 68 (61.7%) eligible residents. The primary outcome measure was gait speed with the secondary measures being spatio-temporal parameters of gait, sit to stand performance and handgrip muscle strength. Feasibility and sustainability of the exercise programme was also measured via intervention uptake, session adherence, attrition, acceptability and adverse events.

Results: Twenty-three residents participated in the exercise intervention (mean (SD) 85.4 (8.1) years, 15 females) and 19 as the control group (87.4 (6.6) years 13 females). ANCOVA results indicated that at post-intervention, gait speed, handgrip strength and sit to stand performance for the exercise group was significantly better than the control group ($p<0.001$). Exercise adherence was 79.3%, with 65% of exercise participants attended ⩾70% sessions, 100% of those originally enrolled completed the programme and strongly agreed with the programme acceptability. Zero exercise-related adverse events were reported.

Discussion: The GrACE+GAIT program was shown to be feasible and significantly improve adults living in RAC facilities gait speed, handgrip strength and sit to stand performance. For adults living in RAC facilities the GrACE+GAIT programme appears an acceptable activity that reduces disability and has potential translation to improved quality of life.

***Keywords:** aged, gait, geriatrics, resistance training*

7.3 INTRODUCTION

On average one million adults use Australia's government funded aged care services on a typical day, with the majority (71%) of these adults residing in RAC facilities (218). Given the emphasis of older adults remaining in their own homes for as long as possible, older adults entering RAC facilities may have poorer levels of physical function when compared to previous times (218). Residents often have multiple chronic diseases, a sarcopenic status and take multiple medications, with the interaction of these factors placing the residents at a high risk of adverse events (1, 188, 219). Ironically, adults living in RAC are among the least researched older adult group even though they have the highest rates for falls and hospital admissions and are among the highest consumers for medications (219). Residing in a RAC facility can be associated with reduced physical activity and a slowing in mobility (37, 136). In fact, older adults, especially residential aged care (RAC) adults, require a lifestyle with regular exercise to reduce the risk of disease and increase their quality of life (125).

Sarcopenia is defined by the European Working Group Sarcopenia in Older People (EWGSOP) as "the progressive and generalised loss of skeletal muscle mass, muscle strength and muscle function" (5) (p.g. 413). The physical decline of gait speed in RAC adults is known to reflect a range of age-related adverse processes such as disability, cognitive impairment, falls, mortality, institutionalisation and hospitalisation (4, 101, 162).

Gait speed is a common tool used to diagnose sarcopenia and its clinically relevant to older adults. The threshold for older adults to be considered as having normal habitual gait speeds is $\geq$0.8 m/s which was reported from a meta-analysis study containing 2,888 adults living in RAC (13). However, in the context of Australian RAC it has been reported that they have slower gait speeds than community-dwelling older adults (203). This same study reported a mean habitual gait speed of just 0.48 m/s (95% confidence interval (CI) 0.40-0.55) for adults living in RAC (13). Work by our group involving 102 randomly selected adults living in RAC reported a mean (SD) gait speed of 0.37 (0.26) m/s (52). This dangerously low gait speed and its association with many adverse events, supports the need for the development and assessment of novel interventions that can be applied in the RAC setting to counter the age-related decline in physical performance (35, 36).

While well supported by evidence to improve overall physical wellbeing and mobility, progressive resistance and weight-bearing exercise is not commonly available in RAC. This may reflect the lack of understanding of what constitutes feasible, safe, sustainable and effective longer-term exercise participation, and, in particular, an inefficient translation of research principles (time, duration and frequency) to practice (3, 104, 144). Exercise has also been found to improve gait speed, muscle strength and physical performance in the RAC setting (104, 136), although the magnitude of changes in physical performance such as gait speed is typically substantially less than that of the strength improvement. This suggests that these exercise programmes may need to target three spatio-temporal parameters (stride length, step time and support base) as these three parameters predict 89% of the variance in gait speed in adults living in RAC (1).

The aim of this study was to evaluate the benefits of a targeted exercise programme for adults living in RAC with a focus on longer-term feasibility than what was done previously with a shorter, more generalised pilot exercise programme in this setting (3). Potential benefits examined included gait speed, spatio-temporal parameters of gait, sit to stand, handgrip strength performance, with feasibility outcomes including intervention uptake, session adherence, attrition, acceptability and adverse events.

7.4 Methods and methods

7.4.1 Participants and design

Participants were eligible if they were:

i. Aged over 65 years
ii. Residing in a RAC for longer than three weeks,
iii. Able to walk with a walker and/or walking stick or could self-ambulate for

the test (including those who have had knee and hip replacements) and,

iv. Could provide informed consent (self- or by proxy).

The exclusion criteria included:

i. End-stage terminal and/or life expectancy <6-months (ethical reasons),
ii. Two-person transfer or unable to self-ambulate (due to increased falls risk),
iii. Unable to communicate or follow instructions,
iv. Dangerous behaviours endangering the client or research staff.

A quasi-experimental study design was used that involved two Australian RAC facilities. An overview of recruitment and delivery is given in Figure 7-1. A total of 26 out of 68 participants eligible for enrolment discontinued on to the next stage with 14 not meeting the inclusion criteria and 12 declining to participate. Following this discussion and reading of the participant information sheet, participants provided their informed consent if they wished to participate. There were no withdrawals from either group during the study. A total of 42 participants took part in the study, with the primary investigator responsible for observing and administering all of the assessments. In brief, participants were identified as eligible and capable of participating by the RAC Service Manager and the Registered Nurses. Residents were then allocated into either the control or the exercise group based on the following variables: the complexity of the RAC setting, the physical environment of the RAC facilities (multi-storey buildings, furniture, safety and location of the rooms, RAC facilities reduced staffing and staff available to transport residents to and from their rooms to exercise class. The exercise programme took place from June to December 2016. Ethical approval to conduct this study was attained from Bond University's Human Ethics Research Committee (RO 1823), with the trial protocol published at Clinical Trial Registry (ID NCT02766738).

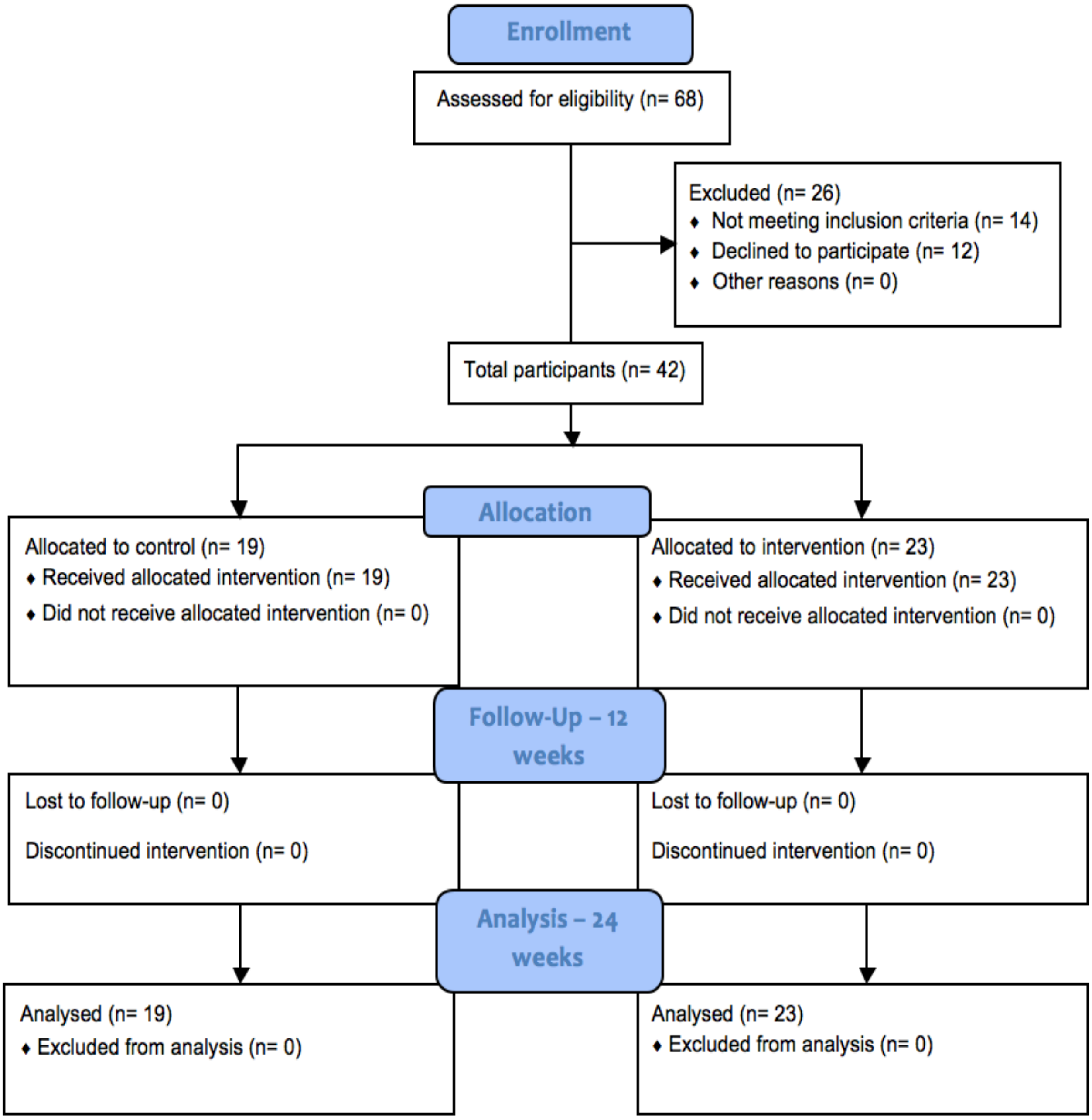

Figure 7-1. CONSORT flow diagram of recruitment and assessment of study participants.

7.4.2 GrACE+GAIT Exercise Intervention

The exercise intervention "GrACE+GAIT" consisted of a 24-week supervised training programme that was divided into two phases, each consisting of 12 weeks. These phases are detailed in Table 1. The first phase involved an identical training programme to that previously been reported in a pilot study (3). The sample of adults living in RAC in this study differed to those reported in the previous study as they were recruited from a Northern NSW region from June 2017. The second phase of the exercise programme in the current study was developed based on an identified need for a greater proportion of standing rather than seated exercise and targeted spatio-temporal gait parameters (1) to enhance mobility.

Both phases of the exercise programme commenced with a four-week conditioning period, allowing participants the opportunity to achieve correct technique, minimise potential for adverse events and adapt to the training protocol (3). In the subsequent eight-week period, sets, repetitions and resistance were progressively increased as participants increased their exercise tolerance (see Table 7-1).

Table 7-1. Exercise intervention GrACE+GAIT (Phase I and Phase II).

Variable	**Intervention: Phase I**		**Intervention: Phase II**	
	Description	Equipment	Description	Equipment
Duration	12-weeks (0-12-weeks)		12-weeks (13-24-weeks)	
Number of sessions per week	45 minutes twice weekly.		45 minutes twice weekly	
Conditioning phase	Included		Not included.	
Weight-bearing and resistance exercises	Chair stands, chair dips, calf raises and hip flexor/abdominal lifts, trunk twists, and bicep curl and shoulder press. 2 sets of 8-10 repetitions	Dumbbells (0.5, 1, 1.5 & 2kg) Chairs	Chair stands, chair dips, calf raises and hip flexor/abdominal lifts, trunk twists, and bicep curl and shoulder press. 3 sets of 10-12 repetitions	Dumbbells (0.5, 1, 1.5 & 2kg) Chairs
Gait exercises	No gait exercises.		Heel and toe raises, stepping in different directions, step-ups, and task-specific balance work for unstable base of support.	Exercise balls
Instructor	Primary investigator (two days/week)		Primary investigator one day/week RAC staff (physiotherapists) one day/week	

7.4.3 Usual Care Group

All participants assigned to the control group continued their regular activities during the intervention period.

7.4.4 Data Collection

All measures in this study have been previously validated for use with older adults, and their protocols reported elsewhere (3, 27, 42). Assessments were completed one-on-one by the primary investigator in the residents' room except for the gait speed test. Due to the space required, gait speed was assessed in a communal room.

7.4.5 Primary Outcome Measure:

7.4.5. (i) Gait speed

The data of the resident's gait speed and spatio-temporal parameters were collected using the Gait Mat II, with a description of how this has been used previously in RAC facilities described in an earlier paper (1). Briefly, the measurement of gait speed and the spatio-temporal parameters commenced from a walking start with 2 metre wooden platform on either sides of the GaitMat II as to reduce the effect acceleration has on gait speed (167). GaitMat II pressure mat system measurement was 3.66 m (11.91 feet) long (39). Participants performed three trials of this walking task and the average was used for data analysis.

7.4.6 Secondary Outcome Measures:

7.4.6 (i) Spatio-temporal parameters

The spatio-temporal parameters were collected from the GaitMat II and included the following measurements: step length, stride length, support base, step time, swing time, stance time, single support time and double support time and are defined by (1).

7.4.6 (ii) Sit to stand performance

Sit to stand performance was measured from sitting and participants stood to a full standing position from a chair as many times as possible in 30 seconds whilst keeping their arms crossed against their chest. Due to the fatiguing nature of this test, only one trial was performed (220).

7.4.6 (iii) Handgrip strength

Isometric handgrip strength was measured with participants seated and their elbow bent to 90° at their side. They were instructed to squeeze a handgrip dynamometer as hard as they could (maximum ability) for a period of up to five seconds (205). The best result of two trials was recorded for analysis (206).

7.4.6 (iv) Feasibility measurements

Feasibility was evaluated against recruitment rate, session adherence, attrition, acceptability and adverse events (3, 149-151). Recruitment rate was defined as the proportion of residents who consented to participate from the group deemed eligible. Session adherence was measured as the percentage of sessions attended out of 48 sessions offered (3, 27, 142, 149). Attrition was defined by the proportion of people who dropped out of the intervention (221). Acceptability was measured via a satisfaction survey, using a five-point Likert scale, completed post-training assessing the burden of participation and testing, as well as overall trial satisfaction. Adverse events (intervention) were defined as incidents in which harm or damage occurred to the participant, including but not limited to, falls and fall-related injuries, musculoskeletal or cardiovascular incidents and problems with medication and medical devices (152) as a result of their involvement in the exercise programme. These adverse events were recorded by the primary investigator via observation and questioning the residents' pre, during and post exercise sessions.

7.4.6 (v) Sustainability measurement

Sustainability was defined as "the existence of structures and processes that allow a programme to leverage resources to effectively implement and maintain evidence-based policies and activities" (222 pg.2) (p.g.2). Sustainability is critical to RAC facilities, if a programme is not sustainable and delivered by the appropriate staff member/s, it can be a waste of money and resources, and may limit the ability of the organisation's ability to achieve RAC goals and effectively implement exercise programmes (222, 223). In regards to the training of an internal staff member to implement an exercise programme, research reveals there the sustainability of an exercise programme within the context of community-dwelling adults is increased if locally trained instructors are integrated into the exercise programme (224, 225). Sustainability was assessed on whether the exercise programme could be completed with one exercise instructor for a group of up to 10 adults living in RAC in a session, performed in a communal multi-purpose room and that it only required 1 set of dumbbells, (ranging in weight: 0.5kg – 2kg) an exercise ball and a dining room chair per resident.

7.5 Participant demographics

Residents were assessed for sarcopenia, cognitive status, body mass index (BMI), body fat percentage (%) and lean mass at baseline. The anthropometric data collected allowed for each resident to be screened for sarcopenia according to the European Working Group on Sarcopenia in Older People (EWGSOP) guidelines (101). The EWGSOP screening algorithm consisted of assessing gait speed, handgrip strength and muscle mass (i.e., lean mass). In order to be defined sarcopenic, individuals needed to have below normal levels of muscle mass and muscle strength or performance, using gender-specific cut-off points (101). A simple five-item questionnaire, the "SARC-F" was also used to subjectively diagnose sarcopenia (226) whereby a participant scoring 4 or more is described as "predictive of sarcopenia and poor outcomes". The total number of mobility aids were also recorded with the category of either ambulant or mobility aids (including: walking stick, walking frame, wheelie walker and wheelchair). Cognitive status was quantified via the Mini Cog (168), with a total score of 1 or 2 out of 5 indicating a higher likelihood of dementia classified for this test as cognitive impairment. Body fat and lean mass were measured using bioelectrical impedance analysis (BIA, Maltron BF-906 body fat analyser) (208, 209).

7.6 Statistical analysis

Descriptive statistics were produced on the baseline characteristics with all continuous variables presented as either mean (SD) or median (range) depending on the statistical distribution of the variables. Categorical variables were summarized as counts and percentages (%). In circumstances where participants were unable to complete a physical measure, they were given the lowest score, generally zero. Baseline characteristics of the two groups were compared using either independent *t*-tests or Mann-Whitney U tests for continuous variables, and chi-square analysis for categorical variables.

The main inferential test undertaken was a one-way analysis of covariance (ANCOVA) to assess the effect of the exercise intervention, after adjusting for potential between-group baseline differences in gait speed and the number of chronic diseases. Paired t-tests were also performed to investigate if a there was a statistically significant pre-post-test difference in the variables at the time points: 12-weeks and 24 weeks for each group. A Bon Ferroni correction was used for the t-tests due to the two time points and the p-value was set for the paired t-tests as p = 0.025. Statistical Package for the Social Sciences (SPSS, version 20) was used for data analysis; statistical significance was set at $p \leq 0.05$ *a priori*.

7.5 Results

Forty-two of the 68 residents (61.7%) deemed eligible provided informed consent to participate. The total cohort had a mean (SD) age of 86.3 (6.7) years (range 66-97 years, 28 females), gait speed of 0.61 (0.17) m/s, BMI of 26.6 (3.7) kg/m^2, 9.4 (2.4) chronic diseases, 10.9 (4.3) prescribed medications and 66.7% were cognitively impaired (see Table 7-2). There were no significant between group differences at baseline except for chronic diseases (p=0.03),

Table 7-2. Baseline characteristics of the residents (N=42) in the RAC setting.

Characteristic	**Control** (***n*=19**)	**Exercise Intervention** (***n*=23**)	**Total Group** (***n*=42**)
Females, *n* (%)	13 (68.4%)	15 (65.2%)	28 (66.7%)
Age (yrs)	87.4 (4.5)	85.4 (8.1)	86.3 (6.7)
BMI (kg/m^2)	26.6 (3.7)	26.4 (3.8)	26.5 (3.6)
Body Fat Mass (%)	36.6 (9.0)	37.5 (8.9)	37.0 (8.9)
Fat Mass (kg)	23.7 (7.6)	24.5 (8.2)	24.1 (7.9)
Lean Mass (kg)	41.0 (8.4)	40.0 (7.0)	40.5 (7.8)
Handgrip Strength, kg (Median, range)	11 (6.0-18.4)	13 (6.0-32.0)	12 (6.0-32.0)
Sit to stand, assistance *n* (%)	13 (68.4%)	10 (43.5%)	23 (54.8%)
Sit to stand *n*	1 (0.75)	2 (1.7)	1.5 (1.4)
Mobility aids, Aid used *n* (%)	15 (78.9%)	16 (69.6%)	31 (73.8%)
Mini COG, impaired *n* (%)	14 (73.7%)	14 (60.9%)	28 (66.7%)
Medical Conditions, #	10.3 (2.3)	8.7 (2.3)	9.4 (2.4)
Medications, #	11.6 (3.3)	10.3 (4.9)	10.9 (4.3)

EWGSOP Sarcopenic status, count	0	0	0
SARC-F total score, #	4 (1.6)	4 (1.9)	4 (1.3)
Gait speed, m/s	0.58 (0.19)	0.64 (0.16)	0.61 (0.17)
Step length, m	0.43 (0.05)	0.41 (0.07)	0.42 (0.06)
Stride length, m (Median, range)	0.88 (0.44-1.08)	0.81 (0.44-1.15)	0.84 (0.44-1.15)
Support base, m (Median, range)	0.15 (0.07-0.40)	0.16 (0.09-0.31)	0.15 (0.07-0.40)
Step time, s (Median, range)	0.63 (0.34-1.00)	0.62 (0.34-1.11)	0.63 (0.34-1.11)
Swing time, s (Median, range)	0.42 (0.33-0.62)	0.40 (0.33-0.68)	0.42 (0.33-0.68)
Stance time, s (Median, range)	0.87 (0.54-1.46)	0.85 (0.68-1.50)	0.86 (0.54-1.50)
Single support time, s (Median, range)	0.42 (0.33-0.79)	0.40 (0.22-0.79)	0.41 (0.22-0.79)
Double support time, s (Median, range)	0.25 (0.19-0.41)	0.21 (0.15-0.41)	0.22 (0.15-0.41)

BMI = Body Mass Index; EWGSOP = European Working Group Sarcopenia in Older People; kg = kilogram; m = metre; mini COG = mini cognitive test; n = number; s = second; SARC-F = sarcopenia questionnaire; yrs = years; # = number; % = percentage.

