TELEHEALTH PHYSIOTHERAPY TO DELIVER EXERCISE IN AGED CARE SETTINGS

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BAppSc (Physiotherapy), BCa (Theatre Studies)

A thesis submitted to fulfill requirements for the degree of Doctor of Philosophy

School of Public Health, Faculty of Medicine and Health

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“Technology adoption boils down to one single thing - motivation.”

Dr. Louise Schaper, CEO of the Australasian Institute of Digital Health

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As supervisors of Rik Dawson's doctoral work, we certify that we consider his thesis "Telehealth physiotherapy to deliver exercise in aged care settings" to be suitable for examination.

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CANDIDATE'S STATEMENT

This thesis is submitted to the University of Sydney in fulfillment of the requirement for the Degree of Doctor of Philosophy.

I, Rik Dawson, hereby declare that this manuscript is my own work and that it contains no material previously published or written by another person except where acknowledged in the text. Nor does it contain material that has been submitted, either in full or in part, for a degree at this or any other institution.

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Rik Dawson

Date: 19 December 2023

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PUBLICATIONS AND PRESENTATIONS

Parts of the work in this thesis have been published, have been accepted for publication or are under review in peer-reviewed journals, or were presented at conferences.

Publications in peer reviewed journal

Dawson R, Oliveira J, Kwok W, Bratland, M, Rajendran I, Srinivasan A, Chu C, Pinheiro M, Hassett L, Sherrington C. Exercise Interventions delivered through Telehealth to Improve Physical Functioning for Older Adults with Frailty, Cognitive, or Mobility Disability: A Systematic Review and Meta-Analysis. *Telemedicine and e-Health* 2023. doi:10.1089/tmj.2023.0177

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Papers accepted

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Dwyer S, Suen J, Kwok V, **Dawson R,** McLennan C, Cameron I, Hill K, Sherrington C. Exercise for falls prevention in aged care: systematic review and trial endpoint meta-analyses. *Age and Ageing* 2023. doi.org/10.1093/ageing/afad217 (accepted).

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International

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Dawson R, Sherrington C, Suen J, Oliveira J, Pinheiro M, Dwyer S. Exercise to prevent falls in aged care: a review of trial characteristics. *Safety 2022 Conference*, 28 November 2022, Adelaide, Australia. Oral presentation.

Dawson D, Suen J, Sherrington C, Oliveira J, Cameron I, Kwok W, Kneale D, Sutcliffe K, Dyer S. Intervention Component Analysis (ICA) and Qualitative Comparative Analysis (QCA) of exercise to reduce falls in residential aged care. *World Physiotherapy Conference*, Dubai UAE, 4 June 2023. ePoster.

Dawson R, Sherrington C, Nelson K, Bowes N, Haynes A. Putting restorative care into focus: exploring the experiences of older people, physiotherapists and staff using physiotherapy telehealth in aged care. *World Physiotherapy Conference*, Dubai UAE, 4 June 2023. ePoster.

Dawson R, Hewitt J. Falls prevention in residential aged care. *Australian and New Zealand Fall Prevention Society Early-Mid Career Researcher Seminar,* 17 August 2023. Online. Oral presentation.

Dawson R. What happens in residential care (invited). *Australian and New Zealand Hip Fracture Hip Fest Conference*. 12 September 2023, Noosa, Australia. Oral presentation.

Dawson R. Telephysiotherapy in aged care. Falls prevention in residential aged care. *Australian and New Zealand Fall Prevention Society Annual Conference and World Falls Congress*, 28 November 2023, Perth, Australia, Oral presentation.

National

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Winner Early Career Researcher Category: Best Gerontology paper.

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<u>Local</u>

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Winner of best oral presentation in Mental Health.

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Dawson R. Implementing physiotherapy in aged care. *Sydney MSK Annual Scientific Program,* 13 December 2023. Oral Presentation.

PREFACE

The work presented in this thesis is organised into eight chapters, written so that each chapter can be read independently. The University of Sydney allows published papers that arose from the candidature to be included in the thesis.

Chapter One is an introduction to the thesis and provides background and context for the following chapters. It also highlights the gaps in knowledge that this thesis aims to address.

Chapter Two presents the results of a retrospective observational study that aimed to investigate the level of agreement between incident reports and resident progress notes as data sources for falls monitoring in residential aged care facilities. This manuscript is presented in the format required by the *Australasian Journal on Ageing,* where it was accepted on 12 December 2023 and it will be published early 2024.

Chapter Three presents the results of an Intervention Component Analysis (ICA) utilising a mixed method approach, aiming to construct a theory describing the likely features of effective fall prevention exercise in residential aged care. This ICA manuscript adheres to the submission guidelines of the *British Journal of Sports Medicine* and is currently under review. Appendix A presents the results of a Qualitative Comparative Analysis (QCA) conducted to test the theory outlined in the ICA led by my collaborators. This paper is formatted according to the requirements of the *BMC Geriatrics* where a revised version is under review.

Chapter Four is a systematic review and meta-analysis of studies investigating the effects of exercise interventions delivered via telehealth in adults aged 60+ with frailty, mobility or cognitive disability on mobility, strength, balance, falls and quality of life. This manuscript is presented in the format required by *Telemedicine and e-Health*, where it was published online 15 November 2023.

Chapter Five presents the TOP UP trial protocol paper, outlining the methodology employed in this hybrid type 1 effectiveness-implementation randomised controlled trial. The trial involve 242 individuals aged 65 and above, recipients of aged care services in community or residential settings. This manuscript adheres to the specific formatting guidelines of the *British Medical Journal of Nutrition, Prevention and Health*, where it was published online 17 November 2023. Analysis of trial results will commence shortly.

Chapter Six outlines the co-design activities and collaborative efforts of diverse stakeholders, including researchers, aged care service users, aged care staff, physiotherapists, and community members, in the design and implementation of the TOP UP trial.

Chapter Seven reports a qualitative evaluation of the TOP UP program among trial participants. It is presented in the format required by the *Journal of Medical Internet Research in Ageing* where it was accepted on 12 December 2023 and it will be published early 2024.

Chapter Eight is a discussion of the implications of the body of work reported in this thesis and draws conclusions from the work.

Each chapter contains its own reference list and appendices. Ethical approval was granted by the Human Research Ethics Committee at The Sydney Local Health District, Concord, Australia (approval CH62/6/2021-009) for the studies presented in Chapters Two, Six and Seven prior to the commencement of trial recruitment.

GLOSSARY

Acceptability: The extent to which an intervention is well received and deemed suitable by the end users and healthcare providers.[1]

Aged care: Comprehensive support and assistance provided to individuals aged 65 and above, addressing their daily needs, offered both at home and nursing homes/aged care facilities.

Balance: The ability to maintain a stable body position, whether stationary or moving, essential for coordination and preventing falls.

Co-design: A collaborative approach involving end users, researchers, and stakeholders working together to design solutions, systems, or services tailored to specific needs.

Commonwealth Home Support Program (CHSP): An Australian government initiative providing in-home support and services to help older adults remain independent**.**

Comorbidities: Presence of two or more simultaneous health conditions or diseases in an individual, often requiring distinct medical management**.**

Dementia: A progressive neurological disorder causing memory loss, impaired reasoning, and changes in behaviour, affecting daily functioning and independence.

Exercise: Structured physical activity that is performed to improve health and fitness, maintain overall well-being, or achieve specific health goals. Exercise can include various activities such as walking, swimming, weightlifting, balance activities and more.

Exercise Intensity: The level of effort exerted during physical activity, typically measured by heart rate, perceived exertion, or workload.

Fall: Unintentional descent to the ground or lower level, often resulting in injury, commonly experienced by older adults, posing health risks.[2]

Frailty: Clinically recognizable state in older people who have increased vulnerability, resulting from age-associated declines in physiological reserve and function across multiple organ systems, such that the ability to cope with everyday or acute stressors is compromised.[3]

Functional Decline: Gradual deterioration in an individual's ability to perform daily activities and tasks due to ageing, illness, or disability.

Gait: A person's manner of walking, including aspects such as stride length, speed, and posture, often assessed for health and mobility.

Hybrid Type 1 Effectiveness-Implementation Randomised Controlled Trial: A research study design that combines elements of effectiveness and implementation research, aiming to assess both the impact of an intervention and its practical implementation in real world settings.[3]

Implementation: The process of putting plans, strategies, or programs into practice, ensuring their effective execution and integration into existing systems.[1]

Independence: The ability to make decisions and perform tasks without external assistance, promoting self-sufficiency and personal autonomy.

Mobility Disability: Limitations in physical movement, hindering an individual's ability to move independently.

Mixed Methods Research: A research approach combining qualitative and quantitative methods, providing a comprehensive understanding of complex phenomena.

Physical Activity: Any bodily movement produced by skeletal muscles that requires energy expenditure. Physical activity encompasses a wide range of movements, from everyday activities like walking up stairs or gardening to structured exercise routines such as running and programs prescribed by a health professional.

Physiotherapy: A healthcare profession focused on restoring and maintaining physical function, mobility, and wellbeing through exercise and physical interventions.

Quality of Life: The overall wellbeing of individuals, encompassing physical, mental, and social health factors, and reflecting their satisfaction and happiness with life.

Quantitative Research: A systematic, empirical research method that uses numerical data and statistical analysis to explore relationships, patterns, and trends.

Qualitative Research: A systematic research method focusing on understanding and interpreting human experiences, behaviour, and social phenomena through non numerical data analysis.

Reablement: Reablement is a person-centred, holistic approach that aims to enhance an individual's physical, and or other functioning, to increase or maintain their independence in meaningful activities of daily living at their place of residence, and to reduce their need for long-term services.[5]

Reach: The extent to which research findings or interventions effectively impact the target audience or community.[1]

Rehabilitation: The World Health Organisation define it as a "Set of interventions designed to optimise functioning and reduce disability in individuals with health conditions in interaction with their environment".[6]

Residential Aged Care Facilities (RACFs): Institutions providing accommodation, healthcare, and support services for older people unable to live independently at home.

Restorative Exercise: Targeted physical activities designed by health professionals to regain and enhance function such as strength exercises, promoting recovery after illness or injury.

Scale up: The process of expanding a successful intervention or program to reach a larger population, often involving the adaptation of the program to different contexts and settings.[1]

Short Physical Performance Battery: A measurement tool assessing physical functioning in older adults, evaluating balance, strength (timed sit to stand), and mobility (gait speed).

Strength: The ability of muscles to exert force against resistance, determining physical power, endurance, and overall functional capabilities.

Sustainability: The ability of an intervention or program to endure over time, ensuring continued effectiveness and benefits for the targeted population.[1]

Telehealth: The delivery of healthcare services using information communication technologies, allowing patients and providers separated by distance to diagnose and treat diseases and injuries**.** Telehealth covers the terms mHealth, telemedicine, virtual health.

Telephysiotherapy: The provision of physiotherapy services remotely using telecommunication technologies.

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ABSTRACT

As the global population ages, addressing the health and care needs of older individuals, particularly those in regional and remote areas, becomes imperative. Falls, a prevalent cause of injury among older people, result in substantial healthcare costs, diminished quality of life, and mortality. Effective fall prevention programs in aged care are vital for enhancing wellbeing, reducing healthcare costs, and ensuring regulatory compliance. It is well known that exercise can prevent falls and enhance mobility in the general population of older adults. However, evidence and implementation gaps exist regarding exercise programs that aim to support to older people in aged care to improve mobility, reduce falls and enhance quality of life.

Many effective mobility and fall prevention exercise programs have been designed and delivered by physiotherapists. Access to physiotherapy services in aged care settings is hindered by funding models, workforce shortages and transportation challenges for those with mobility and cognitive disabilities. Telehealth, a potential solution, remains largely unexplored in aged care.

Falls are a leading problem in aged care settings with approximately half of all people living in residential aged care falling at least once a year, causing poor health outcomes and significant economic burdens on society. Accurate fall data is essential to effectively assess the impact of fall prevention strategies. Incident reports are increasingly used to describe fall rates at a facility level as they can be more quickly generated via online documentation systems compared to time-consuming manual audits of progress notes. However, discrepancies in fall data collected through incident reports and progress notes have been identified in other settings, highlighting the need to investigate the agreement between these reporting methods in residential aged care.

The accuracy of fall incident records compared to progress notes was investigated in the study reported in Chapter Two. This study involved 46 older individuals from six residential aged care facilities. Of the 46 participants, 27 (59%) experienced a total of 75 falls. Incident reports captured 68 (91%) falls, while progress notes documented 73 (97%) falls. Overall, there was a 75% agreement between falls recorded in progress notes and incident reports. This study highlights the effectiveness and convenience of incident records as a data collection method in clinical care and fall prevention research. However, the identified discrepancies emphasise the need for strategies to enhance fall reporting practices, addressing reported barriers such as staffing shortages in accurate fall data collection and fall management. Chapter Two underscores the pivotal role of incident reports as invaluable tools for designing evidence-based fall prevention strategies in aged care settings.

Exercise was found to reduce falls by 24% among community-dwelling older adults in a 2019 Cochrane Review. Conversely, a 2018 Cochrane Review reported uncertainty regarding the effect of exercise on falls in residents of aged care facilities. Although some trials found a positive effect on fall prevention, high heterogeneity meant the Review provided limited guidance to clinicians on exercise evidence. Chapter Three reports the outcomes of an Intervention Component Analysis that explores fall prevention exercise within Residential Aged Care Facilities.

Intervention Component Analysis is a research methodology designed to methodically investigate and evaluate distinct components or elements constituting an intervention, with the objective of discerning their individual contributions to the overall effectiveness of the intervention. It involves thematic analysis that synthesises the insights provided by trialist commentaries from the discussion section of papers to examine the potential positive or negative impacts of various components on the outcomes of interest. The primary goal of ICA is to deconstruct the intervention into its elemental parts and scrutinise the influence of each component on the targeted outcomes such as fall rates. Through the isolation and examination of these components, researchers can acquire a comprehensive understanding of the fundamental elements that shape the success or failure of the intervention. This knowledge subsequently informs the design, implementation, and enhancement of similar programs in the future.

The Intervention Component Analysis presented in Chapter Three revealed that fall prevention exercise programs found effective in trials involved targeted activities addressing balance and strength, were tailored to individual needs, and delivered at a moderate intensity. Furthermore, successful implementation necessitates adequate resourcing for structured and supervised exercises at an appropriate dosage. A Qualitative Component Analysis (QCA) undertaken by the author's collaborators to test the ICA theory is reported in Appendix A. Statistical analysis in the QCA indicates that fall prevention exercise programs are more likely to be effective when providing supervised low to moderate intensity exercise programs, either individually or in a group, for at least one hour per week. Larger-scale studies are imperative to validate these emerging theories.