The ANCOVA on gait speed was used to detect any difference between the two groups whilst controlling for potential baseline differences in gait speed and the number of chronic diseases. The model explained 66.8% of the variation in gait speed (see Table 7-3). The results indicate that there was very strong evidence of a treatment effect on gait speed at the end of the 24-week intervention ($F_{(1,38)} = 15.6$, $p < 0.001$, partial $\eta^2 = 0.29$). The eta-squared η^2 (proportion of the total variance attributed to an effect) was found to be of a large effect size for the variables: baseline gait speed, baseline chronic diseases and exercise group in Table 7-3.

Table 7-3. Analysis of covariance (ANCOVA) model of a 24-week GrACE+GAIT intervention in 42 residents.

Variables	**Beta coefficient (95% CI)**	***p*-value**	***Partial Eta Squared (η^2)[1]***
Baseline gait speed (m/s)	0.66 (0.43, 0.89)	<0.001*	0.462
Baseline chronic diseases (n)	-0.024 (-0.05, -0.003)	0.024*	0.128
Exercise group GrACE+GAIT[2]	0.15 (0.07, 0.23)	<0.001*	0.290

*= statistically significant $p<0.05$.

CI = Confidence Interval; m/s = metres per second; n = number.

[1]= Cohen's effect size η^2: small= 0.01, medium= 0.059, large= 0.138.

[2]= The results for the exercise group are displayed since the reference category was the control group.

Paired t-tests were performed on the following variables: gait speed, gait spatio-temporal parameters, handgrip strength and sit to stand performance to describe the pre-post-test changes within each of the two groups.

7.5.1 Gait

Gait speed statistically improved in the exercise group in the first phase (p = 0.001) but not the second phase (p = 0.042). During the 24-week intervention, the control group's gait speed remained statistically unchanged (p = 0.35, 0.58 (0.19) m/s to 0.57 (0.18) m/s), whilst the exercise group significantly increased (p = 0.002, 0.64 (0.16) m/s to 0.76 (0.18) m/s) (Figure 2A).

7.5.2 Gait spatio-temporal parameters

Stride length statistically improved in the exercise group (p = 0.007) after 24-weeks, although these changes were not statistically significant during the first (p = 0.07) or second phase (p = 0.07). During the 24-week intervention, the control group's stride length remained statistically unchanged (p = 0.39, 0.83 (0.16) m to 0.82 (0.18) m), whilst the exercise group significantly increased (p = 0.007, 0.81 (0.16) m to 0.91 (0.15) m) (Figure 2B). None of the other gait spatio-temporal parameters were significantly altered at any time point for either group (Figure 2C and 2D).

7.5.3 Handgrip strength

Handgrip strength statistically improved in the exercise group in the first phase (p = 0.001) but not the second phase (p = 0.035). During the 24-week intervention, the control group's handgrip strength significantly decreased (p < 0.001, 12.0 (3.7) kg to 10.9 (3.9) kg), whilst the exercise group significantly increased (p = 0.001, 15.2 (7.2) kg to 17.4 (8.5) kg) (Figure 2E).

7.5.4 Sit to stand performance

Sit to stand performance significantly improved in the exercise group in both the first (p = 0.003) and second phases (p = 0.001). During the intervention, the control group's sit to stand performance significantly increased (p = 0.003, 1.0 (0.7) sit to stands to 2.0 (1.5) sit to stands) as did with the exercise group (p < 0.001, 2.0 (1.7) sit to stands to 5.0 (2.2) sit to stands) (Figure 2F).

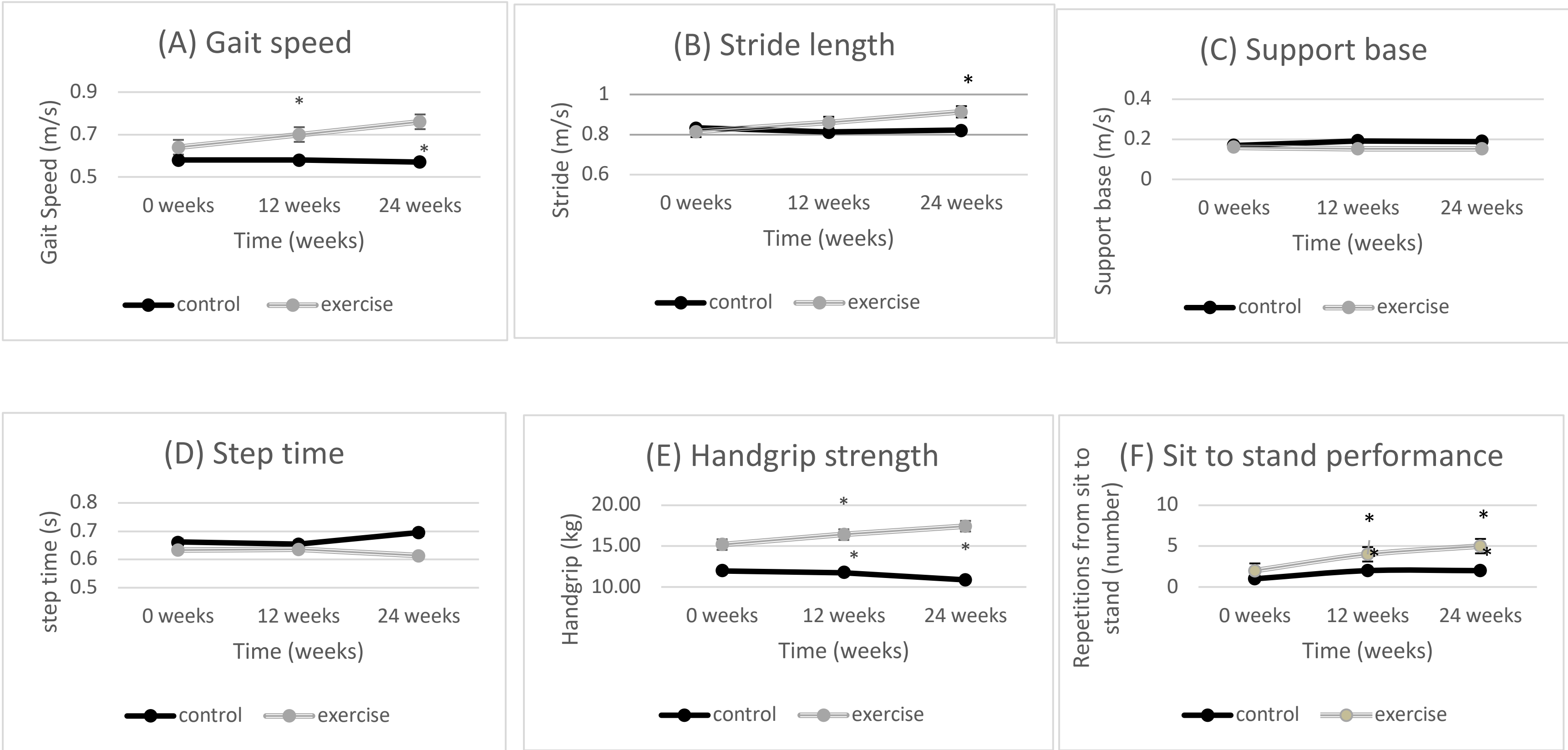

Figure 7-2. Physical performance (A) gait speed, (B) stride length, (C) support base, (D) step time, (E) handgrip strength and (F) sit to stand performance – control versus exercise group over the 24-week GrACE+GAIT exercise programme.

Note: The error bars represent standard error of the mean; * = statistically significant (P<0.05).

A total of 42 residents from the eligible 66 list participated in the study. Overall adherence rate was 79.3%, while no participants attended all 48 sessions, adherence to the exercise sessions was quite good with 15 residents (65%) attending 34 or more exercise sessions (70%). The most common reasons for non-attendance included family/friends visiting, medical appointments/surgeries, sickness and organised external activities. There were no exercise-related adverse events or dropouts during the programme, with all 42 commencing participants completing the post-programme assessment. All participants agreed or strongly agreed that they enjoyed the programme, that they would be happy to continue and were physically better than prior to commencing the programme and benefited from participation (Refer to Appendix 1).

7.6 Discussion

This study indicates that the adults living in RAC exercising in the GrACE+GAIT intervention twice a week for 24 weeks reported significantly improved gait speed, muscle strength and sit to stand performance than residents who were not in the intervention. Such changes would appear reflective of an increased level of functional ability and independence, all of which could likely reduce care burden and improve health related quality of life for the adults living in RAC.

The exercise group experienced an increase in gait speed of 0.12 m/s, whereas the control group declined their mean gait speed by 0.02 m/s. The training related improvements in gait speed for the exercise group were almost double that of the 0.07 m/s (CI 0.02–0.11) increase reported in a meta-analysis by (136) and provide important evidence that exercise can counter the expected annual decline in gait speed of 0.03-0.05 m/s per year for older adults (35, 36). Further, the increase of .012 m/s reported in the study is greater than the 0.10 m/s increase in gait speed that has been considered a meaningful change in previous studies involving older adults (227, 228).

Based on previous research that demonstrated 89% of the variance in the adults living in RAC gait speed was predicted by stride length, step time and support base (1), it was not surprising that stride length was also significantly improved after the 24-weeek period in the exercise group. However, no significant increases in stride length were observed at 12 weeks. As an increase in stride length would typically require improved balance and/or increased anterior-posterior impulse production (22, 42), the lack of significant increase in stride length in the first 12 weeks may have reflected the majority of exercises being performed in a seated position during this time. The inclusion of the gait-focused standing exercises in the second phase of the programme may therefore be crucial to optimise improvements in gait speed and spatio-temporal parameters in adults living in RAC. In the context of community-dwelling older adults research, frail adults, compared to non-frail status, have a reduced gait speed and stride length with increased stride time (77, 229). In particular, the effect size was significant for both studies finding more pronounced discrimination power for gait speed (d ≥ 0.76) and step length (d = 1.32) (77, 229). Gait speed has been reported as one of the strongest to predict adverse outcomes, such as mobility disability, falls, or hospitalization in a range of older populations (229-231). However, assessment of gait speed does not, in and of itself, provide insight into the specific gait pattern, which in turn may limit the sensitivity and specificity of discrimination between different frailty and health statuses (231).

On this basis, we would recommend that exercise prescriptions for older adults in RAC might need to be longer than 12 weeks and have a progression of general (seated) to more specific balance and weight-bearing strengthening exercises to improve gait speed without increasing the risk of exercise-related adverse events like falls. The requirement for exercise programmes exceeding 12 weeks may reflect the multifactorial processes and multiple sensorimotor systems that influence gait speed, and how an increase in gait speed will not be achieved until all these processes and systems have been improved with exercise (136).

This study also sought to determine the feasibility and sustainability of a longer duration (24-weeks) progressive resistance-training programme than has been typically performed (6-12 weeks) in previous studies of adults living in RAC (3, 144). For the 23 residents who were enrolled in the exercise programme, total session adherence rate was 79.3%. This attendance rate appeared similar to or

greater than reported in previous exercise studies involving adults living in RAC with average age ranging from 82 to 86 years old (3, 142, 144, 157). There were no dropouts or exercise-related adverse events reported in the exercise group during the 24-week programme, reiterating that the exercise programme was feasible for the 24-weeks.
Further evidence supporting the sustainability of the GrACE+GAIT was that it utilized one exercise instructor for a group of up to 10 adults living in RAC in a session (156), was performed in a communal multi-purpose room and that it only required 1 set of dumbbells, (ranging in weight: 0.5kg – 2kg) an exercise ball and a dining room chair per resident. In regards to sustainability, the programme was able to maintain two exercise classes per week for 24-weeks. During the second phase, the primary investigator conducted one class per week, whilst an internal RAC staff member conducted the second exercise class. Such findings provide some indication of long-term sustainability of the programme, as it would appear to be financially more viable and easily delivered by exercise professionals and/or trained RAC staff than other exercise interventions examined in the RAC context (35, 125, 138, 142, 144, 145, 157, 224, 225).

However, it must be acknowledged that although the GrACE programme was found to be feasible for those who participated in this study, this amounted to only ~32% of the population of the RAC facility. Collectively, the results of this study suggest that further feasibility trials may need to target adults living in RAC who were ineligible for this study (232) and also examine some of the issues influencing recruitment rates from those who were eligible to participate (211).

7.6.1 Study limitations

The primary limitation was the lack of a randomized control trail (RCT) design and the lead researcher not being blinded to participant allocation. This lack of an RCT design and researcher blinding, which partially reflected the challenges of conducting exercise trials in the RAC setting, may reduce the internal validity of the study's findings. We acknowledge that 42 participants assessed represented a recruitment rate of only 52% of the participants initially thought to be eligible for the study and only about 32% of the facility's population. However, the potential for research of bias was reduced in that the primary outcome of gait speed was assessed by the GaitMat II system which does not allow any researcher bias to influence the results recorded. It is also acknowledged that 3D biomechanical analyses would have also provided additional information regarding the potential mechanisms underlying the improvement in gait speed and stride length, such as the potential for improved postural stability and greater anterior posterior impulse production during the stance phase.

7.6.2 Conclusions

This study found the resident's gait speed and physical performance improved in the GrACE+GAIT exercise group post 24-week and this exercise programme was feasible and sustainable in the RAC setting. In order to ensure such exercise programmes, become a part of usual care in RAC, additional RCT design need to examine how exercise, in particular, progressive resistance and weight-bearing training may improve a range of other indices of health and well-being and whether such programs are economically viable.

7.7 APPENDICES

7.7.1. Exercise group participant questionnaire post 24-week completion of the GrACE+GAIT exercise programme.

Question					
Did you have any concern(s) with the GrACE programme *before starting* exercise programme?					
	SA = 0	A = 2	U = 4	D = 10	SD = 7
Did you have any concern(s) with the GrACE+GAIT programme *upon completing* the exercise programme?					
	SA = 0	A = 0	U = 2	D = 18	SD = 3
Did you enjoy participating in the GrACE+GAIT programme?					
	SA = 23	A = 0	U = 0	D = 0	SD = 0
Do you believe the GrACE programme was well organised?					
	SA = 20	A = 3	U = 0	D = 0	SD = 0
Did you find the GrACE programme impede on your daily routine?					
	SA = 0	A = 1	U = 3	D = 16	SD = 3
Would you be happy to continue participating in the GrACE+GAIT programme or something similar?					
	SA = 23	A = 0	U = 0	D = 0	SD = 0
Overall, would you rate your current physical condition to be better than before you started the GrACE+GAIT programme?					
	SA = 23	A = 0	U = 0	D = 0	SD = 0

SA = Strongly agree, A = Agree U = Unsure, D = Disagree, SD = Strongly disagree.

7.7.2. Feedback from the open-ended questions in the participant post GrACE+GAIT exercise programme.

Feedback Questions	**Comments**
What was the best aspect of the GrACE+GAIT exercise programme?	"Everybody being in a group together" "I enjoyed the class" "I liked the instructor" "Getting out of my room" "Being able to do something" "Having the energy to do it" "The exercise balls" "I was able to push myself" "Seeing everyone" "Having morning tea with everyone afterwards" "I liked the class" "Walking across the plank" "Improving"
What aspect of the GrACE+GAIT needs improvement?	"More scheduled time for exercises" "I wish we didn't get interrupted in our exercise class by other people" "More space" "Nothing" "None" "Needs to go for longer"
Other comments/feedback	"Wonderful" "Thank you for your time" "Thank you"

	"Fantastic" "Very organised"

Chapter 8

General Discussion and Future Directions

8.1 SUMMARY OF FINDINGS

The thesis had two major aims. The first aim was to characterise gait speed and spatio-temporal gait parameters of older adults living in RAC and to determine if spatio-temporal gait parameters could predict gait speed (Chapter 4) and adverse age-related events (Chapter 5) in adults living in RAC. The second aim focused on whether two exercise interventions (one a generalised 12-week programme (Chapter 6) and the other a 24-week exercise intervention (Chapter 7) that involved a more gait specific final 12-weeks of training) would be feasible and improve the gait speed and spatio-temporal parameters of the adults living in RAC. This chapter draws the thesis together by summarising the major findings, linking chapters together, and provides some practical applications of the findings. Limitations of the research are identified, and finally, future research directions are proposed.

The first literature review (Chapter Two) provided valuable information regarding gait speed and spatio-temporal characteristics as well as the adverse events, such as falls, wounds and hospitalisation occurring in adults living in RAC. This literature review identified that 11 studies had measured gait speed among adults living in RAC with sample sizes of 100 or more participants. Little research has been conducted examining whether gait speed thresholds of ≤0.6 m/s, 0.61 – 0.79 m/s and ≥0.8 m/s and gait spatio-temporal parameters associated with adverse events in community-dwelling adults may also be associated with adverse events in adults living in RAC. For example, two other studies had used an electronic pressure platform to quantify the gait spatio-temporal parameters of 100 adults living in RAC. Unfortunately, there appeared to be a lack of research that investigated how gait spatio-temporal parameters may influence or predict gait speed as well as the incidence of adverse events occurring in older adults in RAC. This informed the first two studies (Chapter Four and Chapter Five).

Chapter Four sought to characterise the gait speed and spatio-temporal characteristics of adults living in RAC and to determine what spatio-temporal characteristics may predict gait speed in this cohort. This study recruited 100 adults living in RAC who were able to self-ambulate with or without a walking aid, whose mean gait speed (0.63 ± 0.19 m/s) and spatio-temporal parameters indicated they had poor function and mobility and were at high risk of falls and other adverse age-related events. The significant ability of three spatio-temporal parameters (step time, stride length and support base) to determine gait speed (R^2 = 0.89) would appear to reflect a variety of biomechanical concepts including the impulse momentum relationship. The impulse momentum relationship bites definition is specifically talking about ground reaction force as the impulse is the product of the ground reaction force and the time that is applied over (233). For example, the ability of step time and stride length to determine gait speed may be explained by the impulse-momentum relationship and/or the adult's reduced ability to maintain balance during the gait cycle. Based on the impulse momentum relationship it is fair to conclude that reduced lower body muscle strength and power may mean that the adults living in RAC require greater single/double support times to produce the necessary impulse (force multiplied by time) to propel their body forward during the gait cycle. 26 Their reduced force production ability and greater stance time would then contribute to a reduced stride length, increased step time, and ultimately a reduced habitual gait speed. Poor stride length may also be suggestive of shuffling gait and low plantar flexor and hip flexor strength. 26 Therefore, certain exercises such as calf raises and leg raises coupled with gait training may need to be incorporated in resistance training programs to improve gait speed in nursing home residents. 21

Specifically, results of the regression analyses indicated that step time contributed to the largest change in gait speed, with every 0.1 s decrease in step time resulting in a mean increase in gait speed of 0.09 m/s (95% CI 0.08 – 0.10). A 0.1 m increase in stride length was also associated with a mean increase of 0.08 m/s (95% CI 0.07 – 0.09) in gait speed. However, few studies had quantified the incidence of adverse events in Australian RAC facilities and whether gait speed thresholds could predict the frequency of falls or other adverse events in adults living in RAC.