Telehealth is defined by the World Health Organisation as the delivery of health care services, where patients and providers who are separated by distance, use information communication technologies to diagnose and treat diseases and injuries. Little is known about the effectiveness of telehealth physiotherapy to deliver exercise programs in aged care settings or about how best to implement telehealth exercise in this complex population. Chapter Four systematically reviews the effects of exercise interventions delivered via telehealth in adults aged 60+ with frailty, mobility or cognitive disability on mobility, strength, balance, falls and quality of life. The study found that the overall certainty of evidence was rated as ‘low’ or ‘very low’. Pooled between-group differences were not statistically significant but effect sizes suggested that telehealth produced a moderate improvement on mobility (n = 5 studies; standardized mean difference (SMD) = 0.63; 95% CI -0.25 to 1.51; p = 0.000, I^2 = 86%) and strength (n = 4; SMD = 0.73; 95% CI -0.10 to 1.56; p = 0.000, I^2 = 84%), a small improvement on balance (n = 3; SMD = 0.40; 95% CI -035 to 1.15; p = 0.012, I^2 = 78%) and no effect on quality of life or fall reduction. Analysis of implementation measures suggested telehealth to be feasible in this population given its high rates of acceptability and adherence with minimal safety concerns. Further research is warranted given the limited evidence identified by the review.

Telehealth is emerging as a key method for delivering essential healthcare. Primary care research suggests that telehealth is acceptable and has potential to overcome geographical barriers for older individuals with complex comorbidities and limited mobility by eliminating the need for extensive and costly travel. Despite telehealth’s promise, the significant level of technology literacy required of users may limit its applicability in aged care settings. Co-design is a collaborative strategy uniting end-users, researchers, and stakeholders and is a strategy employed to navigate complex interventions such as telehealth. Co-design has proved essential for customising telehealth solutions, ensuring they align precisely with the unique requirements of end-users, ultimately elevating acceptance, usability, and fostering sustained engagement over the long term.

Chapter Five presents the TOP UP trial protocol - a Hybrid Type 1 effectiveness and implementation randomised controlled trial of telephysiotherapy to improve mobility, reduce falls and enhance quality of life in older people receiving aged care services in community or residential settings. The trial recruited 242 people aged 65+ years receiving aged care services in community or residential settings. Participants were randomised to either: (1) the Telehealth Physiotherapy for Older People (TOP UP) Program or (2) a wait-list control group. The six-month intervention includes ten physiotherapy sessions delivered by video call (Zoom). The intervention includes the local support of an aged care worker and online exercise resources. The primary outcome is mobility at six months post randomisation measured by the Short Physical Performance Battery. Secondary outcomes include the rate of falls, sit-to-stand, quality of life and goal attainment at six months after randomisation. This trial employs a mixed methods methodology to investigate the interventions effectiveness, cost-effectiveness and implementation to support timely translation if found to be safe, acceptable and effective.

Chapter Six examines the co-design process of the TOP UP intervention, a telehealth physiotherapy program for older people in aged care settings. TOP UP’s co-design approach is guided by Fernandez's implementation mapping process, the Integrated Knowledge Translation (IKT) model, and the Nonadoption, Abandonment, and Challenges to the Scale-Up, Spread, and Sustainability (NASSS) implementation framework. Chapter Six addresses the intricacies and challenges associated with implementing telehealth physiotherapy (telephysiotherapy) in aged care. The TOP UP co-design process actively involved input from aged care service users, their caregivers, experienced aged care physiotherapists and support staff, aiming to formulate a research question and implementation plan tailored to the unique needs of the aged care community.

Chapter Six also explores the TOP UP trial progress. Recruitment for the TOP UP trial concluded in February 2023, with final follow-up data collection completed in November 2023. The trial saw robust adoption, with 242 participants recruited from an eligible pool of 512. At the six-month follow-up, 202 participants remained, highlighting TOP UP's high feasibility. The median exercise dose was 29 hours (range 8 to 75), aligning with proposed ICA and QCA doses. One recorded adverse event occurred when a participant fell during exercise with no reported injuries. Post-intervention, participants were surveyed, and all except six expressed a willingness to recommend telephysiotherapy. In 2024, we will explore additional implementation insights, concurrently conducting analyses on effectiveness and cost-effectiveness.

Chapter Seven uses qualitative methodology to explore the insights from aged care service users, physiotherapists, aged care support workers and managers regarding the impact, safety and resource needs associated with adopting telephysiotherapy to deliver exercise in aged care. This thematic analysis of data from those involved with the TOP UP trial uncovered key insights: telehealth can provide convenient access to physiotherapy services for many aged care recipients; the positive impact of tailored physiotherapy, coupled with local support, enhances exercise motivation; the effectiveness of engaging senior-friendly resources in fostering program adherence; and the facilitation of greater independence through a flexible reablement approach. This study emphasises the importance of sustained organisational commitment for the successful implementation of telephysiotherapy programs like TOP UP to deliver exercise in aged care, highlighting the need for training and external funding to ensure the program’s adoption, sustainability and potential scale up.

Falls and impaired mobility incur substantial healthcare costs, diminish quality of life, and, unfortunately, lead to a loss of independence and mortality. The implementation of tailored telephysiotherapy exercise programs in aged care settings could be pivotal for not only enhancing the wellbeing and safety of aged care service users but also for reducing healthcare expenses and ensuring regulatory compliance. The effectiveness and cost-effectiveness outcomes of the TOP UP trial will be presented in 2024. However, the implementation findings in this thesis underscore the potential of telephysiotherapy as a safe, acceptable and feasible solution to deliver exercise interventions for aged care service users including those with moderate levels of mobility and cognitive disabilities. This thesis highlights the urgent need for future large-scale studies to explore the expansion of telephysiotherapy in aged care, particularly within culturally and linguistically diverse populations and among those with more severe mobility and cognitive disabilities.

In conclusion, this thesis addresses critical gaps in existing evidence. The studies described in this thesis a) establish the effectiveness and convenience of utilising fall incident records for collecting fall data; b) indicate that telehealth is a feasible method to deliver exercise to enhance mobility for aged care service users but more research is needed; c) suggest that successful fall prevention exercise in residential aged care should concentrate on balance and strength exercises delivered at a moderate intensity, tailored to individual needs; d) describe the process and output of a collaborative process to design a telephysiotherapy intervention for aged care settings and an embedded trial to test this intervention; e) propose that telehealth combined with local support is an acceptable, safe, and a feasible platform for delivering physiotherapy-led exercise programs within aged care settings; and f) emphasise the necessity of sustained organisational commitment, adequate training and external funding for the successful implementation, sustainability and potential scale-up of telephysiotherapy programs to deliver exercise in aged care settings to improve mobility, reduce falls and enhance quality of life.

This thesis aims to offer valuable insights for policymakers, healthcare providers, and aged care services, aiming to enhance healthcare accessibility and improve the quality of life for our ageing population. The research outlined in this thesis addresses challenges and underscores the transformative potential of telephysiotherapy in facilitating older peoples' access to evidence-based exercise conveniently and in locations where it is most beneficial.