Chapter Five therefore sought to quantify the number and type of adverse events occurring in Australian RAC and to determine how gait speed and spatio-temporal parameters could predict falls and other adverse events. In a sample of 100 older adults living in RAC, there were a total of 226 falls, 243 wounds, 65 hospital admissions and 29 deaths during a six-month period. While there was no significant relationship between gait speed and adverse events, a number of significant relationships were observed between the adverse events. For example, for every additional hospital admission there was a 28% increased rate of falling, for every additional wound there was a 7.8% increased rate of falling and for every kilogram increase in handgrip strength there was a 4.4% increased rate of falling. This is especially interesting as it was not the expected result for this study to find an increase in handgrip strength relating to an increase rate of falling. These higher functioning residents (those with higher strength and cognitive function) may be more physically active and therefore more risk of falls and those who typically remain in bed or seated throughout the day. It is also possible that the more higher functioning residents are monitored less closely than those with reduced strength and cognitive function. Thus, additional research is needed to better understand the mechanisms underlying our results; with the implication being that different approaches may be needed to minimize the risk of adverse falls-related events in higher and lower functioning nursing home residents.

Residents were also found to have an increased rate of falling by 65.5% if they were female compared to males. Further, those with a positive impairment Mini-Cog score were found to have a 52.0% decrease in their rate of falling when being compared to residents who scored a negative cognitive impairment score.

As the incidence of adverse events in these residents was very high, it suggests that continual refinement of assessment, education, awareness and management processes are required to improve RAC resident’s outcomes. In particular, a combination of exercise and fall prevention interventions that challenge balance and muscular strength should be targeted to reduce falls and other adverse events. However, it is equally important to focus on minimising adverse events in the more functional RAC resident (those with higher strength, cognitive function and physical activity levels) for whom the nursing staff may consider to be at lower risk of falls.

The second literature review (Chapter Three) provided information about the benefits and feasibility of implementing exercise as an intervention to improve gait speed for residents within a RAC facility. Gaps identified within the review of the literature led to the design of a 3-month pilot study and a 6-month study; one investigating the feasibility and acceptability of the generalised GrACE exercise programme (Chapter Six), the other investigating a longer-term and more gait-focused 24-week exercise intervention "GrACE+GAIT" to improve mobility and physical performance, with a particular focus on gait speed and spatio-temporal parameters (Chapter Seven).

These chapters demonstrated combined weight-bearing and resistance training exercise programmes which we called the GrACE (12-weeks) and GrACE+GAIT (24 weeks) programmes. Both programmes designed and initially tested in community-dwelling respite day care older adults, were feasible, safe and effective in improving gait speed, sit to stand performance and handgrip strength in adults living in RAC. Findings from these chapters may assist RAC providers and care staff to develop and implement feasible, safe and effective exercise programmes for their residents.

The 12-week exercise intervention was deemed feasible for the RAC setting due to a 100% acceptability rate, 85% adherence rate with no adverse events or dropouts. The exercise group also experienced significant improvements in gait speed, sit to stand performance and handgrip strength when compared to the control group. This high level of feasibility of the pilot study was further supported by the results reported in Chapter 7.

This 24-week exercise programme was delivered in two phases, with the first phase adapted from a respite day care programme consisting of seated exercises. The second phase was developed based on an identified need for a greater proportion of standing rather than seated exercise and focused on key spatio-temporal gait parameters to enhance mobility. Its feasibility within the aged care setting was demonstrated with a 100% acceptability rate, a total adherence rate of 79.3% with no adverse events or dropouts. The exercise group also improved gait speed, handgrip strength and sit to stand performance at 12-weeks, with further significant improvements being observed at 24 weeks.

This work has direct measurable benefits for RAC facilities looking to enhance resident's quality of life, reduce the burden on staff and improve the standards of assessment and intervention for residents. These results also have relevance to other providers of aged care services and health professionals working with older adults. Specifically, this thesis addresses a number of unanswered and understudied questions in relation to RAC organisations' core service population. By having greater understanding of changing mobility and disability, RAC clients can receive better-targeted monitoring and intervention (e.g. exercise for maintaining gait speed and/or to reduce falls risk) with the result being a more fulfilling and dignified life.

8.2 Practical applications

The findings within this thesis can offer some useful recommendations for adults living in RAC:

- Step time, stride length and support base are the strongest spatio-temporal predictors of gait speed among adults living in RAC ($R^2 = 0.89$). The strength of this relationship is significantly higher than has been previously found using a range of demographic and health measures in this cohort (208). This further reinforces the importance of assessing and improving selected spatio-temporal parameters to minimise any gait speed related adverse events and to maximise adults living in RAC independence and function.
- Gait speed was not found to be significantly related to adverse events in older adults living in RAC, a finding that was inconsistent with numerous studies involving community-dwelling older adults (37, 77). This may be a result of the very slow and/or slowing gait speeds found in adults living in RAC, which made it more difficult to identify a particular gait speed threshold under which adverse events were more common.
- However, from this study we do know that for every hospital admission and registered wound, incidence falls rates increase significantly.
- Increased handgrip strength was associated with an increase in falls incidence, perhaps suggesting that stronger, more functional adults living in RAC also need to be a priority in falls prevention programmes.
- On-site, targeted resistance and weight-bearing exercise has potential to significantly improve gait speed and sit to stand performance and handgrip strength in adults living in RAC.
- An increase in handgrip strength was found in both the GrACE and GrACE+GAIT programmes which was found in Chapter 5 to be a factor to increase the risk of falling – highly recommended that these residents are given more information on falling, education about how to walk with assisted devices and awareness on appropriate footwear when walking. All precautions to prevent the high-functioning older adults from falling within and outside the RAC facility.

- Progressive resistance and weight-bearing training, as performed in the GrACE and GrACE+GAIT programmes, are feasible and safe for adults living in RAC.
- Feasible progressive resistance and balance training programmes like that developed and assessed in the GrACE and GrACE+GAIT programmes need to be implemented in the RAC context.

8.3 LIMITATIONS

The following limitations of the studies within the thesis are acknowledged:

- All Chapters:
    - Participation selection bias may have influenced findings as the inclusion criteria deemed that a participant should have the ability to walk with or without an aid. A total of 40-62% of residents in the RAC facilities were ineligible because of their inability to mobilise or because they were deemed too high a risk to participate.
    - While participants had physical and cognitive outcomes typical of adults living in RAC, the selection bias may have led to the overestimation of true mean gait speed and spatio-temporal parameters. This may suggest that the, results must be interpreted with caution for those less-functional residents who were ineligible for these studies.
    - Due to the studies being conducted in a small geographical area within Australia, the results may not be generalisable to other parts of the world in which the demographic characteristics of the adults living in RAC differ at baseline.
    - Static or dynamic balance was not directly assessed in this study. Therefore, while our proposition of poor dynamic balance contributing to gait speed reductions has some indirect experimental support, we cannot explicitly state that is the case with our participants.
    - There was some risk of bias with the same allied health practitioner conducting the outcome measures and supervising the exercise programmes.

8.4 FUTURE RESEARCH DIRECTIONS

The thesis has provided insights into walking performance and the benefits of exercise of adults living in RAC. These results have provided practical applications, which can be utilised by RAC management and staff. However, future research should focus in several key areas:

- In Chapter Four, given the impact of low and slowing gait speed in this population, future research should concentrate on developing and evaluating intervention programmes that were specifically designed to focus on improving step time, stride length and support base in RAC adults. As gait speed has been shown to be predictive of many adverse events in other older adults' groups, we would also suggest that routine assessments of gait speed by an allied health professional i.e. an accredited exercise physiologist, and if possible their spatio-temporal characteristics be done on all adults living in RAC.

- In Chapter Five the incidence of adverse events in Australian RAC was high, suggesting that continual refinement of assessment, education, awareness and management processes are required to improve resident outcomes. In particular, falls reduction interventions appear important, as they would likely reduce the number of hospital admissions and wounds in the RAC setting. However, there is also plenty of opportunities for other interventions to be examined that may reduce the frequency and/or severity of these adverse events in RAC. Additional research also need to be conducted to determine how gait speed and spatio-temporal parameters may contribute to falls risk in different cohorts of adults living in RAC, as has been demonstrated in the wider literature for community-dwelling older adults.

- In Chapters Six and Seven there was a risk of bias with the same allied health practitioner conducting the outcome measures and supervising the exercise programmes. Future research should include RCT designs including researcher blinding and larger samples. Assessment of body composition, muscle morphology and more sophisticated muscular strength, power and 3D biomechanical measures may also provide additional important information underlying potential mechanisms of adaptation.

- In a recent report (34) to the Government, the need for RAC facilities to be supported to delivery physical therapies to residents was identified. If more funding becomes available to support this, small to medium group exercise programmes as utilised in the GrACE and GrACE+GAIT studies could become more common place. With this, the question must be asked; could the positive benefits of the GrACE and GrACE +GAIT be enhanced if the allied health delivery was in a more intensive environment for those adults living in RAC with an urgent need to improve their gait speed and mobility?
- It is also acknowledged that 3D biomechanical analyses would have also provided additional information regarding the potential mechanisms underlying the improvement in gait speed and stride length. Therefore, future studies should look to utilise technological advances such as inertial sensors which may provide additional information regarding the potential mechanisms underlying the exercise-related improvements in gait speed and stride length.

8.5 CONCLUSION

In summary, the results of this thesis demonstrated that: 1) Adults living in RAC have low gait speed that primarily reflects deficiencies in three spatio-temporal parameters (step time, stride length and support base); 2) Adults living in RAC experience a high rate of adverse events, although they cannot be predicted by gait speed and spatio-temporal parameters; and 3) that 12-weeks or 24-weeks' progressive resistance training is safe and feasible for adults living in RAC, and results in significant improvements in muscle function, including gait speed.

Aged care providers and researchers need to work together to implement the research for the practical application of residents living in a RAC facility. The environment within a RAC facility needs to change to meet the demand for an ageing population. More is expected with fewer services and yet providers are expected to continually innovate and improve. For this to occur, the latest findings need to be translated into practice in all RAC facilities.

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Chapter 10 – APPENDICES

APPENDIX 1

EXPLANATORY STATEMENT

BUHREC Protocol Number: RO1823

STUDY TITLE: Gait performance in residential aged adults and the benefits of exercise.

PRINCIPAL INVESTIGATORS:
A/Prof Justin Keogh (PhD)
Bond University
07 5595 4487

A/Prof Michael Climstein (PhD)
Bond University
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Who is doing this study?

Researchers from Bond University and University of Queensland are conducting this study that may help us understand the application of exercise (resistance training) as a possible therapy for reducing gait speed affecting quality of life, prevention of falls and hospitalisation and morbidity.

Why are we doing this study?

We are doing this study as gait speed is an illustration of a multi-systemic activity and slow gait speed might indicate a sub-clinical impairment in an older adult's health status. Those with slower gait are at higher risk for functional or cognitive decline, institutionalisation and mortality.

Through research exercise can intervene and may reverse slow gait speed in older adults. This will have a significant improvement in muscle strength and functional performance. Therefore exercise can improve gait speed, reduce falls and hospitalisation and delay physical dependence in residential aged care older adults.

How can you participate?

You can participate in this study if you meet the criteria (i) aged over 75 years, (ii) residing in a Residential Aged Care (RAC) facility, (234) can provide an informed consent, or if unable to, proxy informed consent obtained from the substitute decision maker.
You will be excluded (i) due to the reported contraindications of bioelectrical impedance (ii) Analysis, any individuals with pacemakers will be excluded from the study (234) if the subject is end-stage palliative or terminal, (iv) If an individual has difficulty in behaving that may limit data collection, (v) If the individual has a medical or other issue that would limit data collection.
We will ask you to complete a series of physical tests that assess your gait, muscle strength, muscle mass and physical function. Prior to each of these tests in these assessment sessions, you will be able to perform practice trials, which will act as a warm up and help you feel comfortable with the nature of the test. Each of these sessions will last up to about 1 hour.
If chosen to participate in the exercise group we will then require you to partake in a 12-week progressive resistance training program. We will have 2 sessions per week, each session lasting about 1 hour. We will ask you to perform a number of different exercises, involving movements of the upper and lower body. Post exercise program you will be assessed on your gait, hand strength, muscle mass and physical function.

Risks that you might experience

As we are following recognised training and testing procedures, participation in this study is very safe. It is however possible you could suffer a muscle strain or joint sprain from exercising, but all precaution will be done to minimise this risk. Following the exercise and testing sessions you may get some delayed onset muscle soreness, particularly if you have not been exercising those muscles recently. The muscle soreness typically appears 12-24 hours after the exercise and should resolve itself within 36-72 hours. Such soreness is not an injury, it will diminish within a few training sessions and is a normal adaptation to new forms of exercise.

Do I get a copy of my results?

If you wish to have a copy of your personal results, we are happy to send a report and a detailed explanation to you or your residential aged care facility.

The expected benefits of the research

By participating in this study, you will help provide us with useful information about the potential use of progressive resistance training in residential aged care older adults gait analysis. Such data will inform future studies whereby we may compare different forms of training on the reversal of gait speed. These results will allow residential aged care older adults like yourself to have improved daily function, less disability and a better quality of life.

Your participation is voluntary

Your participation in this study is voluntary. You may withdraw from the study at any time. You will not need to explain why you have withdrawn and this will not have any effect on your relationship with your residential aged care facility, the researchers, or any of the institutions involved.

All results are confidential

The information that you provide to the investigators during the study is strictly confidential. The answers to all the questions and the results of the tests will be written on a coded form without your name. The list with names and codes will be kept in a safe place, and no information will be disclosed to third parties without your consent. Only the combined <u>anonymous</u> results of all participants will be published in reports and scientific publications and/or presented as scientific and medical conferences.

Questions/further information

If you have any questions about any part of this study, please contact the chief investigator Dr. Justin Keogh from the Faculty of Health Sciences and Medicine on 5595 4487 or any of the other researchers listed on page 1.

The ethical conduct of this research

This research abides by the National Statement on Ethical Conduct in Research Involving humans. If you have any concerns with the ethical conduct of the research party, feel free to contact: Bond University Research Human Research Ethics Committee by phone on (07) 5595 4194 or email buhrec@bond.edu.au

CONSENT SHEET

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BUHREC Protocol Number: **RO1823**

STUDY TITLE: Gait performance in residential aged adults and the benefits of exercise.

PRINCIPAL INVESTIGATORS:

A/Prof Justin Keogh
Bond University

A/Prof Michael Climstein
Bond University

Dr. Timothy Henwood
University of Queensland

Samantha Fien (Masters student)
Bond University

By signing below, I confirm that I have read and understood the information package and in particular have noted that:

- I understand that my involvement will include participation in gait analysis using the Gait Mat II pressure mat system. As well as the completion of a 12-week progressive resistance training program if I am chosen for the exercise group, whereby I will perform upper and lower body exercise. In addition my muscle strength, muscle mass and physical performance will be measured.

- I have had all of my questions answered to my full satisfaction;
- I understand the risks involved;
- I understand there will be no direct benefit to me (that is, financial incentives etc) from my participation in this research;
- I understand that my participation in this research is voluntary;
- I understand that if I have any additional questions I can contact the research team;
- I understand that I am free to withdraw at any time, without comment or penalty;

- I understand that I can contact the Bond University Human Research Ethics Committee on 07 55954194 or email buhrec@bond.edu.au if I have any concerns about the ethical conduct of the project;
- I understand this project will meet the National Statement on Ethical Conduct in Human Research (Privacy), at http://www.nhmrc.gov.au/publications/synopses/e72syn.htm; and,
- I agree to participate in the project.
- I agree to allow the researchers to contact my residential aged carer if required. If you give this consent, please state the name and contact details of your carer here.

Participant	Signature	Date

Proxy (If not participant)	Signature	Date

Investigator 1	Signature	Date

APPENDIX 2

BOND UNIVERSITY
BRINGING AMBITION TO LIFE

HUMAN RESEARCH
ETHICS COMMITTEE
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28 April 2014

Justin Keogh, Samantha Fien, Mike Climstein and Timothy Henwood
Faculty of Health Sciences and Medicine
Bond University

Dear Justin, Samantha, Mike and Timothy

Protocol No: **RO1823**
Project Title: **Gait performance in community-dwelling and residential aged care older adults and the benefits of exercise**

I am pleased to confirm that your project was reviewed under the Full review procedure of Bond University's Human Research Ethics Committee and you have been granted approval to proceed.

As a reminder, BUHREC's role is to monitor research projects until completion. The Committee requires, as a condition of approval, that all investigations be carried out in accordance with the National Health and Medical Research Council's (NHMRC) National Statement on Ethical Conduct in Research Involving Humans and Supplementary Notes. Specifically, approval is dependent upon your compliance, as the researcher, with the requirements set out in the National Statement as well as the research protocol and listed in the Declaration which you have signed.

Please be aware that the approval is given subject to the protocol of the study being undertaken as described in your application with amendments, where appropriate. As you may be aware the Ethics Committee is required to annually report on the progress of research it has approved. We would greatly appreciate if you could advise us when you have completed data collection and when the study is completed

Should you have any queries or experience any problems, please contact early in your research project: Telephone: (07) 559 53554, Facsimile: (07) 559 51120, Email: buhrec@bond.edu.au.

We wish you well with your research project.

Yours sincerely

We wish you well with your research project.

Yours sincerely

Dr Mark Bahr
Chair

www.bond.edu.au

APPENDIX 3

Table 1
SARC-F Screen for Sarcopenia

Component	Question	Scoring
Strength	How much difficulty do you have in lifting and carrying 10 pounds?	None = 0 Some = 1 A lot or unable = 2
Assistance in walking	How much difficulty do you have walking across a room?	None = 0 Some = 1 A lot, use aids, or unable = 2
Rise from a chair	How much difficulty do you have transferring from a chair or bed?	None = 0 Some = 1 A lot or unable without help = 2
Climb stairs	How much difficulty do you have climbing a flight of 10 stairs?	None = 0 Some = 1 A lot or unable = 2
Falls	How many times have you fallen in the past year?	None = 0 1–3 falls = 1 4 or more falls = 2

APPENDIX 4

STROBE for JGPT paper.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract Pg1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Pg1-2
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported Pg3-5
Objectives	3	State specific objectives, including any prespecified hypotheses Pg5
Methods		
Study design	4	Present key elements of study design early in the paper Pg5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection Pg5-6

Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants Pg6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable Pg6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group Pg6-8
Bias	9	Describe any efforts to address potential sources of bias Pg15
Study size	10	Explain how the study size was arrived at Pg5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why Pg5-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding

		Pg8-9
		(*b*) Describe any methods used to examine subgroups and interactions Pg8-9
		(*c*) Explain how missing data were addressed N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy Pg8-9
		(*e*) Describe any sensitivity analyses Pg8-9
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed Pg9
		(b) Give reasons for non-participation at each stage Pg9-10
		(c) Consider use of a flow diagram Pg9-10
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic,

		clinical, social) and information on exposures and potential confounders Pg9-10
		(b) Indicate number of participants with missing data for each variable of interest N/A
Outcome data	15*	Report numbers of outcome events or summary measures Pg9-11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included Pg9-11
		(*b*) Report category boundaries when continuous variables were categorized Pg9-11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period Pg9-11
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses Pg9-11
Discussion		

Key results	18	Summarise key results with reference to study objectives Pg11-15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias Pg15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Pg16
Generalisability	21	Discuss the generalisability (external validity) of the study results Pg16
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

APPENDIX 5

CONSORT for PeerJ paper.

CONSORT for PeerJ paper.

CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	n/a
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	1 & 2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	2-4
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	5

	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	5
Participants	4a	Eligibility criteria for participants	4
	4b	Settings and locations where the data were collected	4-6
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	5-6
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	7-9
	6b	Any changes to trial outcomes after the trial commenced, with reasons	n/a
Sample size	7a	How sample size was determined	5
	7b	When applicable, explanation of any interim analyses and stopping guidelines	5
Randomisation:			
Sequence	8a	Method used to generate the random allocation sequence	n/a

generation	8b	Type of randomisation; details of any restriction (such as blocking and block size)	n/a
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	n/a
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	n/a
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	n/a
	11b	If relevant, description of the similarity of interventions	n/a
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	9
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	9
Results			
Participant flow (a diagram is strongly	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	10-11 n/a for

recommended)			randomisation
	13b	For each group, losses and exclusions after randomisation, together with reasons	10-11 n/a for randomisation
Recruitment	14a	Dates defining the periods of recruitment and follow-up	10-11
	14b	Why the trial ended or was stopped	10-11
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	10
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	10-11
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	10-11
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	10-11

Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	10-11
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	10-11
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	11-16
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	11-16
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	11-16
Other information			
Registration	23	Registration number and name of trial registry	5
Protocol	24	Where the full trial protocol can be accessed, if available	n/a
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	17

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org

APPENDIX 6

Exercise Participant's quotes

The following quotes provide some context to the perceptions of the residential aged care residents on their participation in the exercise programs included in the thesis.

"Considering I am 3 months older now than when I commenced, I am surprised that I now feel okay at the end of the programme, I was exhausted at the start of the programme"

~ Residential aged care adult (88 y)

"I find it easier to walk now after the exercise programme"

~ Residential aged care adult (76 y)

"I like the structure, no interruptions, everyone seems to cope and it is so worthwhile"

~ Residential aged care adult (82 y)

"A very good, organised programme – even one could say meticulous"

~ Residential aged care adult (91 y)

"It is a joy to do the exercises with our instructor"

~ Residential aged care adult (87 y)

Appendix 7

Blog for Applied Research in Connected Health – Ireland (re: ERA Travel Exchange)

ARCH Applied Research for Connected Health

TECHNOLOGY CENTRE ENTERPRISE IRELAND IDA IRELAND SUPPORTED

Home About us Research Industry News Events Blog Media Contact

Aussie draws the short straw!

‹ Previous Next ›

Aussie draws the short straw!

Guest Blog by Samantha Fien, visiting PhD student.

During my exchange someone mentioned "Geez, you drew the short straw coming to Ireland if you are from Australia." I thought "oh, how wrong could you be". Yes, Australia is amazing but so is Ireland! This was my first time in Ireland and it did not disappoint! I had amazing weather, I made life long friends, expanded my knowledge and research skills and will continue to keep in contact with ARCH for many years to come.

Whilst on my exchange I had the opportunity to be involved with ARCH and the research team. It's taken me a couple of weeks to think and reflect on my experience more so because it still doesn't seem real that I had the opportunity to come to Ireland and get involved with so many research studies. After much deliberation I have finally settled on the following three words to describe the time I spent in ARCH:

ARCH Applied Research for Connected Health Home About us Research Industry News Events Blog Media Contact

DIVERSE. GRAND. MATESHIP.

DIVERSE.

The ARCH centre is diverse in so many ways. The context of the studies ranged from community-dwelling dementia patients to nursing home residents to general practitioners, all involving connected health. They seem to cover quite a lot but manage it all really well. There was always something for me to do or be involved with, which I loved!

The methodological approaches used included both qualitative and quantitative research. I was able to sit in on a workshop about Photo Voice, which was something I had never heard of before (the organisation and research methodology) and I found both to be extraordinary. The lengths that went into planning and organising events and studies were a great insight to see first hand.

The team itself were researchers from all over the world. They all had different backgrounds and passions but came together for the common objectives and research aims that were currently being investigated at the time. I was so eager to learn and expand my knowledge on all perspectives of research and this really was the best place to do so. I was never bored and enjoyed coming into the ARCH every day.

GRAND.

"Ah grand", "That's grand!" – Frankly, I had to add this word into my blog as it's my favourite Irish word that was used as many times during the day as Australians would use "mate". Every time I would hear the word, I would just smile and even now it reminds me of Ireland whilst writing this. I do feel the word "grand" (especially when pronounced with a typical Irish accent) describes the atmosphere and culture embedded in ARCH. The team ensured I was involved in as many opportunities as possible – I was fortunate to go to a number of workshops for different research methodologies. I attended the ARCH Open Day where I was able to meet various health collaborators and gain further knowledge in connected health and the Irish health care system. Overall it was grand!

MATESHIP.

The team of researchers I met at ARCH welcomed me with open arms and created an opportunity for myself to see and engage the Irish health care and connected health in community-dwelling, hospitals, nursing homes, health professionals and health organisations.

To put it into context, the term mateship dates back to WW1 and Australian diggers. The Australian culture of mateship is held quite highly as such is a word that is not used every day to describe something. But yet it is perfect for the ARCH team. The team itself were mates and made me feel like part of the team. Nothing was too hard for them and they ensured I was involved in as many things as possible during my stay there.

I put the team in high regards as they asked for my opinion numerous times and actually listened to what I was saying. They weren't doing this to be nice. They were genuinely interested in what I had to say about what they working on for their projects in connected health. This was major for me because sometimes I question myself and think to myself "who would want to listen or hear what a PhD student has to say" or "she does not have enough experience or knowledge". And yet I found the complete opposite with ARCH. Not once I questioned myself. I felt comfortable working with the research team and as such I did not feel like I was working, as I found the whole experience to be so enjoyable!

If this experience was "drawing the short straw" well then I would pick the short straw any day of the week. I had an incredible experience whilst at ARCH – the knowledge I have come away with, the network I have created and expanded, the insight into planning a research project and collaborative thinking is second to none! I am truly grateful for the experience and will treasure the opportunity for life. I am already planning my next trip to Ireland!

I would also like to thank and acknowledge Emerging Researchers in Ageing, CEPAR (ARC Centre of Excellence in Population Ageing Research), Bond University and University College Dublin for sponsoring me to travel to Ireland and be part of this exchange.

You can contact Samantha Fien on samantha.fien@student.bond.edu.au .

Biography

Samantha Fien is a PhD student at Bond University and a member of the Australian Association of Gerontology (AAG). Her research is examining gait performance and the benefits of exercise in residential aged adults. She has also helped in a number of studies: sarcopenia status in residential aged care adults, tremor training study and Masters Games athletes. Samantha is also a cardiac technician at the Cardiac Centre on the Gold Coast.

June 29th, 2017

Bond University Tumblr post (Journey as a Bond University student)

Follow bonduniversity tumblr.

From Student for a Semester to International Scholar

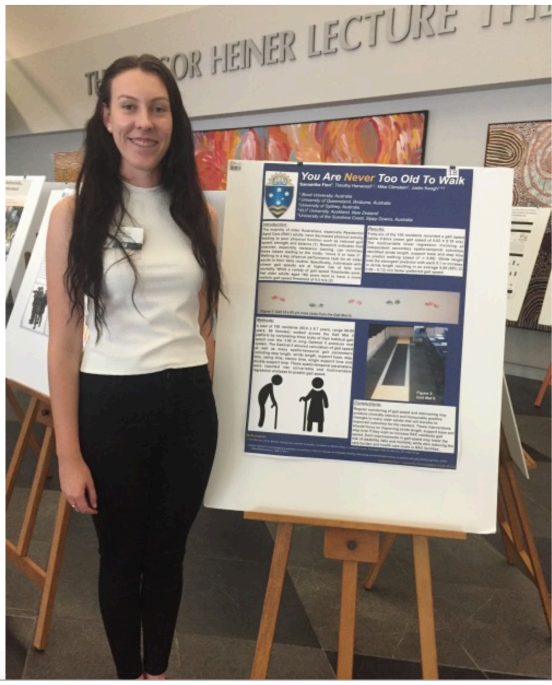
The importance and role of a university is so vital to one's career pathway. I did not fully realise just how much this meant to me until late last year. I never wanted to feel like a number at university and get lost in the crowd. I wanted to find myself and ignite the passion that I had and pursue my dreams. Sounds simple, right?

Follow bonduniversity tumblr.

But without the right university, tools and equipment you cannot get to where you want to be. You have to step outside of your comfort zone and chose a university that is best suited to you and your career path. This is easier said than done. But you have to take that leap, as it will be worth it in the end!

I began my Bond journey in Year 10 when I completed the Student for A Semester Program. Little did I know that it would trigger and begin the journey that has lead me to where I am now and also created the foundation for my career.

After completing my Bachelor's degree in Exercise Science I decided to continue along the research aspect of university and enrolled in Master of Science by Research (Health Sciences) and am now a PhD student with a research topic on "Gait performance in residential aged adults and the benefits of exercise" with Associate Professor Justin Keogh as my primary supervisor.



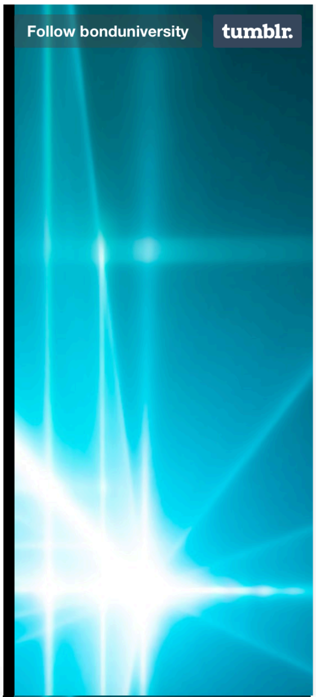
The past few years have exposed me to so many invaluable and life-changing experiences and I am so thankful and grateful. Without access to a friendly and safe atmosphere, the right networks and collaborations and amazing support team I would not be doing what I love.

I consider myself extremely lucky to have the greatest team of supervisors, family and friends who are there for me 24/7; willing to listen to me practice speeches, read my papers and just listen and be there for me whether I am having a good or bad day.

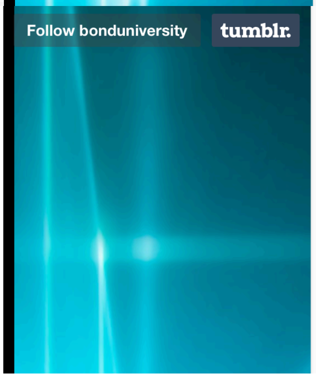
My advice to Bond students is that you take on every opportunity that comes your way! You chose this university for a reason; so don't regret your time here. Please do everything you can and seize the moment you have!

Oh and do not forget to surround yourself with a supportive circle!

Follow bonduniversity tumblr.



I am so thankful for the opportunities, skills, knowledge and experiences that I have already gained from Bond University and I'm incredibly excited for the next adventure. I will be presenting and attending the International Research on Sarcopenia and Frailty Conference in later April this year and will be completing a research project in Dublin under the supervision of Dr. Catherine Blake this Australian Winter. There are no words for how excited I am for this experience. It is truly amazing where research and the right university can take you!



Written by Samantha Fien

Read more about Samantha's story here. Interested in starting your own journey at Bond University? Explore your options and find out more by visiting https://bond.edu.au/future-students/study-at-bond.

Tags: study university bond university health hsm research scholarship dublin australia exercise science master of science health sciences

February 06, 2017

Bond University Tumblr post – ERA International Travel Exchange experience

Follow bonduniversity tumblr.

Be fearless in the pursuit of what sets your soul on fire

My experience was just too good not to share! I was lucky enough to win the Emerging Researchers in Ageing (ERA) International Travel Exchange which allowed me to travel to Europe in 2017. The scholarship was Funded by the ERA Steering Committee, and with the support of the Ageing Research Centre's Centre of Excellence in Population Ageing Research. The scholarship offered me the opportunity to grow and develop as a researcher, as well as create connections with my peers, senior academics and policy makers on an international scale.

I was able to attend and present my research at the International Conference in Sarcopenia and Frailty Research in Barcelona in April 2017. I then ventured over to Dublin where I attended University College Dublin (UCD) under the supervision of Dr. Catherine Blake for seven weeks.

Follow bonduniversity tumblr.

This was my first time in Ireland and it was an 11/10! On my first day in Dublin city centre I stumbled across a billboard that had "Make yourself at home Sam". If there was ever a sign needed that was the one I needed. I did exactly as what the sign said and had the best experience ever. Literally.

I could not be happier with the whole experience! I had an amazing supervisor who allowed me to be involved in a variety of areas from Gaelic football to residential aged care adults. I have met some absolutely unreal people with special mention to the ARCH team, UCD Physiotherapy and PhD students, UCD Physio Hub and Boston Simmons Physical Therapy students. I made lifelong friends, expanded my knowledge for research, enhanced my research skills and developed as a researcher and PhD student.

I placed two quotes above my desk whilst I was in Ireland and will continue to have these quotes engrained in my head for the rest of my life. “Be fearless in the pursuit of what sets your soul on fire” and “If it doesn’t challenge you, it won’t change you.”

Even the weather was perfect! I had to go and buy sunscreen because I got burnt and didn’t even think to pack sunscreen for Ireland.

Reflecting and looking back upon the whole experience I have realized just how lucky I was to receive the scholarship. I am so grateful and glad I received the scholarship to travel across the world and I will cherish the memories made for life.

Written by Samantha Fien. Sam has come from being a Student for a Semester when she was in year 10, to doing a Bachelor of Exercise and Sports Science to a Master of Sports Science to doing a PhD all at Bond University!

Tags: Bond University, Bond Uni, Scholarship, international, international scholarship, international student, exchange, study abroad, research, Dublin, Ireland, PhD, academics, university of now

September 28, 2017

Follow bonduniversity tumblr.

APPENDIX 8

Letter to the Editor - AJA

Clinical Viewpoint - AFP

Final revision of the research paper - JGPT

Original research paper - JHNRS

Original research paper - PEERJ

Pumping iron in residential aged adults: Why isn't this more commonly available?

Dear Editor,

The demand for residential aged care (RAC) placement will more than treble by 2050 [1]. With population ageing, an Australian adult who is currently 65 years of age has a greater than 20 projected years of life expectancy. When coupled with the increased prevalence and number of complex health-care conditions, it is reported that the impending need for care nationally will dramatically increase [1]. Consequently, the Australian health-care system may need to adopt more innovative, evidence-based approaches to offset the high level of sedentary behaviour, disability and poor health in many of our older people, especially those residing in RAC [2].

For the healthy community-dwelling older adults, research has long established that exercise, even when commenced later in life, has measurable benefits to well-being [3,4]. More recently, exercise is receiving significant attention as a means of prolonging and revitalising health in community-dwelling older adults with care needs. However, it is resistance and weight-bearing training that have been demonstrated to be the most potent stimulus to increase muscle mass, muscle strength and muscle function among older adults with care needs, with significant reductions in mobility disability and number of falls. In a recent systematic review on resistance and weight-bearing exercise training in RAC, it was shown that participation significantly improves balance, flexibility, ability to rise from a chair, stair climbing power, gait performance, positive self-perception and self-sufficiency [5]. In addition, participants had a greater satisfaction with life despite their age, level of chronic diseases, sedentary lifestyle and function disabilities [5]. However, resistance and weight-bearing exercise continue to be underutilised and understudied as a disability preventative in RAC.

We therefore strongly encourage health professionals working with older adults to more actively promote and/or deliver progressive resistance and balance training to as many older adults as possible. We also strongly encourage many more researchers to examine issues affecting the feasibility of progressive resistance and weight-bearing exercise in RAC settings. Such interactions between health professionals and researchers have the potential to result in significant benefits to RAC residents, staff and the national health-care expenditure.

Samantha Fien
Faculty of Health Science and Medicine, Bond University, Robina, Queensland, Australia
Timothy Henwood
University of Queensland/Blue Care Research and Practice Development Centre, School of Nursing and Midwifery, The University of Queensland, Brisbane; and Faculty of Health Science and Medicine, Bond University, Robina, Queensland, Australia
Mike Climstein
Exercise, Health and Performance Faculty Research Group, The University of Sydney, Sydney, New South Wales, Australia
Justin William Leslie Keogh
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The full text of the view point article *"Clinical importance of assessing walking speed in older adults in general practice"* is freely available on the RACGP's publication website www.racgp.org.au/afp.

Gait Speed Characteristics and Its Spatio-Temporal Determinants in Nursing Home Residents: A Cross-Sectional Study

ABSTRACT

Background and purpose: Low and slowing gait speeds among nursing home residents are linked to a higher risk of disability, cognitive impairment, falls, and mortality. A better understanding of the spatio-temporal parameters of gait that influence declining mobility could lead to effective rehabilitation and preventative intervention. This study aims were to objectively quantify the spatio-temporal characteristics of gait in the nursing home setting and define the relationship between these parameters and gait speed.

Methods: One hundred nursing home residents were enrolled into the study and completed three habitual gait speed trials over a distance of 3.66 m. Trials were performed using an instrumented gait analysis. The manner in which the spatiotemporal parameters predicted gait speed was examined by univariate and multivariable regression modelling.

Results: The nursing home residents had a habitual gait speed of 0.63 ± 0.19 m/s, a stride length of 0.83 ± 0.15 m, a support base of 0.15 ± 0.06 m and step time of 0.66 ± 0.12 s. Multivariable linear regression revealed stride length, support base and step time predicted gait speed (R^2= 0.89, p<0.05). Step time had the greatest influence on gait speed with each 0.1 s decrease in step time resulting in a 0.09 m/s (95% CI 0.08 - 0.10) increase in habitual gait speed.

Conclusion: This study revealed step time, stride length and support base are the strongest predictors of gait speed among nursing home residents. Given the impact of low and slowing gait speed in this population, future research should concentrate on developing and evaluating intervention programs that were specifically designed to focus on improving step time, stride length and support base in nursing home residents. As gait speed has been shown to be predictive of many adverse events in older adults, we would also suggest that routine assessments of gait speed, and if possible their spatiotemporal characteristics be done on all nursing home residents in an attempt to identify residents with low or slowing gait speed.

Keywords: health professionals; gait speed; nursing home; spatio-temporal determinants

INTRODUCTION

Walking is a key physical performance task for people of all ages, including older adults. The majority of older adults, especially those living in nursing home (residential aged care) settings have decreased physical activity[1] and poor physical function as indicated by their reduced gait speed, muscle strength and balance.[2] Older adults with slower gait speeds are at higher risk of disability, cognitive impairment, institutionalization, falls, and mortality.[3] While a variety of gait speed thresholds exist, healthy community dwelling older adults tend to experience poorer health when their habitual gait speed is < 0.8 m/s,[3,4] whereas for nursing home residents > 80 years of age, a threshold of < 0.5 m/s has been proposed.[4,5] A recent systematic review which included 34 studies quantifying the gait speed of residents living in nursing homes reported a mean habitual pace gait speed of 0.48 m/s (95% confidence interval (CI) 0.40-0.55).[6] Gait speeds this low suggest that most nursing home residents are limited in mobility and independence, have decreased stability and are at increased risk for many other age-related conditions.[6]

Currently, little is known in relation to the physical determinants or risk factors for low gait speed in low-functioning older adults and those living in nursing home facilities. While McGough et al.[7] and Keogh et al.[8] have reported that measures of physical function, balance, lifetime physical activity levels and sitting time correlate with gait speed in these less functioning older cohorts, no studies have quantified the spatio-temporal determinants (e.g. step length, step rate) that determine gait speed in a nursing home population.[9] Figure 1 presents a pictorial representation of the relationship between selected spatio-temporal parameters and gait speed. When compared to younger adults, older adults walk more slowly; have a shorter step length and a broader support base than their younger counterparts, with these differences more pronounced in older adults living in nursing home and/or with a high risk of falls.[10-13]

Insert Figure 1 here.

A greater understanding of nursing home residents' gait speed and spatio-temporal determinants may assist health professionals to identify nursing home residents at high risk of adverse events and allow for a more specific-tailored physical therapy and rehabilitation program for each individual.[11] We would argue this is very important as indicated by a systematic review that found exercise-related improvements in older adults' gait speed are typically smaller in magnitude and more variable than the improvements in muscular strength.[14] Specifically, semi-regular monitoring of gait speed and spatiotemporal parameters could assist appropriate health professionals to prescribe resistance, balance and gait exercises that target their clients' major spatiotemporal limitations. The collection of this gait spatiotemporal data may also allow the exercise therapist to provide their client task-relevant augmented feedback (e.g. visual cues, instant or delayed feedback) during these exercises to improve the transfer of training to their habitual walking performance[15,16].

This study aims were to objectively quantify the spatio-temporal determinants and gait speed of nursing home residents and to gain some insight into whether these spatiotemporal parameters may predict their gait speed.

METHODS

Recruitment and Study Design

The study employed a cross-sectional design, with data collected over an eight-month period across three nursing home facilities in South East Queensland, Australia. The facilities were from different providers that were either part of a small chain of nursing homes or a not for profit organisation. The flow of recruitment to assessment is represented in Figure 2. Facilities were approached via email and telephone follow-up seeking an expression of interest for participation. Following an expression of interest, nursing homes were visited and the study explained to the Service Manager. Once the service manager approved the participation of their nursing home in the project, eligible participants were identified at a meeting between the project lead researcher and the Service Manager, head Registered Nurse and head Diversional Therapist. Ethical approval for this study was attained from the University Human Ethics Research Committee (RO 1823) and gatekeeper's approval obtained through the nursing homes.

Insert Figure 2 here.

Based on study's eligibility, participants were eligible for inclusion if they were: a) aged 65 years and over, b) residing in a nursing home facility, c) ambulate independently or without a walking aid and d) could provide informed consent. The exclusion criteria included: a) end-stage terminal and/or life expectancy <6-months (ethical reasons), b) two person transfer or increased falls risk during ambulation (as assessed by the nursing home staff), c) unable to communicate or follow instructions (personal needs beyond the scope of this project) and d) behaviors that would endanger the participant or research staff.

All participants were approached personally about participation and given the opportunity to ask questions or raise concerns about the study. Following this discussion and reading of the participant information sheet, participants provided their informed consent if they wished to participate. A total of 100 participants took part in the study, with the primary investigator responsible for observing and administering all of the assessments.

Primary Outcome Measures: Gait Speed

Gait speed was assessed using a computer interfaced electronic system (model GaitMat II, EQInc, USA) which required participants to walk across a level pressure mat system that was 3.66 m (11.91 ft.) long.[17] The concurrent validity of the spatio-temporal determinants of gait recorded with the GaitMat II is extremely high when compared to the criterion method of 3-D motion capture (*R* =.99).[18,19] The Gait Mat II was chosen due to it being much more feasible to use in nursing homes and 3-D motion capture. The GaitMat II system automatically measured gait speed and spatio-temporal determinants, with this data automatically stored in a Microsoft Excel spreadsheet.

Participants completed the trials at their habitual gait speed in their regular footwear. The following instructions were provided, "Walk towards the end of the room in the centre of the mat at a pace that is comfortable for you". All measures were initiated from a standing start 2 m (6.56 ft.) from the GaitMat II platform in order to reduce the effect that acceleration or deceleration may have on the outcomes.[20,21] The average gait speed (m/s) from three attempts was used for data analysis. Participants were allowed as much rest as required between attempts, with rest periods typically being up to one minute.

Secondary Outcome Measures

A full spectrum of spatio-temporal gait determinants outputted was recorded. These spatio-temporal gait determinants included step length, stride length, support base, step time, swing time, stance time, single support time and double support time and are defined by the GaitMat II manual found in Table 1.

Insert Table 1 here.

In addition handgrip strength, the Mini-Cog test[22] and a simple five-item questionnaire (SARC-F) [23,24] were collected for the purpose of cohort characteristics description. Nursing home facility records provided other relevant descriptors including the number of medical conditions and medications.

Data Management and Statistical Analysis

All data were initially checked for normality prior to analysis. As data were normally distributed, descriptive statistics are presented as mean and standard deviations for continuous variables. A one-way ANOVA and post-hoc Tukey and Scheffe tests were performed to investigate between nursing home differences. Linear regression analyses were performed to gain insight into the potential determinants of gait speed (i.e. gait spatio-temporal determinants) in residents. Univariate analyses of all gait spatio-temporal determinants were employed to identify possible determinants of gait speed (two-tailed). Factors with a significance $p \leq 0.10$ determined from simple linear regression analyses were included in the multiple linear regression model. This multivariable model determined which combination of variables best-predicted gait speed in residents. The 95% confidence interval (95% CI) was included for the coefficients in the multivariable model. All data were analysed using SPSS statistic software (version 22) with statistical significance set at $p<0.05$ a priori.

RESULTS

Participants

One hundred of 166 (60.24%) invited, eligible residents were recruited to the study. There were no significant differences between all variables for nursing home cohorts in this study ($p>0.05$), thus data combined into one group for analysis. Cohort data are present in Table 2. The average age of the 100 residents was 85.7 (7.1) years with a mean gait speed of 0.63 (0.19) m/s, an average of 11.0 (4.9) medical conditions and 14.0 (5.8) prescribed medications. There were no significant differences with gait speed and spatio-temporal parameters, handgrips strength, sarcopenia status and medications and chronic diseases across males and females. However, males were significantly younger ($p = 0.038$) and had a lower Mini-Cog assessment ($p = 0.002$) in comparison to females.

Insert Table 2 here.

The majority of participants (79%, n = 79/100) presented with below normal habitual gait speeds (< 0.80 m/s), whilst 26% (n = 26/100) ambulated at below the mean reported for nursing facilities residents (< 0.48 m/s, 95% CI 0.396-0.554).[6]

Results of the univariable linear regression analyses identified three spatio-temporal factors as being predictive of gait speed: stride length ($p<0.001$), support base ($p<0.001$) and step time ($p=0.002$) (see Table 3). Of these factors, stride length contributed to the largest change in gait speed, with each 0.1 m increase in stride length resulting in an average 0.09 m/s (95% CI 0.06 – 0.13) faster habitual gait speed.

Insert Table 3 here.

The multivariable linear regression model that included stride length, support base and step time predicted 89% (R^2 = 0.89) of the variation in gait speed (see Table 3). Specifically, step time contributed to the largest change in gait speed with every 0.1 s decrease in step time resulting in a mean increase in gait speed of 0.09 m/s (95% CI 0.08 – 0.10). A 0.1 m increase in stride length was also associated with a mean increase of 0.08 m/s (95% CI 0.07 – 0.09) in gait speed. The third determinant identified in the multivariable regression, support base appeared to have a smaller effect on gait speed, with a 0.1 m decrease in support base resulting in a mean gait speed increase of 0.04 m/s (95% CI 0.02 – 0.07).

DISCUSSION

This study demonstrated that nursing home residents who can self-ambulate with or without a walking aid still walk at a gait speed (0.63 ± 0.19 m/s) and possess spatiotemporal parameters that place them at high risk of falls and other adverse age-related events.[3,11,12] A total of 79 participants presented with below normal habitual gait speeds (< 0.80 m/s), which is a threshold defined to screen for sarcopenia in older adults aged 80 years and older.[25] A total of 27 participants also walked at a threshold below 0.48 m/s which a meta-analysis of 48 studies found to be the mean gait speed for older adults in nursing homes.[6]

Results of the regression analyses also indicated that nursing home residents who ambulated at a slower habitual gait speed were more likely to have an increased step time, shorter stride length and a wider support base than their more ambulatory counterparts. While the finding that some spatio-temporal parameters do predict gait speed is not overly surprising, to our knowledge this is the first study to investigate the potential for spatio-temporal determinants to determine gait speed in the nursing home setting. The importance of the spatio-temporal parameters in determining gait speed also appear consistent with Sterke et al.[11] and Taylor et al.[12] who demonstrated that slower older walkers with increased falls risk had shorter stride lengths, longer double support times and a wider support base when compared to aged matched individuals with no falls history.

The significant ability of spatio-temporal determinants such as step time, stride length and support base to determine gait speed in the current study ($R^2 = 0.89$) and falls in previous studies[11,12] would appear to reflect a variety of biomechanical concepts. For example, the ability of step time and stride length to determine gait speed may be explained by the impulse-momentum relationship and/or the nursing home residents' reduced ability to maintain balance during the gait cycle. It is fair to conclude that reduced lower-body muscle strength and power may mean that the nursing home residents require greater single/double support times to produce the necessary impulse (force multiplied by time) to propel their body forward during the gait cycle.[26] Their reduced force production ability and greater stance time would then contribute to a reduced stride length, increased step time and ultimately a reduced habitual gait speed. Poor stride length may also be suggestive of shuffling gait and low plantar flexor and hip flexor strength.[26] Therefore, certain exercises such as calf raises and leg raises coupled with gait training may need to be incorporated in resistance training programs to improve gait speed in nursing home residents.[21]

The clinical significance of this study is that gait speed characteristics and spatio-temporal determinants are becoming more easily measured and analysed in nursing home settings. Health professionals can then use this individualized gait data to identify residents at risk of adverse events and intervene where appropriate by providing an individualized exercise intervention for each resident. In doing so, residents are likely to benefit more from these exercise programs as they are better tailored to the specific spatio-temporal parameters underlying the participants' poor gait speed and/or falls risk. Such an approach may also improve exercise adherence as these programs can better concentrate on improving gait performance in activities of daily living (ADL).[27]

Collectively, the manner in which the nursing home residents walk (as described by their spatio-temporal determinants) have major implications to exercise therapy and rehabilitative approaches to improving gait speed in this cohort. With the clinical implications being that if health professionals can continually monitor and assess gait speed and spatio-temporal determinants, we may be able to decrease or prolong the amount of residents who are induced into the vicious cycle of reduced physical activity and decreased mobility and physical performance that have a direct effect on their health and survival.

However, it is also possible that the tendency for the slower nursing home residents to have shorter stride lengths, increased step times and wider support bases may be indicative of a compensation for their reduced strength and dynamic stability. Longer strides and a narrower support base increase the distance that the centre of mass travels outside the anterior-posterior and medial-lateral bases of support, respectively.[26] As Sherrington et al.[28] has reported that exercise programs that do not sufficiently challenge balance may actually increase rather than decrease the risk of falling of nursing home residents, we would recommend that nursing home residents with short strides and wide support bases focus initially on improving their static and dynamic balance. Once balance has been improved in the anterior-posterior and medial lateral directions, these residents may further prioritize resistance and gait retraining to safely improve their gait speed and overall mobility.

Given the interplay between decreasing mobility and increasing disability, the monitoring of gait speed by health professionals (and if possible the primary spatio-temporal determinants) on at least an annual basis in the nursing home setting has been recommended.[8,29] For those nursing home residents identified with poor and slowing mobility, systematic review evidence suggests that regular progressive resistance and balance training can improve their habitual gait speed by 0.07 m/s (95% CI 0.02-0.11) when compared to non-exercising controls.[30] While these reported improvements in gait speed are positive, there may be two potential criticisms of the studies reviewed in this meta-analysis (and the wider literature). The first is that the studies have typically used quite generic exercise prescriptions that focus on improving muscular hypertrophy and strength in a variety of muscle groups. Based on emerging evidence that reduced gait speed in older adults is primarily a result of reduced ankle plantarflexor rather than hip or knee extensor moment and muscle power,[26] a greater focus on increasing the muscle strength and power of the plantarflexors compared to the traditional focus on the knee and hip extensors may be warranted. In addition, the majority of studies in this area that have included balance training primarily used static balance tasks that require the older adults to hold a position for a period of 10-20 s e.g. two feet stands on unstable surface or with eyes closed or semi-tandem/tandem stance. Based on our results, we suggest that dynamic balance ability, which would appear more closely related to the balance requirements of human gait, be taught by health professionals on a weekly basis. Therefore, nursing home residents may obtain greater gait speed benefit from performing dynamic balance tasks (e.g. stepping and perturbation response) than static balance tasks.[31-33]

The Gait Mat II provided a feasible, reliable and valid tool to measure gait speed and spatio-temporal determinants in nursing home adults.[2,18,19] New equipment has been developed since the data collection of this study. One suggestion for future studies would be to use inertial sensors[34] which may be a more portable and affordable gait assessment. Such advancements in inertial sensor technology would more easily allow health professionals to routinely monitor gait speed and spatiotemporal parameters in the nursing home setting, which may further increase allow the development of targeted exercise programs for each nursing home resident.

Participation selection bias is a limitation that may have influenced our findings as the inclusion criteria deemed that a participant should have the ability to walk with or without an aid. A total of 55% of residents in the nursing home facilities were ineligible because of the inability to mobilize or because they were deemed too high a risk to participate. Because of this bias in selecting individuals who were ambulant (with or without assistive devices), the gait speed and spatiotemporal parameters obtained in this study may not be generalized to all nursing home residents. Nevertheless, the participants in the current study were still below the cut off for physical performance and at risk of further decreased disability, cognitive decline and mortality,[35] with every 0.1 m/s reduction in gait speed equating to a 10% decrease in older adult's ability to perform ADLs.[36] It must also be acknowledged that static or dynamic balance ability were not directly assessed in this study. Therefore, while our proposition of poor dynamic balance contributing to the reduced gait speed of nursing home participants has some experimental support,[37,38] we cannot explicitly state that is the case with our participants.

CONCLUSIONS

This is the first study to investigate gait speed characteristics and spatio-temporal determinants in the nursing home setting. While our cross-sectional study suggests that step time, stride length and support base are highly predictive of gait speed in nursing home residents, longitudinal research is required to determine if changes in these three spatio-temporal determinants may be predictive of changes in gait speed. If these longitudinal relationships between gait speed and spatio-temporal determinants can be found, health professionals may be better able to alter aspects of their exercise prescription and augmented feedback approach to improve outcomes for nursing home residents.

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Figure Legends

Figure 1. Deterministic model of gait speed outlining the direct relationships between the spatio-temporal determinants and gait speed.

Figure 2. Consort flow diagram of the recruitment process within the nursing home facilities.

Figure 1

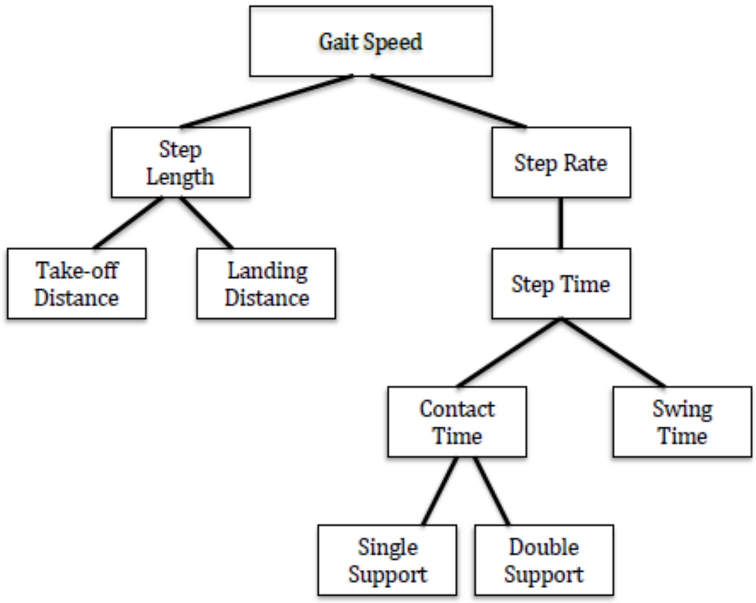

Figure 1. Deterministic Model of Gait Speed Outlining the Direct Relationships Between the Spatio-Temporal Determinants and Gait Speed.

Figure 2

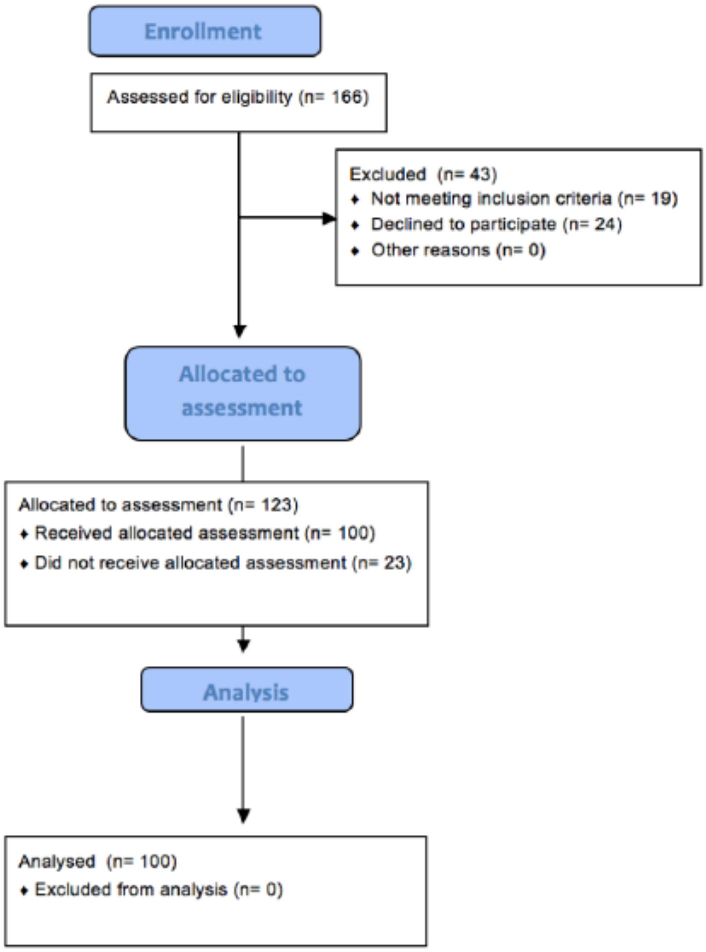

Figure 2. Consort Flow Diagram of the Recruitment Process Within the Nursing Home Settings.

Table 1

Table 1: Spatio-temportal gait determinants and definitions as defined by the GaitMat II manual.

Spatio-temporal gait determinants	Definitions
Step length	The distance from the first switch closure of one footprint to that of the footprint on the contralateral side.[39]
Stride length	The distance from the first switch closure of one footprint to the next footprint on the ipsilateral side.[39]
Support base	The medial lateral distance across the mat to the innermost switch closure for one footprint from the innermost switch closure of the previous footprint on the contralateral side.[39]
Step time	The time to the earliest switch closure of a footfall from the earliest switch closure of the previous footfall on the contralateral side.[39]
Swing time	The time to the earliest switch closure of a footfall from the latest switch opening of the previous footfall on the ipsilateral side.[39]
Stance time	The time to the latest switch opening of a footfall from the earliest switch closure of the same footfall.[39]
Single support time	The time to the earliest switch closure of the next footfall on the contralateral side from the latest switch opening of the previous footfall on the contralateral side.[39]
Double support time	The time to the latest switch opening of the previous footfall on the contralateral side from the earliest switch closure of a footfall.[39]

Table 2

Table 2: Characteristics of the Cohort of 100 Nursing Home Residents.