CHAPTER ONE

Introduction

Preamble

The purpose of this introduction is to provide background information and context for the research topic and to establish the rationale for each of the research studies described in the thesis. Text boxes are used in the introduction to highlight research gaps, improve clarity, and emphasise significance.

1.1 The impact of population ageing – setting the scene

1.1.1 The international experience

Every country in the world is experiencing growth in the number of older people and proportion of older people in their population.[1] Today most people can expect to live well into their sixties and beyond.[2] This phenomenon is known as population ageing.[1] The World Health Organisation (WHO) estimates that by 2030 over 17% of the world's population will comprise of older people. They predict that the number of older people will increase from 1.0 billion in 2020 to 1.4 billion in 2030 and by 2050, the world's population of older people will double to 2.1 billion. WHO predicts that the number of persons aged 80 years or older is expected to triple between 2020 and 2050 to reach 426 million.[1]

Population ageing initially emerged in high-income countries, but the trend is now particularly evident in low and middle-income countries.[2] It is estimated that by 2050 over two-thirds of the world's population of older people will be living in low and middle-income countries. The WHO indicates that this demographic shift will significantly impact the socioeconomic and healthcare systems of these countries and that collaboration between governments, health professionals, academia, the media and the private sector is required to foster longer and healthier lives.[1] To promote more equitable health care it is expected that significant reform will need to take place, reform that is both effective in improving the experience of ageing, and reform that is cost-effective to ensure that health care is affordable.[3]

1.1.2 The Australian experience

Australia's population is ageing, in common with the global trend.[2] The latest report from the Australian Institute of Health and Welfare (AIHW) updated in June 2023 states that there were an estimated 4.2 million older people, those aged 65 years+, living in Australia.[4] This number has increased from 1.0 million (8.3% of the total population) in 1970 to 4.2 million (16%) in 2020.[4] It is expected that by 2026 older people will make up approximately 22% of the total Australian population. AIHW expects that the population of those people aged over 85 will rise from 63,000 (0.5% of the total population) in 1970 and 528,000 (1.1% of the population) in 2020 to 1.6 million (4% of the population) in 2066.

1.1.3 The health experience of older people

Ageing is a complex phenomenon presenting a myriad of challenges that impact on an individual's quality of life, shaping their physical, mental, emotional and social wellbeing of older people.[5] The Australian Bureau of Statistics (ABS) National Health Survey (NHS) 2017-18 report estimated that 26% of older people rated their health as being fair or poor with older people aged over 75 years more likely to report their health as poor.[6] The 2018 ABS Survey of Disability, Ageing and Carers (SDAC) found that 50% of older people in Australia had a disability.[7]

The prevalence of disability increases with age. In 2018, 36% of people aged 65–69 had a disability compared to 85% of those aged 90 and over.[7] The SDAC survey concluded that the need for assistance with activity of daily living due to disability in older people is a trigger for needing formal support services such as aged care. A 2019 scoping review that explored the care and support needs of older people living with chronic conditions found that they required care and support in three main areas: 1) social activities and relationships; 2) psychological health; and 3) activities related to mobility, self-care and domestic life.[8]

1.1.4 The rural and remote health experience of older people

Providing adequate health and aged care to older people living in rural and remote regions of Australia is problematic for several reasons. Australia is a large continent making physical access to health and aged care services more difficult.[9] The distance between towns and appropriate medical facilities can be substantial, resulting in longer travel time, increased costs and limited access to health care professionals, especially in rural areas which have a documented shortage of health and aged care professionals.[10] As a result, many older people in Australia's rural and remote communities experience poorer health outcomes compared with their metropolitan counterparts. Rates of disease, mortality and avoidable hospitalisation are significantly increased with geographical remoteness.[11]

The Australian Physiotherapy Council estimated there were 40,018 registered physiotherapists working in Australia in 2022.[12] They estimate that there is a shortage of six thousand physiotherapists nationwide and that this workforce shortage has been exacerbated by the COVID-19 pandemic situation.[12] Workforce shortages are worse in regional and remote Australia as evidenced by statistics showing that only 18% of physiotherapists work in regional and remote Australia to cater for 28% of the Australian population.[13] The recent Royal Commission into Aged Care Quality and Safety concluded that the inequitable access to allied health services for older people in rural and regional Australia needs to be addressed with the support of innovative solutions such a telehealth.[14]

There is a need to increase rural and remote health care access for older people and reduce the health outcome disparity between metropolitan and rural/remote Australia.

1.1.5 An overview of the Australian aged care system

Australia's aged care system is structured to address the diverse needs of its ageing population, offering a spectrum of services tailored to individual requirements. These services span from enabling older people to maintain independent living in their homes with necessary supports to providing round-the-clock care within residential facilities. Most older people receive federally funded aged care services while resident in their own homes. Statistics as of 30 June 2022, indicate that 210,000 older people accessed Home Care Package services, while approximately 800,000 benefited from Commonwealth Home Support Program services (CHSP).[4]In contrast, 185,000 older people received aged care services in Residential Aged Care Facilities (RACFs).[4] Apart from these services, additional flexible aged care services are accessible through Federal and State funded initiatives. These services support hospital based programs into the community, including hospital in the home, short term restorative care, multi-purpose services programs, National Aboriginal and Torres Strait Islander Flexible Age Care Program and Department of Veterans Affairs services.[4]

1.1.6 The cost of aged care

During the financial year 2021-2022, the Australian Federal Government allocated a substantial budget of over $25.1 billion on aged care services. A significant portion, amounting to 59%, was dedicated to residential aged care, totaling $14.9 billion.[4] This allocation was nearly double the combined expenditure on home care and other aged care support services. Specifically, Home Care Package services received funding of $5.0 billion, while the CHSP was allocated $3.1 billion. Additionally, a sum of $0.2 billion was allocated to other aged care community services, supporting programs such as the Department of Veterans' Affairs community nursing and Veterans' Home Care (VHC) initiatives. It is crucial to note that aged care funding has increased by 27% since 2017-18 compared to the overall population rise of only 4% during the same period.[4] This escalating financial commitment to health and aged care services has prompted extensive discussions among health professionals, economists and politicians.[15]

Australia's ageing population pose significant challenges for future governments. As the aged demographic expands, there will be surging demand for funding in the aged care sector. At the same time, a smaller proportion of the population will be in the working age bracket, reducing the tax base available to support aged care services. This demographic shift exerts pressure on the economy and on future government budgets.[16] The recent Royal Commission on Aged Care quality and Safety highlighted the critical nature of this increased demand for aged care. Addressing this challenge requires specific policy development to ensure Australians receive high quality and sustainable care that remains affordable.[17] This expenditure growth emphasises the urgent need to solutions that enable older people to age at home, avoiding costly admission to RACFs and hospitals.[17]

There is a need to implement cost-effective strategies to support older people to age well at home ensuring both their wellbeing and the economic viability of the health care system.

1.1.7 Minimising the admission risks to aged care

The lifetime chance of being admitted to a RACF is 40% for Australian women and 25% for men.[18] It is important to understand that older people receiving aged care services often have complex health conditions, multiple comorbidities including high levels of frailty, mobility and cognitive disability and falls.[19] Admissions to RACF are often the result of repeated falls and their consequences.[20] Hajek and colleagues found that the probability of institutionalisation increased significantly with the occurrence of mobility impairment.[21] The move to residential care for older adults is complex and influenced by multiple factors. Chatindiara and colleagues in their 2020 study provides evidence for high prevalence of malnutrition and frailty at admission to residential aged, with 76% being frail and 24% pre-frail and most (93%) were either malnourished (48%) or at risk of malnutrition (45%).[22] Other risks for older people entering residential aged care face include functional decline, social isolation, medication management issues, nutrition and hydration challenges, abuse, neglect, and psychosocial factors.[23] it is in everyone's interest to develop programs that minimise the risk of these health problems and reduce the need for older people to receive costly aged care services.

1.1.8 Unmet care needs for older people

The global healthcare systems are grappling with the challenges of meeting the diverse care and support needs of older people.[24] Addressing these unmet needs and creating services tailored to their specific requirements are swiftly emerging as critical public health priorities.[25] Despite this urgency, there is a notable gap in recent research synthesising evidence concerning the care and support needs of older people living with disability and chronic conditions.

In a recent systematic review exploring the impact of multimorbidity on older people, Marengoni and colleagues[26] reported significant consequences such as functional decline, poor quality of life and escalating health-care costs for those living with disability and complex co-morbidities. However, this review provided limited insights in the specific types of support essential for older people to navigate these challenges. Additionally, there is a scarcity of evidence addressing how healthcare can be tailored to accommodate the unique needs and preferences of older people fostering greater engagement with evidence-based practices. Addressing these research gaps is imperative in shaping effective and person-centred healthcare solutions for ageing communities.

1.1.9 Challenges for integrating research in aged care

The growth of implementation science has seen a focus on bridging the gap between research findings and practical application, particularly in healthcare settings.[27] It emphasises identifying effective strategies for implementing evidence-based practices and overcoming barriers to their adoption. By studying implementation processes, researchers gain insights into factors influencing successful adoption, dissemination, and sustainability of interventions in aged care, ultimately improving the quality of care and outcomes for older adults.[28]

However, the integration of research findings into aged care setting faces challenges when the needs and preferences of older people are not adequately considered by healthcare providers.[29] Failures by researchers to incorporate the needs and preferences of older people may also limit the translation of research into practice.[30] Implementation research highlights the importance of genuine collaboration involving researchers, service users, service providers, policymakers, and other concerned stakeholders for the successful design, adoption and scale up of effective interventions.[31] Ageing is a complex process and collaborative research processes that bring together interdisciplinary insights, comprehensive care approaches, resource optimisation, innovation and problem solving from all stakeholders and most important services users themselves can accelerate the translation of research.[32]

Collaborative research is needed in aged care to understand how best to engage older people at risk of costly institutionalisation and/or hospitalisation. More collaboration in aged care research is required to enhance the depth and breadth of research opportunities and solutions for the challenges faced by ageing populations. Aged care reform needs to be informed by collaborative research that includes older people in the design and implementation of intervention to identify strategies that are most acceptable in supporting older people to age well, reducing the impact of disability and reducing regional/remote access disparities.

1.2 Defining the potential value of exercise for older people

1.2.1 The value of restorative exercise

Regular physical activity offers numerous benefits for both physical and mental well-being.[33] It reduces the risk of cardiovascular diseases, plays a crucial role in weight management and weight-bearing activities and resistance exercises contribute to muscle and bone strength, fostering overall physical resilience.[33] The cognitive benefits of physical activity include improved memory, attention, and overall brain health.[33] It's essential to recognise that the benefits may vary based on factors such as activity type, intensity, and duration, as well as individual health conditions, underscoring the importance of consulting with a healthcare professional before starting a new exercise program, especially for those with existing complex health concerns.

Exercise is a structured form of physical activity that can enhance the quality of life for older people by improving lung and cardiac function,[34] decreasing the impact of osteoarthritis,[35] improving muscle strength,[36] balance,[37] mobility[38] and reducing falls.[39] Exercise can improve balance, mobility and falls risk in older people with dementia.[40 41] Importantly, exercise can be implemented at a relatively low cost.[42] The Royal Commission into Aged Care called for aged care reform to better assist older people to age well at home and to improve their quality of life, and to deliver services that tackle the increasing economic burden of aged care.[17] They recommended funding restorative exercise interventions prescribed by physiotherapists and other allied health professionals to enhance physical function, improve mobility and reduce falls in aged care settings.

1.2.2 Fall prevention matters

In Australia falls is the leading cause of hospitalised injuries and injury deaths among older Australians accounting for 77% of all injury hospitalisations and 71% of injury deaths.[43] In 2020 there were 5,034 deaths and 364 hospital admissions per day due to a fall among older people across the country.[43] Three-quarters of hospitalisations for older people are due to falls, increasing at a rate of 3% per year with recurrent health service expenditure on falls at $4.2 billion per annum ($2.3 billion in those aged 60+).[43] This increase is particularly evident in residential care, where 50% of the residents fall each year.[44]

Falls can result in severe injuries such as fractures, head trauma, often leading to reduced mobility and independence.[45] Recovery from these injuries can be lengthy and challenging, impacting the overall quality of life.[46] The physical consequences of falls can trigger a downward spiral, where reduced mobility leads to muscle weakness which further increases the risk of falls, creating a vicious cycle of decline.[47] Psychologically, falls can have a profound impact causing fear, anxiety and a loss of confidence in an individual to move safely.[48] This fear of falling can lead to social isolation as people limit their activities and interaction to avoid potential falls. Such social withdrawal can contribute to feelings of depression and loneliness, further deteriorating mental health.[49] Additionally, the fear of falling often results in selfimposed restrictions on daily activities, hindering the individuals ability to lead an active and fulfilling life.[50]

Fall reports serve a crucial purpose in health and aged care settings by documenting and analysing falls experienced by patients or residents. These reports help healthcare providers and organisations understand the circumstances surrounding each fall, including the location, time, contributing factors, and consequences.[51] By systematically documenting fall incidents, healthcare facilities can identify trends, risk factors, and areas for improvement in fall prevention strategies and interventions. The data collected from fall incident reports inform quality improvement initiatives, guide the development of tailored interventions, and support evidence-based practices such as exercise aimed at reducing the incidence of falls.[52] Accurate reporting of falls in routine care is crucial for assessing and monitoring the impacts of any changes that are introduced.

Accurate fall data is vital for evaluating the effectiveness of fall prevention strategies. Falls are currently measured via two methods within Australian RACFs: through progress notes or incident forms.[53] In Australia, mandatory fall reporting was established in 2021 through the National Aged Care Mandatory Quality Indicator program.[54] Incident reports are commonly used to describe fall rates at a facility level due to their efficiency in online documentation systems.[55] However, discrepancies in falls data collected through incident reports and progress notes were found in hospitals emphasising the need to investigate the agreement between these reporting methods in Residential Aged Care Facilities (RACFs).[56]

Chapter Two describes a retrospective observational study to assess the agreement between fall incident reports and progress notes in RACFs and explore potential variations in agreement across different aged care facilities. **Chapter two will identify whether incident reports are an effective and efficient method to collect accurate fall data** and therefore serve as a crucial initial step in identifying modifiable fall risk factors to implement fall prevention exercise programs as well as enabling monitoring of intervention effects..