Parameter	Group Mean (SD)	Females (n=67) Mean (SD)	Males (n=33) Mean (SD)
Age, y	85.7 (7.1)	86.1 (6.6)*	85.0 (8.1)
Handgrip Strength, kg	11.1 (4.9)	10.7 (4.2)	11.7 (6.2)
Mini COG, #	1.2 (0.4)	1.8 (0.4)*	1.3 (0.5)
SARC-F, #	5.5 (3.3)	4.9 (3.3)	6.6 (3.1)
Medical Conditions, #	11.0 (4.9)	11.4 (4.9)	10.2 (4.9)
Medications, #	14.0 (5.8)	13.8 (6.1)	14.4 (5.3)
Gait speed, m/s	0.63 (0.19)	0.65 (0.20)	0.58 (0.16)
Step length, m	0.41 (0.08)	0.42 (0.07)	0.41 (0.07)
Stride length, m	0.83 (0.15)	0.84 (0.16)	0.81 (0.14)
Support base, m	0.15 (0.06)	0.16 (0.06)	0.15 (0.07)
Step time, s	0.66 (0.12)	0.64 (0.12)	0.70 (0.12)
Swing time, s	0.42 (0.07)	0.41 (0.07)	0.44 (0.08)
Stance time, s	0.91 (0.20)	0.88 (0.19)	0.98 (0.20)
Single support Time, s	0.42 (0.07)	0.41 (0.06)	0.43 (0.08)
Double support Time, s	0.24 (0.07)	0.23 (0.06)	0.27 (0.08)

= number; Mini COG = Mini Cognitive test; SARC-F = Sarcopenia Five-Item Questionnaire

* = Statistical significance $p<0.05$.

Table 3

Table 3: Univariable and Multivariable Linear Regression Model of the Spatio-Temporal Predictors for Habitual Gait Speed in 100 Residents Living in Nursing Homes.

Factor	**Univariable**		**Multivariable**	
	Coefficient (95% CI)	***p*-value**	**Coefficient (95% CI)**	***p*-value**
Stride length, m	0.93 (0.55 – 1.31)	< 0.001	0.83 (0.74 – 0.92)	< 0.001
Support base, m	-0.51 (-0.77 to -0.26)	< 0.001	-0.44 (-0.68 to -0.21)	< 0.001
Step time, s	-0.70 (-1.13 to -0.27)	0.002	-0.92 (-1.03 to -0.81)	< 0.001

CI = Confidence Interval.

R2 of multiple regression equals 0.892.

Note: All results significant $p<0.05$.

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GAIT SPEED AND ADVERSE EVENTS IN NURSING HOME RESIDENTS: A PROSPECTIVE COHORT STUDY.

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Abstract: *Background:* Falls, wounds and hospitalisation are serious adverse events that may result in reduced independence and quality of life, and contribute to higher risks of disability and death in nursing homes. *Objectives:* To quantify the incidence of events (falls, hospital admissions and wounds) in nursing home residents and to determine if gait speed thresholds can predict falls. *Design:* A prospective cohort design was used to estimate the incidence and types of adverse events. *Setting:* Three nursing homes on the Gold Coast/ Northern New South Wales, Australia. *Participants:* 100 nursing home adults consented to participate in this project. *Measurements:* The primary outcome included the number of adverse events (falls, wounds and hospital admissions) accessed through the nursing homes records. We used negative binomial regression models adjusted for potential confounders to examine associations between gait speed group and falls suffered by residents in nursing home settings, and we reported incidence rate ratios (IRRs) with 95% CIs and the actual P-value. *Results:* During the six months, there were a total of 226 falls, 243 wounds, 65 hospital admissions and 29 deaths with 12% of the residents having a fall(s), wound, admitted to hospital and dying in the 6-month period. Gait speed was not a statistically significant factor that impacted adverse events. However, for every additional hospital admission there was a 28% increased rate of falling, for every additional wound there was a 7.8% increased rate of falling and for every kilogram increase in handgrip strength there was a 4.4% increase rate of falling. Residents were also found to have an increased rate of falling if they were female (65.5%) and a decreased rate of falling with a positive impairment Mini-Cog score residents were likely to have a 52% decrease in their rate of falling when compared with negative cognitive impairment. *Conclusion:* The incidence of adverse events in Australian nursing homes is high, suggesting that continual refinement of assessment, education, awareness and management processes are required to improve resident outcomes. In particular, falls reduction interventions appear important, as they would likely reduce the number of hospital admissions and wounds in the nursing home setting.

Key words: Adverse events, falls, hospitalisation, nursing homes, wounds.

List of Abbreviations: ADL: Activities of Daily Living; CI: Confidence interval; EWGSOP: European Working Group on Sarcopenia in Older People; IRR: Incidence Rate Ratio; Mini-Cog: Mini-Cognitive test; SARC-F: Sarcopenia Five-Item Questionnaire.

Introduction

With an ageing population and rising life expectancy rates, older adults are likely to move into nursing homes as their physical and/or cognitive function declines. Falls, hospitalisation and wounds are serious problems that result in higher risks of disability, loss of independence, reduced quality of life and mortality in nursing homes (1).

These adverse events are also proving to become very costly with falls being the leading cause of injury-related hospitalisation in adults aged 65 years or older. In those aged 85 years and over, 4% of men and 7% of women are admitted to hospital annually as result of a fall (2). As a result, the cost of falls is expected to rise to $1.4 billion in Australia by 2051. Thus, continual improvements in fall prevention programs are required in order to reduce the falls incidence rate or additional strain on the health expenditure will incur (3). One component of the high costs of falls is the need for hospital beds. In 2010, there were 240,000 hospital bed days per year related to falls in Australia, with this expected to nearly double to 450,000 hospital bed days by 2051 (2).

To the authors' knowledge, little research has investigated the incidence of adverse events specific to falls, wounds and hospital admissions in Australian nursing home adults. A recent document on adverse events in Australian nursing home residents is a 2014-15 Australian Government report which has provided insight into older adults in hospital, however there appears to be a lack of peer-reviewed research that focuses purely upon nursing home settings (4). Residents often have multiple chronic diseases, a sarcopenic status and take multiple prescribed medications, with the interaction of these factors placing the residents at a high risk of adverse events (5, 6). Ironically, residents of nursing homes are among the least researched older adult group even though they have the highest rates for falls and hospital admissions and are among the highest consumers for prescribed medications (5).

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A recent systematic review has indicated that a significant predictor of adverse events including mobility disability, cognitive decline, mortality, falls and institutionalisation for community-dwelling older adults (aged 65 and older) was low gait speeds (7). In 2012, Sterke et al. (8) sought to extrapolate the findings for community dwelling older adults to those in nursing homes by examining whether gait speed was a significant predictor of short-term falls risk in 57 nursing home residents with moderate to severe dementia in the Netherlands. Sterke et al. (8) conducted a longitudinal study and assessed the gait performance of the nursing home residents with a computer-interfaced instrumented pressure mat every three months for a period of 15 months. A reduced gait speed (OR = 1.22; 95% CI 1.04 – 1.43) and reduced mean stride length (OR = 1.19; 95% CI 1.03 – 1.40) were the strongest gait predictors for falling within three months (8). Knowing this, we wanted to investigate if in the Australian context gait speed could predict adverse events in six months with nearly double the amount of participants. Such a study would appear warranted as Keogh et al. (9) reported that a randomly selected sample of 100 nursing home resident's mean (SD) walking speed was 0.37 (0.26) m/s, a value substantially less than a recent meta-analyses of 34 studies that reported the nursing home residents' mean walking speeds to be 0.48 m/s (95% CI 0.40 – 0.55) (10). As very few studies have used gait speed to predict adverse events in nursing home residents, additional research utilising functional performance tasks such as gait speed to predict adverse events in Australian nursing homes appears warranted.

The primary aim was to quantify incidence of adverse events in Australian nursing home residents over a period of six months. The secondary aim was to determine if gait speed thresholds could predict the frequency of falls in nursing home residents. We hypothesized that the incidence of adverse events (i.e. falls) in Australian nursing home residents would be greater than what is commonly reported for community dwelling older adults and that gait speed thresholds could predict falls in Australian nursing home residents.

Methods

Study Participants

A prospective cohort design was used to estimate the incidence and types of adverse events experienced by 100 residents in nursing home settings for six months.

Participants were eligible for inclusion if they were: (i) aged 65 years and over, (ii) residing in a nursing home facility, (11) able to self-ambulate with or without a walking aid and (iv) could provide informed consent. The exclusion criteria included: (i) end-stage terminal and/or life expectancy <6-months (ethical reasons), (ii) two person transfer or increased falls risk during ambulation, (11) unable to communicate or follow instructions (personal needs beyond the scope of this project) and (iv) behaviours that would endanger the participant or research staff.

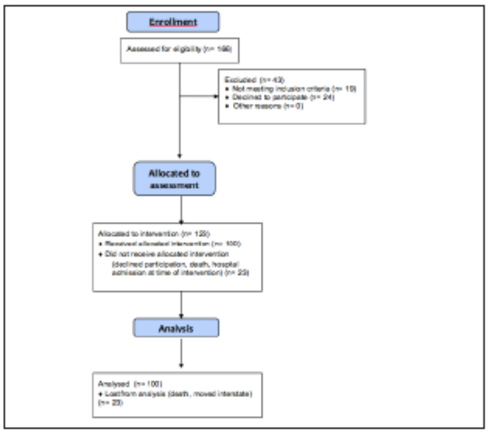
All participants were approached personally about participation and given the opportunity to ask questions or raise concerns about the study. A total of 100 participants supplied informed consent and took part in the study whereby the primary investigator was responsible for observing and administering all of the testing.

Recruitment and Study Design

Three nursing homes from Northern NSW/Gold Coast were approached and recruited for participation via telephone and email. A meeting was arranged with the facility Service Manager at each site; following an explanation of the procedures, purposes, benefits and associated risks of the study, potential participants were identified with the Service Manager. The primary investigator went and visited all potential participants and explained the procedures, purposes, benefits and associated risks of the study, participants also had the opportunity to ask questions. A total of 100 residents (66 females and 34 males), aged between 66 and 99, with mean (SD) 85.5 (7.2) years, provided written informed consent for the study. The final sample obtained was a convenience sample from all three nursing homes. Participant recruitment and assessment occurred over a nine-month period.

The flow of recruitment to assessment is represented in Figure 1. Ethical approval for this study was attained from the University Human Ethics Research Committee (RO 1823) and gatekeeper's approval obtained through the nursing homes.

Figure 1
CONSORT flow chart diagram of the recruitment process within the nursing home



Adverse Events

Adverse events were defined by the World Health Organisation (12) as an injury caused by medical management

Table 1
Characteristics of the 100 nursing home residents aged 66 to 99 years

Characteristics	Frequency
Age mean (SD)	85.5 (7.2)
Sex	
Male	34
Female	66
Number of chronic diseases	
1-5	11
6-10	46
11+	43
Total medications	
1-5	7
6-10	23
11-20	57
20+	13
Psychotropic medications	69
Falls	
Fell once	24
Fell twice	14
Fell three times	12
Fell > 3	23
Total number of residents who suffered a fall	73
Gait aids	
Ambulant	18
Walking stick/Wheelie walker	73
Wheelchair	9
Fall: time of day	
12am – 7:59am	15
8am – 3:59pm	33
4pm – 11:59pm	25
Hospital admissions	
Admitted once	27
Admitted twice	9
Admitted ≥3	4
Total number of residents placed into hospital	40
Wounds	
1-5	37
6-10	6
11+	2
Total number of residents who suffered wounds in 6 months	45
Gait speed threshold	
≥ 0.80 m/s	23
0.61 to 0.79 m/s	31
≤0.6 m/s	46
Handgrip strength (kg) mean (SD)	11.1 (4.9)
SARC-F* Score	
"Minimal risk"	33
"At risk"	67
Mini-Cog Score	
Negative cognitive impairment	25
Positive cognitive impairment	75

* SARC-F = Sarcopenia Five-Item Questionnaire

or complication rather than by the underlying disease itself, and one that results in either prolonged healthcare, or disability at the time of discharge from care, or both (12). Adverse events (falls, wounds, hospital admissions and deaths) information was collected by the nursing home staff and nurses, for a total of six months post gait speed assessment. A fall was defined as unintentionally coming to rest on the ground, floor, or other lower level (13). Hospital admission was defined as an individual who met the criteria for admission to the hospital category and care type, and underwent a hospital's admission process (documented) to receive treatment and/or care for a period of time – minimum four hours for medical admissions (4). Wounds were defined as the result of tissue damaged by trauma. This may be deliberate, as in surgical wounds of procedures, or due to accidents caused by blunt force, projectiles, heat, electricity, chemicals or friction (14).

Gait

The GaitMat II system measured the participants gait speed as they walked across a level pressure mat system that was 3.66 m (11.91 ft.) long (15). Three trials were completed at the participants' habitual speed, with the following instructions provided to the participants, "Walk towards the end of the room in the centre of the mat at a pace that is comfortable for you". An extra 2 m (6.56 ft.) platform was included on both ends of the GaitMat II in order to reduce the effect of acceleration or deceleration (16, 17). Participants were allowed as much rest as required between attempts, with rest periods typically being up to one minute. For safety reasons, all participants wore their own preferred footwear or walked barefoot and were spotted by the primary researcher who followed each participant with the average gait speed used for data analysis.

Other Measures

In addition, handgrip strength, the Mini-Cog test (18) and SARC-F questionnaire (19, 20) were collected for the purpose of cohort characteristics description. Nursing home facility records provided other relevant descriptors including the number of medical conditions and prescribed medications for each resident.

Data Management and Statistical Analysis

Three gait speed thresholds were defined; (i) ≥0.8 m/s; (ii) 0.61 to 0.79 m/s; ≤0.6 m/s. Baseline categorical variables like gender and gait speed group were tested using chi-square tests to determine if these characteristics were similar in the three nursing homes. Frequencies were reported for categorical variables. All continuous data were initially checked for normality prior to analysis. As data were normally distributed, descriptive statistics are presented as mean and standard deviations for continuous variables. A one-way ANOVA and post-hoc Tukey and Scheffe tests were performed to determine if statistically significant differences existed between the three nursing home facilities.

Table 2
Adverse events by gait speed thresholds after a period of six months in 100 nursing home residents

	Adverse event		Gait Speed Thresholds		
	No. of cases	No. of Individuals	≤ 0.60 m/s n (%)	0.61 to 0.79 m/s n (%)	≥ 0.80 m/s n (%)
Falls	226	73	33 (45.2)	26 (35.6)	14 (19.2)
Wounds	243	45	21 (46.7)	16 (35.6)	8 (17.7)
Hospital admissions	65	40	17 (42.5)	14 (35.0)	9 (22.5)
Deaths	29	29	16 (55.2)	7 (24.1)	6 (20.7)

n (%) represent the number of residents (%) who experienced any of the four adverse events (falls, wounds, hospital admissions and deaths) during the six month period.

The results for falls were reported when it comes to finding a relationship between gait speed and an adverse event. Chi-square and logistic regressions were conducted to examine the relationships between gait speed and other adverse events but these did not turn out to be statistically significant.

The total number of cases of adverse events were computed, as well as the incidence as reflected by the number of residents who suffered an adverse event, out of 100 residents at risk. The counts and percentages who suffered an adverse event were also calculated by gait speed group.

A Poisson regression was run to predict the number of falls in nursing home in the last six months based on the gait speed group and the number of hospital admissions within those six months. However, the data were over dispersed and a negative binomial regression with custom parameter was performed to correct for over dispersion.

For the number of falls in the time frame of six months, we report incidence rate ratios (IRRs) with 95% CIs and the actual P-value (21). All data were analysed using SPSS statistic software (version 22) with statistical significance set at $p<0.05$ a priori.

Results

Participants

One hundred of the 166 (60.2%) invited, eligible adults were recruited to the study. There were no significant differences between all variables for the three nursing home cohorts in this study ($P>0.05$), thus the data was combined into one group for analysis. Table 1 summarises the characteristics of study participants. The average age of study participants was 85.5 (SD: 7.2) years old. The majority of participants were female (66%) and 29 deaths (15 females) occurred during the 6-month period with the average age being 85.3 (SD: 6.5) years ranging from 79 to 97 years at the time of death. The residents took an average of 14.0 (SD: 5.8) medications and had a total of 11.0 (SD: 4.9) medical conditions.

Many of the 100 participants experienced adverse events during the six months of data collection (refer to Table 2). Of the 100 participants, 73 fell during the follow-up period with 24 falling once and 49 falling two or more times. One third of the residents fell between 8:00 am and 3:59 pm (33%). Forty-two residents were admitted to hospital with the majority of these individuals (29 residents, 69%) being hospitalised once in the six-month period. The numbers of days in hospital ranged from 1 to 30 days. There were 45 residents who received treatment for wounds. The majority, (79%, n = 79) of residents had a low gait speed according to European Working Group on Sarcopenia in Older People (EWGSOP) criteria (22) that was characterized as normal (< 0.80 m/s) and 26% (n = 26) ambulated below the mean reported for nursing home residents in the local area (< 0.37 m/s) (9).

Table 3
Univariable negative binomial regression model (IRRs with 95% CIs) to predict the number of falls over six months in 100 nursing home residents

Parameters	IRR	95% CI	P-value
Number of hospital admissions**	1.34	1.11 – 1.62	.002
Number of wounds*	1.10	1.03 – 1.17	.004
Mini-Cog: positive impairment*	0.59	0.36 – 0.97	.037
Chronic diseases**	1.04	1.00 – 1.09	.053
Handgrip strength (kg)*	1.07	1.02 – 1.12	.005
SARC-F**	1.07	1.00 – 1.15	.062
Medications	1.02	0.98 – 1.06	.387
Sex: female	0.86	0.53 – 1.38	.532
Age (years)	1.00	0.97 – 1.03	.926
Gait speed threshold†			
≤0.6 m/s	1.30	0.72 – 2.35	.379
0.61 – 0.79 m/s	1.40	0.75 – 2.62	.297

* = Statistically significant $P<0.05$. ** = Statistically significant $P<0.1$.; † = Reference group is gait speed ≥0.80 m/s; IRR = Incidence Rate Ratio; CI = Confidence Interval

A negative binomial regression was run to predict the number of falls in nursing homes in a six-month follow up based on their baseline gait speed. Specifically, the residents were categorised into one of three gait speed groups: ≤0.6 m/s, 0.61 – 0.79 m/s and ≥0.80 m/s. The gait speed threshold of ≥0.80 m/s was used as the reference group. The results of univariable regression analyses (Table 3) indicated that hospital admissions (IRR = 1.34, 95% CI 1.11 - 1.62, P = 0.002), wounds (IRR = 1.10, 95% CI 1.03 - 1.17, P = 0.004), SARC-F (IRR = 1.07, 95% CI 1.00 - 1.15, P = 0.062), handgrip strength (IRR = 1.07, 95% CI 1.02 - 1.12, P = 0.005) and Mini-Cog (IRR = 0.59, 95% CI 0.36 - 0.97, P = 0.037) were statistically significant predictors of falls at the 0.10 significance level. In contrast, gait speed thresholds (below or equal to 0.6 m/s and 0.61 – 0.79 m/s) were not statistically significant predictors of falls in nursing homes residents (P = 0.379 and P = 0.297, respectively).

Table 4
Multivariable negative binomial regression model (IRRs with 95% CIs) to predict the number of falls over six months in 100 nursing home adults

Parameters	IRR	95% CI	P-value
Handgrip strength*	1.04	1.00 – 1.09	.040
Mini-Cog: positive impairment*	0.48	1.03 – 2.65	.002
Number of hospital admissions*	1.28	1.07 – 1.53	.006
Number of wounds*	1.08	1.02 – 1.14	.008
Sex: female*	1.66	1.03 – 2.65	.037
Gait speed threshold†			
≤0.6 m/s	1.10	0.65 – 1.88	.715
0.61 – 0.79 m/s	.93	0.53 – 1.63	.792
Chronic diseases	1.00	0.97 – 1.05	.842
Medications	1.01	0.98 – 1.05	.518
SARC-F	1.06	0.99 – 1.14	.060
Age	0.99	0.96 – 1.02	.394

* = Statistically significant P<0.05. † = Reference group is gait speed ≥0.80 m/s. IRR = Incidence Rate Ratio; CI = Confidence Interval

Variables that were significantly associated with a fall at the 0.10 significance level (hospital admissions, wounds and Mini-Cog) were included in a multivariable regression model, and adjusted for other covariates including age, sex and gait speed group. Results of the multivariable regression are provided in Table 4. These results indicated that hospital admissions (IRR = 1.28, 95% CI 1.07 - 1.53, P = 0.006), wounds (IRR = 1.08, 95% CI 1.02 - 1.14, P = 0.008), handgrip strength (IRR = 1.04, 95% CI 1.00- 1.09, P = 0.040), sex: female (IRR = 1.66, 95% CI 1.03 – 2.65, P = 0.037) and Mini-Cog (IRR = 0.48, 95% CI 1.03 - 2.65, P = 0.002) were statistically significant predictors of falls. Hence for every unit increase in hospital admissions, the incidence rate (or rate of falls) increases by 28%, for every unit increase in wounds; the incidence rate of falls increases by 7.8% and for every additional kilogram increase in handgrip strength the incidence rate of falls increases by 4.4%. Residents who were female had an increased risk of falling by 65.5% compared to males; residents were found to have a 51.7% decrease in the rate of falling if they scored a Mini-Cog score of positive impairment. Age, gait speed thresholds below and/or under 0.6 m/s and 0.61 – 0.79 m/s, SARC-F score, number of chronic diseases and number of medications were not statistically significant and thus did not influence the rate of falling.

Discussion

The present study reported that over a period of six months, a sample of 100 nursing home residents experienced a total of 226 falls, 243 wounds, 65 hospital admissions and 29 deaths. The rate of these adverse events happening within nursing homes appeared substantially greater than what is reported for community dwelling older adults (7).

The frequency of these adverse events provides an ongoing challenge in the nursing home setting. For example, the rate of falls in nursing home males were seven times higher than those living in the community in 2009-10; whilst the equivalent comparison for females was five times higher (5). The results of the current study and findings reported within the literature for older adults (23, 24) show that females may be 65.5% more likely to fall than compared to males; suggesting that females should be the focus of fall prevention programmes in nursing homes.

In Australia, Everett and Powell (25) found skin tears constituted 41% of known wounds amongst a nursing home that contained 347 residents (with an average age of 80 years) with an average of 22 skin tears occurring each month. During the six months of the current prospective study, 45% of residents experienced a wound, higher than that of Everett and Powell which had 38% of residents experiencing a skin tear in six months (25). Wounds experienced by up to 50% of residents in nursing home settings is a major concern due to the associated link of pain, risk of infection, decreased functional ability and poor quality of life (26). Thus, wounds needs to be recognised as a major health issue in nursing homes due to residents having a high risk of suffering from wounds such as skin tears, pressure ulcers and chronic leg ulcers (27).

In regards to hospital admissions, older adults accounted for 41% of Australian patients admitted into hospital in 2014-15 (4). In particular, a growing concern is that the number of older adults (aged 85 years and older) admitted into hospital each year (5.8%) is higher than the population growth for this age group (4.1%) (4). It has also been highlighted that adverse events such as falls and wounds may lead to longer hospital stays and may even contribute to in-hospital deaths (28). In 2009-10, approximately one in five falls that resulted in hospitalisation were reported to have occurred in a nursing home setting (5). Further findings suggest that the rates of fall-related injury cases in nursing homes remain nearly six times higher than community-dwelling adults (29-31).

In contrast to findings in several other studies (32, 33), we found that those residents who were classified as having a positive cognitive impairment in the Mini- Cog score had a 51.7% reduction in falling when compared to those who scored a negative cognitive impairment score. While such a result was initially unexpected, this may reflect a fact that residents who are classified as being cognitively impaired are more closely monitored by nurses and staff and require more assistance (i.e. assisted transfer walking to dinner table) when compared to those who are not cognitively impaired.

The substantially greater rate of adverse events in nursing home than community dwelling settings for older adults is not an unexpected finding. However it does continue to raise the question of how to minimise the incidence and severity of these events in the nursing home facilities. One factor that may be implicated in this number of adverse events in nursing home facilities is the age of the residents (85.7, SD: 7.1 years), number of medical conditions (11.0, SD: 4.9) and number of prescribed medications (14.0, SD: 5.8). Currently, two thirds of Australians aged over 75 years take five or more prescribed medications, an outcome referred to as "polypharmacy". Depending upon the setting and definition used, 20-70% of older adults use at least one medication that is either harmful or unnecessary (34), with polypharmacy increasingly becoming the norm in nursing home settings. Unfortunately; polypharmacy has been shown to increase the risk of medication errors, falls, confusion, frailty, loss of independence, hospitalisation and mortality (34). As age is a non-modifable risk factor for falls, reductions in polypharmacy and/or number of medical conditions may reduce these adverse effects. Non-pharmacological approaches such as exercise programs involving progressive resistance, balance and/or cardiovascular exercise may provide such benefits (34, 35).

Another approach that may assist nursing home staff reduce the severity and incidence of these adverse events is to screen their residents based on factors that are predictive of these adverse events. Prior to conducting the study, one such simple factor to screen nursing home residents was gait speed. This approach was based on a systematic review in community-dwelling older adults (aged 65 and older) that indicated low gait speed was a significant predictor of a range of adverse events, including mobility disability, cognitive decline, mortality, falls and institutionalisation in community dwelling adults (7). The potential use of gait speed to predict adverse events in nursing home residents was also supported by Sterke et al. (8) who identified reduced gait speed and stride length as significant predictors of falls over the following three months for a group of 57 nursing home residents with dementia.

As a result of the over-dispersion identified in the initial Poisson analysis, the best approach according to the nature of the data was a negative binomial regression analysis to further examine the relationship between potential risk factors and falls in our sample.

Our multivariable analysis found that for every additional hospital admission, the incidence rate (or rate of falls) increases by 28%; for every additional wound, the incidence rate of falls increases by 7.8% and for every additional kilogram increase in handgrip strength the incidence rate of falls increases by 4.4%. Residents who were female had an increased risk of falling by 65.5% when compared to males. Residents who scored a positive impairment on the Mini-Cog had a reduced rate of falls by 51.7% compared with those who were negatively impaired. Such results suggest that continuing improvements in fall prevention programs are required in the Australian nursing home context so to minimise the high social, economic and care burden associated with falls-related hospitalisation and wound care. As suggested in a recent meta-analysis by Lee and Kim (36), to prevent these adverse outcomes from occurring programs that combine exercise and fall interventions that challenge balance should be targeted at high and low falls risk older adults in nursing home facilities.

Study Limitations

Some limitations must also be acknowledged. Due to the study being conducted in a small geographical area within Australia, the results may not be generalizable to other parts of the world. Additionally, in contrast to Sterke et al. (8) who quantified gait speed every three months over a period of 15 months, the present study only assessed gait speed at the beginning of the six-month follow-up.

Conclusion

This study identified the high incidence of adverse events in regards to falls, wounds and hospital admissions in Australian nursing home residents over a period of six months. To reduce the frequency and/or severity of these adverse outcomes, population-based intervention programs should be targeted at the population at risk. As the number of hospital admissions, wounds and handgrip strength increases the risk of falls, with females and Mini-Cog scores classifying positive cognitive impairment with a decrease rate of of falling, a combination of exercise and fall interventions that challenge balance should be targeted to reduce falls in older adults in nursing home facilities. This is especially important for the residents for whom the nursing staff may consider to be at lower risk of falls (those with higher strength and cognitive function). These higher functioning residents may be more physically active and monitored less closely than those with reduced strength and cognitive function. Thus, additional research is needed to better understand the mechanisms underlying our results; with the implication being that different approaches may be needed to minimise the risk of adverse falls-related events in higher and lower functioning nursing home residents.

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GAIT SPEED AND ADVERSE EVENTS IN NURSING HOME RESIDENTS: A PROSPECTIVE COHORT STUDY

Ethical Standard: Permission to conduct this study was granted by the University Human Ethics Research Committee and respective gatekeepers at the nursing home settings.

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Feasibility and benefits of group-based exercise in residential aged care adults: a pilot study for the GrACE programme

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ABSTRACT

The objective of the study was to examine the feasibility and benefits of a group resistance training exercise programme for improving muscle function in institutionalised older adults. A feasibility and acceptability study was designed for a residential aged care (RAC) facility, based on the Gold Coast, Australia. Thirty-seven adults, mean age 86.8 ± 6.1 years (30 females) living in a RAC facility. Participants were allocated into an exercise (n = 20) or control (n = 17) group. The exercise group, the Group Aged Care Exercise (GrACE) programme, performed 12 weeks of twice weekly resistance exercises. Feasibility was measured via recruitment rate, measurement (physiological and surveys) completion rate, loss-to-follow-up, exercise session adherence, adverse events, and ratings of burden and acceptability. Muscle function was assessed using gait speed, sit-to-stand and handgrip strength assessments. All intervention participants completed pre- and post-assessments, and the exercise intervention, with 85% (n = 17) of the group attending ≥ 18 of the 24 sessions and 15% (n = 3) attending all sessions. Acceptability was 100% with exercise participants, and staff who had been involved with the programme strongly agreed that the participants "Benefited from the programme." There were no adverse events reported by any participants during the exercise sessions. When compared to the control group, the exercise group experienced significant improvements in gait speed ($F(4.078) = 8.265$, $p = 0.007$), sit to stand performance ($F(3.24) = 11.033$, $p = 0.002$) and handgrip strength ($F(3.697) = 26.359$, $p < 0.001$). Resistance training via the GrACE programme is feasible, safe and significantly improves gait speed, sit-to-stand performance and handgrip strength in RAC adults.

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INTRODUCTION

Ageing can lead to an impaired physical function, mobility and reduction in quality of life (*Krist, Dimeo & Keil, 2013*). A decrease in mobility may prompt a vicious cycle of

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sedentary behaviours, reduced physical activity and deconditioning, with residential aged care (RAC) adults shown to be more sedentary than their community-dwelling counterparts (Reid et al., 2013). The mobility decline may reflect the emergence of sarcopenia, which is defined as the progressive and generalised loss of skeletal muscle mass and subsequent muscle function (muscle strength and physical performance) associated with the ageing process (Cruz-Jentoft et al., 2010). The preferred sarcopenic measure for physical performance in older adults is gait speed, which is also considered a primary precursor to age-related adverse events including disability, cognitive impairment, falls, mortality, institutionalisation and hospitalisation (Abellan van Kan et al., 2009; Cruz-Jentoft et al., 2010; Peel, Kuys & Klein, 2013). The threshold to be considered as having normal or above habitual gait speeds is 0.8 m/s (Kuys et al., 2014), a value almost identical to the 0.82 m/s cut-off proposed as being predictive of death within two years for older men (Stanaway et al., 2011).

A meta-analysis of 2,888 long-term ambulant RAC residents reported a mean habitual gait speed of 0.48 m/s (95% confidence interval (CI) 0.40–0.55) (Kuys et al., 2014). However, it was cautioned that the true mean gait speed of RAC adults may be even less than 0.48 m/s as many of the reviewed studies utilised non-randomly selected samples, meaning the participants were likely to be more mobile than those who did not consent to participate. Consistent with such a view, a recent study of 102 randomly selected RAC residents reported a mean gait speed of 0.37 m/s (Keogh et al., 2015). The widespread low gait speed documented for RAC adults and the link between low gait speed and many adverse age-related effects suggests that further research needs to be conducted to examine feasible and efficacious approaches to improving or at least offsetting the expected annual decline in gait speed of 0.03–0.05 m/s per year (Auyeung et al., 2014; Onder et al., 2002).

Two recent reviews have examined the potential for exercise, and specifically progressive resistance training (e.g. strength) and weight bearing exercise (e.g. balance and mobility) to improve many aspects of muscle function including gait speed in RAC/frail older adults (Chou, Hwang & Wu, 2012; Valenzuela, 2012). In their meta-analysis of 225 participants across four studies, Chou, Hwang & Wu (2012) reported that exercise produced a significant 0.07 m/s (CI 0.02–0.11) increase in gait speed compared to the control group (~6% change). However, a limitation of this literature is that the implementation of these exercise programmes in RAC is still relatively uncommon. This lack of translation may reflect the many barriers to the sustainability of resistance combined with weight bearing training programmes in RAC (Federal Interagency Forum on Aging-Related Statistics, 2004) and to our knowledge, a complete lack of research quantifying the feasibility of this form of exercise in this setting.

A possible exception is an exercise programme, which was targeted at respite care older adults in Australia (Henwood, Wooding & de Souza, 2013). Older adults accessing respite care are unable to completely care for themselves due to the adverse effects of ageing, chronic disease, physical and/or cognitive disability and are at increased risk of entry into RAC. These individuals typically access respite day care for several hours per day for one or more days per week to allow their carer the opportunity to attend to other everyday activities or to have a break from their caregiving responsibilities. An analysis of the exercise programme demonstrated a high feasibility for translation into an ongoing respite day care centre and that 2 h of participation per week for 20 weeks significantly improved functional capacity and balance among participants (*Henwood, Wooding & de Souza, 2013*). While this programme was feasible and effective in a disabled community-dwelling population, it is yet to be trialled amongst RAC adults. Given the demonstrated uptake of this exercise programme by a low functioning older adult population at risk of entry into RAC, it was hypothesised that the Group Aged Care Exercise (GrACE) programme would exhibit similar levels of feasibility and benefits in RAC adults (*Henwood, Wooding & de Souza, 2013*).

The primary aim of this study was to determine the feasibility of the GrACE programme in RAC, with the secondary objective of measuring the programme benefits on gait speed, sit to stand and handgrip strength.

MATERIAL AND METHODS

Participants

Participants were included if they were:

i. Aged 65 years and over;
ii. Residing in a RAC;
iii. Able to walk with a walker and/or walking stick or could self-ambulate; and
iv. Could provide informed consent.

The exclusion criteria included:

i. End-stage terminal and/or life expectancy < 6-months (ethical reasons);
ii. Two person transfer or unable to self-ambulate (due to increased falls risk);
iii. Unable to communicate or follow instructions (personal needs beyond the scope of this project);
iv. Insufficient cognitive function to provide informed consent; and
v. Dangerous behaviours that would endanger the client or research staff.

Study design and recruitment

This study compared the delivery feasibility and outcomes of a 12-week combined resistance and weight bearing exercise programme, which we named the GrACE programme. Participant recruitment and assessment occurred over a five-month period. The flow of recruitment to assessment is represented in Fig. 1.

The RAC was approached about participation via email and telephone follow-up. Potential participants were identified at a meeting with the facility Service Manager. Participants were screened via the inclusion criteria at the meeting with the Service Manager and a Registered Nurse, whom also deemed who would be able to perform the exercises due to the inclusion and exclusion criteria. The Service Manager and a Registered Nurse created two lists from the eligible participants, one that contained the names of

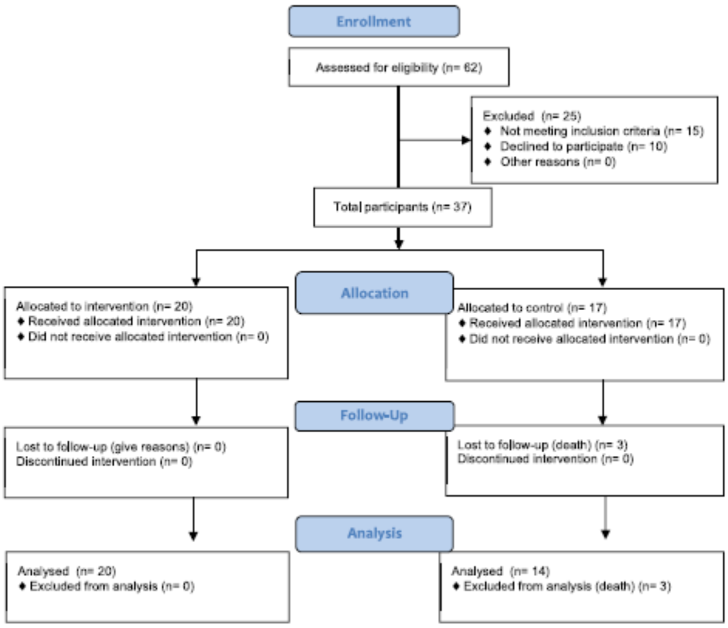

Figure 1 Project CONSORT diagram of recruitment and assessment of study participants. Enrolment numbers and withdrawals, or those lost to follow-up, are indicated in the boxes.

residents who could be recruited for the exercise group and one for the recruitment of the control group. This group allocation was based on the location of their bedroom with respect to the training room, as the Service Manager and a Registered Nurse felt that only participants who resided on the same level as the exercise room were likely to join and adhere to the GrACE programme. As we wished to get some idea on the number of participants who would enrol in such an exercise program, the sample obtained in the current study reflected the maximum number of participants who were eligible and provided their informed consent to participate. The final sample obtained was a convenience sample from one RAC facility. Following an explanation of the procedures, purposes, benefits and associated risks of the study, participants had the opportunity to ask questions. A total of 37 older RAC adults (86.8 ± 6.1 years, range 72–99 years, 30 females) provided written informed consent for the study. The exercise group contained 20 participants (86.9 ± 5.7 years, range 72–97 years, 15 females) and the control group 17 participants (86.3 ± 6.6 years, range 75–99 years, 15 females). Ethical approval to conduct this study was attained from Bond University's Human Ethics Research Committee (RO 1823). The protocol for this trial was published at Clinical Trial Registry ID NCT02640963.

Intervention: the GrACE programme

Previous work by our group trialed a successful exercise programme in respite day care that could promise benefits to those in RAC (Henwood, Wooding & de Souza, 2013). The GrACE programme's full outline is available in Appendix 1. In brief, the programme included a number of targeted weight-bearing exercises (using body weight and dumbbells) and a range of seated, non-resisted upper- and lower-body dynamic and reaching movements. While developed for respite care older adults, the programme was slightly modified for the RAC setting; initially using reduced range of motion and resistance, and an extended conditioning/familiarisation phase. The conditioning phase lasted for three weeks in which technique was emphasised without using any weights or additional resistance. The focus of this technique of the conditioning phase was to develop the correct technique and minimise the potential for any delayed onset muscle soreness or adverse effects. After concluding the conditioning phase, participants were able to use light dumbbells (often starting with 0.5 kg) increasing to heavier dumbbells (up to 4 kg) with their increasing capacity over the course of the programme.

Participants performed the exercises twice per week for 12 weeks, with an average of 15 of the 20 participating residents attending each exercise class. Training sessions lasted approximately 45 min, were separated by at least 48 h and were delivered by an allied health professional experienced working with older adults. The sessions were conducted in the communal dining room, where the furniture was moved around prior and post training. The dining room was selected as the facility in which the exercise programme was performed had three levels, with the dining room located on the level having the highest number of residents. The allied health professional (exercise physiologist) was not blinded to the allocation of participants as they collected both pre- and post-outcomes for the study as well as conducting the exercise programme. The exercise physiologist was experienced working with community dwelling older adults, but received additional training prior to the project delivery via the respite community-training package used in a previous study (Henwood, Wooding & de Souza, 2013) and by RAC facility staff on issues relevant to working with RAC residents.

Control group

All subjects assigned to the control group were given the option to engage in other activities that were offered by the facility during the 12-week intervention period. Activities were conducted either in their fitness room or communal areas, and included Zumba Gold, aerobic exercise and walking. These sessions lasted for 30–45 min and conducted by their facility's leisure staff. However, no specific resistance exercises were offered in these activities.

Data collection

Reasons for refusal (non-consent) to participate were recorded (Henwood et al., 2014). All muscle function outcome measures in this study have been previously validated for use with older adults, and their protocols reported elsewhere (Henwood, Wooding & de Souza, 2013; Sterke et al., 2012). Assessments were completed one-on-one with each participant, assessing muscle function as well as a range of demographic characteristics, which are important in describing the sample. During muscle function measures assessments, participants were encouraged to rest as needed and given verbal support and encouragement to reduce any potential burden to the participant.