1.2.3 Fall prevention exercise in residential aged care

Impaired balance and strength are key risk factors for falls and fractures.[57] Exercise is known to prevent falls in community dwelling older people. Sherrington and colleagues' Cochrane Review in 2019 pooled 59 studies and found high certainty evidence that exercise reduces the rate of falls in community-dwelling older people by at least 23% and their sub-group analysis showed that exercise targeting balance, functional abilities and strength was particularly effective reducing the rate of falls by 34% (moderate-certainty evidence).[58]

However, the evidence for fall prevention exercise within RACFs is less clear. The 2018 Cochrane Review by Cameron and colleagues on fall prevention exercise in RACFs revealed uncertain outcomes regarding the effectiveness of exercise in this population.[59] This uncertainty was compounded by the limited number of studies (n=17) included in the review, characterised by high heterogeneity. These studies encompassed a broad spectrum of fall prevention exercise programs, ranging from brief, self-directed walking programs lasting five minutes per session[60] to complex strength and balance programs requiring 60 minutes and involving electronic gym equipment.[39] This diversity in interventions poses challenges for clinicians in interpreting the findings.[61]

Chapter Three of this thesis seeks to bridge this gap through an Intervention Component Analysis (ICA)[62] concentrating on fall prevention exercises within residential aged care settings. The primary objective was to identify the crucial components of fall prevention exercises and identify any successful implementation strategies, drawing insights from the trialist commentaries in Cameron's updated Cochrane Review. This mixed methods study endeavours to provide clinicians with evidence-based guidance on the most effective fall prevention exercise programs meticulously designed for the unique context of aged care. Such research is imperative to equip clinicians with recommendations regarding the most effective fall prevention exercise programs tailored specifically for the aged care population.

1.2.3 Improving mobility for older people

Mobility limitations are increasingly commonplace in older people affecting approximately 35% older people and most people over 85 years.[63] Mobility limitations are associated with an increased falls, disability, hospitalisation, and mortality risk as well as decreased quality of life.[64] Mobility impairment significantly diminishes the quality of life for older people by influencing multiple aspects of their daily living.[65] Those living with limited mobility often depend on service providers for essential tasks like bathing, dressing and shopping, eroding their independence and autonomy.[66] This reliance restricts their social interactions and involvement in community activities, fostering feelings of isolation, loneliness and depression.[67] Additionally, reduced participation in hobbies, social events and recreational activities results in an overall decline engagement with life, fostering poor mental health.[68 69] The impact of mobility impairment on these crucial aspects of life highlights the importance of interventions and support systems tailored to enhance the wellbeing of older people facing mobility challenges.

Recent studies of gait speed of residents in aged care facilities have demonstrated that residents have a slow gait speed of approximately 0.4 m/s4-6 compared with more than 0.9 m/s in healthy adults aged over 80 years.[70] This suggests that these residents are frailer and at higher risk of health complications than their community counterparts. Interventions are needed to facilitate improving or at least minimising decline in mobility.

Hardy and colleagues demonstrated additional health care costs in older persons with mobility limitations.[64] Musich and colleagues found that higher levels of mobility limitations were strongly associated with negative health outcomes.[63] They concluded that mobility-enhancing interventions should be supported to promote successful ageing. In a recent systematic review investigating the effectiveness of exercised-based interventions for community dwelling frail older people in enhancing physical function, findings revealed that exercise improved mobility. This improvement was quantified through the Short Performance Physical Battery (SPPB) test, which measures gait speed, sit to stand speed and standing balance.[71] Uysal and colleagues investigated the impact of physiotherapy led strength and aerobic exercise on community dwelling older people with mild cognitive impairment and found significant improvements in their mobility, physical performance and quality of life outcomes.[72]

These results are in line with those of Scrivener and colleagues who conducted a mixed-method prospective cohort study of an ongoing physiotherapist-led exercise program for residents of an Australian RACF.[73] Participants had an average age of 83 years (SD 13) and the majority (61%) required physical assistance for mobility. Compliance with scheduled sessions was high (94%). The program had high levels of acceptability with most (92%) participants indicating that they would recommend the program. The majority (55%) experienced improved walking speed. The authors concluded that a restorative exercise program can maintain the physical status of aged care residents, despite the common decline in physical performance in this population.

1.2.4 Frailty prevalence in aged care

Frailty is defined as a "clinical state in which there is an increase in an individual's vulnerability for developing an increased dependency and/or mortality when exposed to a stressor".[74] As people become more frail they begin to develop mobility problems which can lead to increased risk of falls.[75]

Different authors and organisations have described frailty and physical function in different ways. For this thesis "pre-frail" was considered a state of health in older adults that is intermediate between robust health and frailty. It signifies a stage in which individuals may be at increased risk of developing frailty due to age-related declines in physical function, mobility, and other physiological systems.[76] Pre-frail individuals may exhibit some early signs of frailty, such as reduced muscle strength, endurance, balance, and decreased tolerance to stressors, but they generally maintain a level of independence in activities of daily living. Identifying pre-frailty allows healthcare professionals to intervene with preventive measures to slow or reverse the progression to frailty and associated adverse health outcomes in older adults.[77] The new Australian National Aged Care Classification (AN-ACC) has included the Clinical Frailty Rockwood Scale as part of its mandatory suite of assessment tools, highlighting the importance of frailty measurement and management in the Australian healthcare context.

A systematic review found that the prevalence for frailty in community dwelling older people varied from 4% to 59%.[78] Eager and colleagues' 2019 demographic analysis of the Australian residential aged care population found that 78% of residents were identified as frail. They also found that 61% of residents required some level of staff assistance to mobilise and 50 % had had a recent fall.[19] A recent retrospective audit of older people across 14 RACFs found 75% of resident were frail and 19% pre-frail. Seventy-three percent of residents required a walking frame to mobilise, and their mean walking speed was 12 seconds over 4 metres which previous research has shown to increase their risk of mortality, morbidity and increase their healthcare utilisation.[79]

Rookwood argues that frailty and its consequences is a complex problem which needs a complex response and that frailty management should focus on individualised assessment and intervention to address this multisystem problem.[80] The clinical profile of residents supports the hypothesis that residential aged care costs are driven by care burden associated with frailty, mobility and functional decline as well as end of life care, cognition, behaviour and technical nursing needs.[19] Any future intervention in aged care must avoid routine responses and deliver multidisciplinary and tailored interventions.[80] It is also important to acknowledge the WHO i-Cope program's potential to broaden our understanding of frailty by emphasising its intersection with mental health and promoting person-centered approaches to care.[81] By integrating mental health services into aged care, the program may catalyse transformative changes in service planning and provision, ultimately leading to more comprehensive and responsive care for frail older adults.

1.2.5 The exercise experience in aged care

In the context of the older person, there are distinctions between physical activity, exercise, and incidental physical activity[82 83]:

1. **Physical Activity**: Physical activity refers to any bodily movement produced by skeletal muscles that requires energy expenditure. This includes activities such as

walking, gardening, household chores, and recreational activities. Physical activity encompasses both structured activities (such as exercise routines or sports) and unstructured activities (such as daily tasks or leisurely walks). For older persons, engaging in regular physical activity is important for maintaining mobility, independence, and overall health.

2. **Exercise**: Exercise is a subset of physical activity that is planned, structured, repetitive, and performed with the goal of improving or maintaining physical fitness and health. Exercise often involves specific activities or routines designed to target cardiovascular fitness, strength, flexibility, or balance. Examples of exercise for older adults may include walking, cycling, swimming, strength training, yoga, or tai chi. Regular participation in appropriate exercises can help older individuals improve muscle strength, cardiovascular health, balance, and flexibility, thereby reducing the risk of falls and maintaining functional independence.
3. **Incidental Physical Activity**: Incidental physical activity refers to the spontaneous or unplanned physical movements that occur as part of daily life activities. This includes activities such as taking the stairs instead of the elevator, walking to the store, standing while doing household chores, or gardening. Incidental physical activity contributes to overall energy expenditure and can help older adults maintain mobility and functional capacity. While incidental physical activity may not be as structured or intense as planned exercise, it still provides health benefits and contributes to the overall physical activity level.

Understanding the attitudes and preferences of older adults towards physical activity is crucial for developing effective interventions targeting this demographic. Through six focus groups involving 46 adults aged 65 years and older, participants' preferences and attitudes towards physical activity were explored.[84] Content analysis revealed a preference for incidental activities like gardening and household chores over planned exercise, although leisurely walking was also popular. Despite recognising the health benefits of physical activity, participants cited barriers such as poor physical health, extreme weather, and fear of injury. They expressed interest in organised exercise groups and tailored physical activity programs. Most preferred engaging in physical activity with others. These insights could inform the development of future interventions tailored to the needs of older adults in Australia, emphasising the importance of addressing barriers and catering to preferences to promote active lifestyles and structured exercise among aged care services users.

Despite the evidence affirming the positive impact of exercise on enhancing the quality of life for older individuals, their involvement in exercise remains notably low.[85] Within the community, only 6-12% of older individuals participate in balance and strengthening exercises. The situation is more dire for those residing in RACFs, where individuals spend 85% of their day in a seated position, with a mere 14% engaging in low-intensity seated exercise and only 1% participating in restorative exercises aimed at reducing falls and enhancing mobility.[86]

The 2020 WHO's updated guidelines on physical activity recommend that all adults, including older individuals, should strive for 150–300 minutes of moderate-intensity or 75–150 minutes of vigorous-intensity physical activity.[87] Older individuals are specifically encouraged to partake in as much physical activity as possible to optimise health outcomes and minimise sedentary behaviours where feasible. The challenge lies in devising strategies to motivate older individuals receiving aged care services to participate in physical activity and exercise safely and effectively, particularly when access to allied health services such as physiotherapy may be limited.

1.3 Engaging in exercise via telehealth

1.3.1 Understanding telehealth

Telehealth, or telemedicine, relates to health services provided with telecommunication technologies, ranging from websites containing health information, to text reminders for physiotherapy appointments, use of apps to track medical information such as heart rate and rhythm, to video-conference or phone consults between a doctor and a patient.[88] The three distinct types of telehealth services are synchronous, asynchronous, and remote monitoring.[89]

- *Synchronous telehealth* refers to the real-time exchange of health information, enabling live discussions and assessments between the patient and healthcare practitioner, facilitating the delivery of health expertise.
- *Asynchronous telehealth* involves the "store-and-forward" method, where a patient or healthcare practitioner gathers medical history, images, and pathology reports, transmitting them to a healthcare practitioner for diagnostic and treatment expertise. Alternatively, it can include patients following health and education programs, such as exercise videos, created by a health professional, allowing them to use the resources at a convenient time.
- *Remote patient monitoring* involves continuous evaluation of a patient's clinical status, whether through direct video monitoring of the patient or via review of tests and images collected remotely.

Telehealth presents complexity for users, as healthcare practitioners can integrate multiple telehealth components into a single treatment session. Telehealth not only involves a variety of technologies but also intricate clinical practices, workflows, and organisational structures. These components collectively form a complex framework essential for ensuring the feasibility, safety, and effectiveness of virtual patient care.[90] Consequently, healthcare practitioners and users need to remain adaptable to swiftly incorporate the rapid advancements in information technology, telecommunications and healthcare practices associated with telehealth service delivery.[91] The dynamic nature of telehealth emphasise the necessity for a deep understanding of these multifaceted elements to deliver comprehensive and successful healthcare services from a distance. The WHO Digital Investment Implementation Guide provides practical telehealth guidance, encouraging countries to develop costed telehealth programs to optimise the health of all people.[89]

The Vital Directions for Health and Health Care initiative by the United States National Academy of Medicine recently identified telehealth as one of the six key directions for enhancing healthcare for older adults.[92] These directions include creating a prepared workforce, strengthening public health, addressing health disparities, implementing new care delivery approaches such as telehealth, allocating resources for end-of-life care and redesigning long-term services and supports.[92] The initiative recommends that governments establish policies facilitating the integration of telehealth into both existing and emerging evidence-based practice models. Despite these recommendations, countries worldwide have encountered challenges in ensuring sustained, widespread access to telehealth services, even in those with advanced healthcare systems.[93]

1.3.2 The impact of COVID-19's on telehealth utilisation on older people

The COVID-19 pandemic has had a disproportionate impact on older people.[94] Older individuals face an elevated risk of severe illness if they contract COVID-19, attributed to their age and higher prevalence of comorbidities.[95] Interventions such as social distancing were implemented to curb the pandemic's spread, yet they contributed to a notable 60% decline in older individuals seeking medical care in 2020, likely resulting in adverse health consequences.[96] Additionally, recent studies have established a connection between COVID-19 and diminished physical activity, thereby increasing the risk of falls among older individuals.[97]

Before the pandemic, studies were already indicating that telehealth represented an efficient and effective mode of healthcare delivery, particularly beneficial for older individuals residing in the community.[98] However, the advent of COVID-19 prompted a swift and extensive adoption of telehealth, compelled by the imperative to adhere to social distancing measures aimed at curbing community transmission and safeguarding both patients and healthcare practitioners.[99] The pandemic underscored the pivotal role of telehealth in healthcare delivery, emphasising its potential to provide healthcare access to all, particularly addressing the needs of those in remote areas and communities grappling with workforce shortages.[99]

Although telehealth has the potential to mitigate certain inequities in healthcare access, its benefits are not evenly distributed, especially among older populations receiving aged care services. Factors such as poverty, limited access to digital technology, and challenges in digital health literacy within this population can further compound existing disadvantages.[100] Therefore, it is crucial to investigate the implementation of telehealth physiotherapy as a means to enhance its future sustainability, with a particular focus on telehealth programs designed to enhance physical activity and reduce the incidence of falls. Such exploration is essential in devising strategies that ensure fair access and meaningful utilisation of telehealth services across diverse demographic groups.

1.3.3 Telehealth utilisation in RACFs during the COVID-19 pandemic

In 2020, the Australian federal government integrated telehealth into the nation's universal health insurance scheme, Medicare.[101] In 2022, additional funding was provided through the Primary Health Networks to support telehealth uptake in aged care.[102] While there is no specific research to date investigating the impact of these funding changes on telehealth utilisation there is emerging evidence exploring the impact telehealth is having on aged care. A retrospective study conducted in 2022, analysing telehealth consultations for medical practitioners serving individuals residing in RACFs in the United States, revealed that telehealth effectively reduced unnecessary emergency and inpatient services, leading to reduced healthcare costs for RACF residents.[103] A similar retrospective cohort study in Australia indicated that only 17% of General Practitioner (GP) consultations were conducted via video conferencing, with the majority (93%) utilising telephone consultations.[104] The study also highlighted that RACF residents in rural areas exhibited a higher rate of telehealth utilisation compared to those in metropolitan areas, suggesting greater acceptance of telehealth in regions facing significant challenges in accessing healthcare professionals.