MEASURES

Feasibility outcomes

The assessment of feasibility was defined by recruitment rate, measurement (physiological and surveys) completion rate, loss-to-follow-up, exercise session adherence, acceptability and adverse events (*Bower et al., 2014*; *Peddle-McIntyre et al., 2012*; *Suttanon et al., 2013*). Recruitment rate was defined as the number of residents recruited from those invited. Measurement completion rate was defined as the number of participants able to complete each outcome measure at baseline and follow-up. Loss to follow-up was defined as participants who withdrew or dropped out and did not consent to a follow up assessment. Exercise session adherence was measured by the number of sessions attended out of the maximum 24 sessions. Consistent with previous exercise studies involving low functioning older adults (*Bossers et al., 2014*; *Bower et al., 2014*; *Henwood, Wooding & de Souza, 2013*), the proportion of participants who completed 75 and 100% of the required 24 sessions was recorded. Acceptability was measured via a programme satisfaction survey completed post-training that assessed the burden of training and testing, as well as how participants felt about the trial. Questions included:

- "Prior to commencing the exercise programme did you have any concern(s) with the GrACE programme?";
- "Did you enjoy participating in the GrACE programme?";
- "Do you believe the GrACE programme was well organised?";
- "Whilst participating in the GrACE programme do you believe that the programme impeded on your daily routine?";
- "Would you be happy to continue participating in the GrACE programme or something similar?"; and
- "Overall, would you rate your current physical condition to be better than before you started the GrACE programme?"

Answers to the acceptability questions were scored on a five-point Likert Scale (1 = strongly agree, agree, neither, disagree or 5 = strongly disagree).

Adverse events were defined as incidents in which harm or damage resulted to a participant and included, but were not limited to, falls and fall-related injuries, musculoskeletal or cardiovascular incidents and problems with medication and medical devices (*Government of Australia, 2014*). These adverse events were recorded via the facility's records. The exercise group also received a diary to record if they had any muscle soreness or complaints about the exercise class. These diaries were returned to the instructor at the end of each week. The exercise instructor also verbally confirmed the information contained in these diaries with each of the exercise group participants at the end of each week.

Muscle function measures outcomes

Gait speed

Gait speed was recorded via the GaitMat II system (Manufacturer is EQInc; Model is GaitMat II), which required participants to walk across a level pressure mat system 3.66 m (11.91 ft.) long (McDonough et al., 2001). Participants completed the trials at their preferred (habitual) walking (gait) speed. The following instructions were given, "Walk towards the end of the room at a pace that is comfortable for you." Participants were allowed to walk in their own footwear. All measures were initiated from a standing start 2 m (6.56 ft.) from the GaitMat II platform as suggested by Kressig & Beauchet (2004) to reduce the effect that acceleration may have on gait speed. The average gait speed (m/s) from three attempts was used for data analysis. Participants were allowed as much rest as required between attempts, with rest periods typically being up to 1 min.

Handgrip strength

Upper body muscle function was measured by isometric handgrip strength. When performing the handgrip strength assessments, participants were seated, instructed to keep their elbow at 90° and asked to squeeze a handgrip dynamometer (Sammons Preston Roylan, Bolingbrook, IL, USA) to their maximum ability for a period of up to 5 s (Mathiowetz, 2002). Three trials were performed with the subject's dominant hand with one-minute rest between trials and the best result used for analysis (Roberts et al., 2011).

Sit to stand performance

The sit-to-stand measure was performed to assess lower body muscle function of the participants. In the sit-to-stand measure, participants sat and stood to their full standing position from a 43 cm high chair as many times as possible in 30 s whilst keeping their arms crossed against their chest (Millor et al., 2013). Timing commenced when the assessor gave the command "go."

Participant demographics

All participants were assessed for Body Mass Index (BMI), body fat percentage (%) and cognitive status at pre- and post-testing. BMI was calculated based on body mass (kg) divided by the square of height (m^2). Body fat was estimated via Bioelectrical Impedance Analysis (BIA, Maltron BF-906 body fat analyser) (Senior et al., 2015). The BIA required participants to have two electrode stickers placed on their hand as well as two on their foot whilst in the supine position. The flow of electrical signals was measured through fat, lean tissue and water, which was then applied to a database of algorithms revealing the whole body analysis (Chien, Huang & Wu, 2008). Cognitive status was quantified via the Mini Cog (Borson et al., 2000). The Mini Cog was scored out of three words that are recalled after drawing the face of a clock on a piece of paper to read 10 min after eleven o'clock, with scores > 1–2 recalled words and abnormal clock drawing, indicative of cognitive impairment (Borson et al., 2000).

Table 1 Descriptive data for the residents in the exercise control and group.

Variable	Exercise group (n = 20)	Control group (n = 17)
Age (yrs)	86.9 ± 5.7	86.3 ± 6.6
Range (yrs)	72–97	75–99
No. of females (no. %)	15 (75%)	15 (88%)
Length of stay in RAC (days)	745.1 ± 622.6	755.0 ± 492.1
Medical conditions (no.)	15.3 ± 5.2	14.2 ± 5.3
Medications (no.)	14.3 ± 6.1	14.6 ± 5.9
Use of walking aid	11 (55%)	13 (76%)
BMI (kg/m^2)	26.5 ± 3.7	27.2 ± 4.7
Body fat %	33.2 ± 10.8	38.8 ± 5.6
Marital status		
Married	4 (20%)	2 (12%)
Divorced	3 (15%)	0 (0%)
Widowed	13 (65%)	15 (88%)
Nationality		
European	20 (100%)	15 (88%)
Asian	0	2 (12%)
Primary language		
English	19 (95%)	16 (94%)
German	1 (5%)	0
Russian	0	1 (6%)
Mini-COG status #		
Positive	12 (60%)	14 (82%)
Negative	8 (40%)	3 (18%)

Note:
Data are mean ± standard deviation; yrs, years; no., number.

Statistical analysis

Descriptive statistics were calculated to describe the baseline characteristics and feasibility results, with all continuous variables presented as mean and standard deviation (±SD), and for categorical variables as the total number and percentage (%) of responses. In circumstances where participants were unable to complete a physical measure, they were given the lowest score, generally zero. All data were initially checked for normality prior to analysis by investigating homogeneity of regression slopes, scatterplots for linearity, kurtosis, skewness and Levene's test of equality of error variances. Baseline characteristics of the two groups were compared using ANCOVA and chi-square analysis for continuous and categorical variables, respectively. A one-way ANCOVA was performed to assess the between-group changes in gait speed, handgrip strength and sit to stand performance. SPSS (version 20) was used for data analysis; statistical significance was set at $p \leq 0.05$ a priori.

RESULTS

Descriptive characteristics of the sample, provided in Table 1, showed no significant difference between groups at baseline. Of the 62 individuals put forward for participation

Table 2 Exercise group participant questionnaire post 12-week completion.

Question				
Prior to commencing the exercise programme did you have any concern(s) with the GrACE programme?				
SA = 0	A = 0	U = 1	D = 15	SD = 4
Did you have any concern(s) with the GrACE programme upon completing the exercise programme?				
SA = 2	A = 18	U = 0	D = 0	SD = 0
Did you enjoy participating in the GrACE programme?				
SA = 20	A = 0	U = 0	D = 0	SD = 0
Do you believe the GrACE programme was well organised?				
SA = 20	A = 0	U = 0	D = 0	SD = 0
Whilst participating in the GrACE programme do you believe that the programme impeded on your daily routine?				
SA = 0	A = 0	U = 0	D = 17	SD = 3
Would you be happy to continue participating in the GrACE programme or something similar?				
SA = 20	A = 0	U = 0	D = 0	SD = 0
Overall, would you rate your current physical condition to be better than before you started the GrACE programme?				
SA = 20	A = 0	U = 0	D = 0	SD = 0

Note:
SA, Strongly agree; A, Agree; U, Unsure; D, Disagree; SD, Strongly disagree.

Table 3 Changes in the muscle function outcomes for the exercise and control groups.

Muscle function outcome	Exercise group			Control group			Between-group significance
	Pre	Post	% Change	Pre	Post	% Change	
Gait speed (m/s)	0.65 ± 0.19	0.68 ± 0.17	+4.6	0.64 ± 0.16	0.60 ± 0.16	−6.0	0.007*
Sit to stand (repetitions)	0.0 ± 0.0	6.4 ± 4.5	NA	0 ± 0	1.3 ± 3.2	NA	0.002*
Handgrip strength (kg)	15.2 ± 5.3	15.9 ± 5.9	+4.6	13.2 ± 4.5	10.6 ± 4.1	−19.7	0.001*

Notes:
All data were reported as mean ± standard deviation; m/s, metres per second; kg, kilogram; NA, not applicable as the pre-test score equalled zero.
* Statistical significance ($p < 0.05$).

by the RAC Service Manager, 47 were found to be eligible and 37 consented to involvement. At follow-up, three participants in the control group had passed away, resulting from falls complications (n = 1) and pre-existing heart disease (n = 2). Apart from these three deaths, the study experienced a 100% retention rate of surviving participants and final analysis was conducted on 34 individuals (20 intervention and 14 control). Seventeen (85%) participants in the exercise group attended 18 or more exercise sessions, with three (15%) of these 17 participants attending all 24 training sessions.

Participant responses to the exercise programme questionnaire, measured by the Likert scale questions are summarised in Table 2. Acceptability of the programme was very high with 100% of exercise participants and staff who had been involved with the programme (i.e. nurses who helped bring the residents from their rooms to the GrACE programme or observed the class from the nurses' station) strongly agreeing that the participants "Benefited from the GrACE programme" and "Happy to continue participating." Refer to Appendix 2 to see the full responses to the open-ended questions. With respect to diary completion, all diaries were returned with five partially completed (ranging from 50–80%) and 15 fully completed. There were no adverse events reported by any participants during the exercise sessions.

The exercise group had significantly greater improvements in habitual gait speed ($F(4.078) = 8.265$, $p = 0.007$), sit to stand performance ($F(3.24) = 11.033$, $p = 0.002$) and handgrip strength ($F(3.697) = 26.359$, $p < 0.001$) when compared to the control group. Pre- and post-intervention muscle function measures data are presented in Table 3.

DISCUSSION

This study demonstrated a combined weight bearing and resistance training exercise programme which we called the GrACE programme, designed and tested in community-dwelling respite day care older adults, is feasible, safe and effective in improving gait speed, sit to stand performance and handgrip strength in RAC adults. Findings from this study may assist RAC providers and care staff to develop and implement feasible, safe and effective exercise programmes for their residents.

The recruitment rates for this exercise trial appeared similar or better than other similar trials in respite care, hospital inpatient or RAC populations (*Bower et al., 2014*; *Henwood, Wooding & de Souza, 2013*; *Peddle-McIntyre et al., 2012*; *Suttanon et al., 2013*). Sixty-two of the 151 residents were identified by the service manager as being potentially eligible for the study, a proportion equating to approximately 40% of total population of the RAC facility. The other 89 RAC residents were deemed ineligible due to the following: being in a wheelchair or restricted to bed duties, not being able to follow simple instructions, lack of attention or unpredictable behaviour. It is interesting to note that some residents (n = 10) refused to participate due to fear of change in their schedule, fear of never doing resistance training before and not wanting to try and after being in the RAC facility for over five years had declared they weren't doing exercise anymore. Suggested ideas to overcome this were through word of mouth via residents to other residents, especially at communal times such as breakfast, where the residents remind each other of exercise class.

Of the 62 residents identified by the service manager as being eligible to participate, 37 (60%) provided informed consent and were placed into either the exercise or control groups. While a recruitment rate of 60% of the eligible participants may appear relatively low, this value appeared comparable (*Henwood et al., 2015*) or slightly higher (*Álvarez-Barbosa et al., 2014*; *Bossers et al., 2014*; *Sievänen et al., 2014*) than previous exercise trials in RAC. The reason provided by the 25 (40%) potentially eligible participants who declined to participate included: not being interested in the study or exercise programme, lack of time: didn't want to commit to the 12 weeks, didn't want to try something different/that was out of the normal routine and were happy with their current lifestyle. The reasons reported by the potential participants who declined participation in this project should be taken into account by future researchers considering conducting RAC exercise RCTs if they wish to ensure maximum participant recruitment and statistical power of the resulting analyses.

For the 20 participants who were enrolled into the GrACE programme, adherence rates were high with 85% of the participants attending at least 18 (75%) of the required 24 exercise classes. This relatively high attendance rate appeared similar (*Álvarez-Barbosa et al., 2014*; *Bossers et al., 2014*; *Sievänen et al., 2014*) or greater than (*Hassan et al., in press*; *Henwood et al., 2015*) previous feasibility exercise studies involving RAC older adults. Such results suggest that many exercise class options (if offered) may be well attended by residents of RAC facilities. The acceptability of the programme was further assessed by using a five-point Likert scale questionnaire that focused on the participants' perceptions of the exercise sessions. All exercise participants strongly agreed that they obtained substantial benefits from their participation and that they wished to continue being involved in the programme. These results are consistent with previous studies reporting high acceptability of RAC exercise participation (*Álvarez-Barbosa et al., 2014*; *Bossers et al., 2014*; *Henwood et al., 2015*; *Sievänen et al., 2014*). However, in contrast, our study supports the feasibility of an in-centre delivery using targeted supervision and inexpensive equipment, where previous work has employed more complicated deliveries. Specifically, *Bossers et al. (2014)* delivered individualised, supervised walking and strength training programmes five days per week, *Sievänen et al. (2014)* and *Álvarez-Barbosa et al. (2014)* delivered their interventions using relatively expensive whole body vibration devices, *Hassan et al. (in press)* used expensive resistance training machines and *Henwood et al. (2015)* trialled aquatic exercise that required participants to be transported to and from a community pool and change in and out of swimming attire. Our study required only one qualified trainer, the exercises were conducted at the RAC facility so there was no transport needed and delivery was not affected by busy times or school holidays such as experienced by *Henwood et al. (2015)*. Further, our study didn't need to have a personalised exercise programme developed for each individual resident or require the purchase and storage of expensive equipment (*Álvarez-Barbosa et al., 2014*; *Hassan et al., in press*; *Sievänen et al., 2014*). The acceptability of the programme was further demonstrated by the lack of any adverse effects reported within the exercise group. This lack of adverse effects is again consistent with the literature on a variety of exercise programmes for RAC residents (*Álvarez-Barbosa et al., 2014*; *Bossers et al., 2014*; *Hassan et al., in press*; *Henwood et al., 2015*; *Sievänen et al., 2014*). Therefore, our study further supports the safety of supervised exercise in this population, and demonstrates that the perception held by some care staff that exercise is a dangerous for RAC residents is not based on the current peer-reviewed evidence.

However, it must be acknowledged that although the GrACE programme was found to be feasible for those who participated in this study, this amounted to only ~25% of the population of the RAC facility. Collectively, the results of this study suggest that further feasibility trials may need to target RAC residents who were ineligible for this study (*Gibbs et al., 2015*) and also examine some of the issues influencing recruitment rates from those who were eligible to participate (*Kalinowski et al., 2012*).

While the primary focus of this study was to demonstrate feasibility and acceptability of the GrACE programme in RAC, we were also interested in further quantifying the benefits of exercise in this population as such data may inform future RCTs in this area. Significant between-group differences were reported for gait speed, sit to stand performance and handgrip strength, all of which favoured the exercise over the control group. Such results are impressive due to the relative simplicity of the GrACE programme performed in the current study and the importance of these outcome measures for older adults, particularly those living in RAC who wish to maintain their health and independence.

The significant between group effect for gait speed was a promising finding, with the relative 0.07 m/s improvement in gait speed for the exercise group was identical to the results of a recent meta-analysis involving exercise for RAC residents (*Chou, Hwang & Wu, 2012*). However, results of the within-group analysis indicated that the exercise group experienced an increase in gait speed of 0.03 m/s (~5%), whereas the control group experienced a decline of 0.04 m/s (~6%). As the control group's decline of 0.04 m/s was consistent with the expected annual decline of 0.03–0.05 m/s per year for older adults (*Auyeung et al., 2014*; *Onder et al., 2002*), the GrACE programme appears able to maintain or perhaps slightly increase gait speed in this population.

The significantly greater improvement in sit-to-stand performance for the exercise group was of considerable interest, with none of the residents being able to perform the sit-to-stand with their hands on the chest during baseline assessments. The ability to safely rise from a chair and sit down is a prerequisite for maintaining Activities of Daily Living (ADL) function (*Zijlstra et al., 2012*). Specifically, older adults who are unable to perform the sit to stand are considered below the capacity for independence and at risk of accelerated physical deterioration associated to extended sedentary behaviours (*Zijlstra et al., 2012*). The RAC participants' lack of leg strength (as demonstrated by their initial inability to perform even one sit to stand) was consistent with previous research that observed over 70% of RAC adults were unable to rise from a chair without assistance (*Sabol et al., 2011*).

The exercise group's significantly greater improvement in handgrip strength was also considered important, as lower handgrip strengths have predicted an accelerated decline in ADL disability and cognition as well as functional limitation and physical disability in older adults (*Bohannon et al., 2007*; *Hairi et al., 2010*; *Taekema et al., 2010*). The exercise-related increase in handgrip strength was also consistent with a previous exercise study in RAC (*Justine et al., 2012*).

Study limitations

There were several limitations in the current study. We acknowledge that 37 participants assessed represented a recruitment rate of only 59.6% of the participants initially thought to be eligible for the study and only about 25% of the facility's population. However, this rate of uptake is not uncommon in RAC, nor is the strict eligibility criteria imposed or participant safety reasons in exercise intervention. Therefore, caution is warranted if considering this GrACE programme feasibility across all RAC populations. It should also be noted that there was a risk of bias with the same allied health practitioner conducting the outcome measures and supervising the exercise programme. Future RCT should address this limitation by blinding the assessor to the participants' group allocation. The significant improvements observed in the present study for gait speed, sit to stand performance and handgrip strength also need to be replicated in RCTs due to the lack of a controlled study design and attention matching of the participants of each group.

CONCLUSION

The GrACE programme, consisting of progressive weight bearing combined with resistance training, was shown to be feasible, safe and effective in improving muscle function in RAC residents. Improved muscle function measurements are valuable client outcomes, and may have significant cost saving benefits to the RAC setting, as increased muscle function could reduce the RAC residents' degree of disability, care needs and risk of falls (*Chou, Hwang & Wu, 2012*). This work has direct measurable benefits for RAC residents, staff and providers and other health professionals working with older adults. Our findings addressed a number of previously unanswered and understudied questions in relation to the feasibility, safety and benefits of exercise classes that could be offered by RAC facilities to their residents. By having a greater understanding of these issues, RAC providers can better target interventions (e.g. exercise for maintaining gait speed or to reduce falls risk) to their residents. We would therefore encourage other RAC providers to strongly consider implementing similar programmes.

Clinical messages

- Progressive resistance and weight bearing training, as performed in the GrACE programme, is feasible and safe for RAC residents.
- Progressive resistance and weight bearing training may significantly improve gait speed, sit-to-stand performance and handgrip strength in RAC residents.

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Competing Interests

Justin William Leslie Keogh is an Academic Editor for PeerJ.

Author Contributions

- Samantha Fien conceived and designed the experiments, performed the experiments, analyzed the data, contributed reagents/materials/analysis tools, wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.
- Justin William Leslie Keogh conceived and designed the experiments, analyzed the data, contributed reagents/materials/analysis tools, wrote the paper, reviewed drafts of the paper.
- Timothy Henwood conceived and designed the experiments, reviewed drafts of the paper, developed exercise programme that GrACE was developed from.
- Mike Climstein conceived and designed the experiments, reviewed drafts of the paper.

Clinical Trial Ethics

The following information was supplied relating to ethical approvals (i.e., approving body and any reference numbers):

Bond University's Human Ethics Research Committee (RO 1823).

Data Deposition

The following information was supplied regarding data availability:

The SPSS data sheets are supplied as Supplemental Files.

Clinical Trial Registration

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