The authors of a 2020 systematic review investigating the utilisation barriers and medical outcomes with the use of telehealth concluded that more implementation research is needed to provide better understanding video conferencing use in RACFs.[105] They argue that sufficient investment in telehealth technology, continuous support and telehealth training for frontline staff and residents may contribute to the successful implementation of telehealth programs for older adults.[105] These findings emphasise the need for ongoing efforts, increased funding, and support from governments to optimise the utilisation of telehealth services within the aged care sector.

1.3.4 Telehealth can effectively promote mobility and reduce falls in older people

A 2022 systematic review investigated the effectiveness of home-based exercise delivered by telehealth in healthy older adults.[106] It was a large review that included 26 studies investigating 5,133 community-dwelling participants with an age range of 69–83 years. The telehealth programs delivered planned and structured exercise that was designed to improve and/or maintain one or more physical fitness measures such as muscular strength, gait speed, balance, mobility, cardiorespiratory endurance, physical performance, and functional capacity. The telehealth interventions included the utilisation of mobile apps, phone consultations, websites, exercise videos and video conferencing platforms to support the achievement of health objectives. The outcomes of this systematic review showed significant improvement in muscular strength (five times sit-to-stand test, −0.56s, 95% confidence interval, CI −1.00 to −0.11; P=0.01), functional capacity (Barthel index, 5.01 points, 95% CI 0.24–9.79; P=0.04), health related quality of life (SMD 0.18; 95% CI 0.05–0.30; P=0.004); and reduce the incidence of fall by 23% (odds ratio, OR 0.77, 95% CI 0.64–0.93; P=0.008). The subgroup analysis of older adults with more complex comorbidities found that telehealth improved mobility and balance.

1.3.5 Telephysiotherapy is feasible for older people

Research on telerehabilitation following knee replacement surgery has demonstrated positive outcomes, supported by substantial evidence attesting to their effectiveness and cost-benefit advantages.[107] Despite this, there has been limited exploration of participant experiences and satisfaction with telehealth interventions.[108] Moffet and colleagues conducted a study comparing the satisfaction levels of cognitively normal community-dwelling older adults (mean age 65 +/- 8 years) who underwent telehealth physiotherapy rehabilitation through videoconferencing versus those who received regular home visits.[108] The synchronous telehealth intervention utilised a videoconference system for physiotherapy assessments and program development. Both cohorts displayed high satisfaction rates, surpassing 85%.

In 2020, Hassett and colleagues conducted a study testing asynchronous telehealth, which involved a tailored prescription of affordable digital devices, in addition to usual care for individuals with mobility limitations admitted to aged care and neurological rehabilitation.[109] The study aimed to determine if participants would engage in extra exercise using virtual reality video games and activity monitors both during their hospital stay and at home after discharge. The results indicated that asynchronous telehealth was cost saving and led to improved mobility levels at 3 weeks and 6 months after the baseline assessment, compared to the control group. Importantly, their approach was found to be feasible within the hospital health service delivery system and was well-received among older populations. The study demonstrated that asynchronous telehealth interventions could be effectively implemented across various care settings, including the post-hospital environment, with predominantly remote support.

Research involving telephysiotherapy to deliver exercise in aged care is needed as there is a notable gap in research exploring the feasibility and implementation of telehealth for delivering exercise interventions aimed at improving mobility and reducing falls among aged care service users.

Chapter Four of this thesis presents a systematic review and meta-analysis to explore the effectiveness of telehealth exercise for older individuals in aged care services experiencing frailty, mobility issues, or cognitive disabilities. Additionally, we examined the determinants influencing the implementation or adoption of telehealth exercise in this population.

1.4 The importance of co-design in implementation research

Co-design is a collaborative research approach that actively engages individuals, families, caregivers, and healthcare professionals, ensuring that research aligns with real-life experiences and challenges.[110] During the phases of design and planning, this cooperative methodology generates valuable insights that guide the development and implementation of interventions precisely tailored to the targeted demographic.[111] Additionally, co-design identifies practical solutions with seamless integration potential into existing healthcare systems, emphasising feasibility.[112] This interdisciplinary collaboration promotes innovative thinking to tackle the intricate challenges faced by older adults in aged care services.[113]

In aged care research, the co-design approach emerges as indispensable, facilitating the development of inclusive initiatives that are not only relevant but also possess effective translational potential.[114] Through the active engagement of older adults and stakeholders, co-design ensures that solutions are not only grounded in evidence but also deeply embedded in the lived experiences of the ageing population.[111] Ultimately, co-design contributes to enhanced outcomes and timely translation, thereby improving the quality of care and support provided to older adults in healthcare settings.[115]

Implementation research is a field of study focused on understanding the processes, strategies, and factors involved in translating evidence-based interventions, programs, or policies into real-world practice and policy.[116] It aims to bridge the gap between research evidence and effective implementation in diverse settings, such as healthcare, education, and public health. Implementation research investigates how interventions are adopted, adapted, implemented, and sustained within specific contexts, considering organisational, cultural, social, economic, and political factors. The ultimate goal of implementation research is to identify best practices, strategies, and approaches to optimize the delivery and effectiveness of interventions, ultimately improving outcomes and promoting positive changes in practice and policy.[117]

The connection between codesign and implementation research is rooted in their mutual focus on developing and executing effective interventions or programs within real-world contexts.[118] Codesign, involving stakeholders like end-users and policymakers, collaboratively designs solutions to address needs and preferences.[111] Implementation research, meanwhile, delves into processes and factors influencing the successful integration of evidence-based practices into routine use.[117] Stakeholder engagement is pivotal in both processes, with codesign identifying needs and preferences and implementation research navigating contextual factors and tailoring interventions accordingly. This user-centered approach ensures interventions are relevant and feasible, fostering iterative processes that refine interventions based on feedback and real-world experiences. Integrating codesign principles into implementation research enhances intervention effectiveness, promoting positive changes in healthcare and beyond, while emphasising the active role of stakeholders in driving meaningful change.[119]

A recent successful multifactorial falls prevention program implemented in care homes for older people in the United Kingdom underscores the significance of a co-design methodology involving collaboration with care home staff and residents. This approach resulted in an impressive 43% reduction in fall rates.[120] The research team adopted a co-design strategy, developing and testing a comprehensive program encompassing awareness raising, education, screening, decision support, physiotherapy-led exercise, and tailored implementation plans. Notably, the intervention proved to be cost-effective, and no adverse effects were observed. The authors attribute the success of their trial, in contrast to other trials, to the co-design approach. This approach facilitated the creation of an intervention that was contextually sensitive to care homes and cognisant of the unique challenges associated with falls prevention in this sector. This aligns with a growing body of evidence suggesting that interventions that take into account and adapt to the aged care context,[121] while also empowering aged care staff and organisations as collaborative partners in design and implementation,[122] are more likely to achieve successful outcomes.

Implementation frameworks have been found to offer a strategic and comprehensive approach to supporting co-design research in aged care, promoting a better understanding of the context, fostering stakeholder engagement, and ultimately increasing the likelihood of successful and sustainable implementation of interventions.[123] The Nonadoption, Abandonment, and Challenges to the Scale-Up, Spread, and Sustainability (NASSS) framework is an implementation framework developed to understand the complexities and challenges associated with the implementation and integration of healthcare technologies, innovations, or interventions within real-world settings.[124] The NASSS framework recognises that the implementation of telehealth is not solely a technical process but involves various interacting factors related to the technology itself, the individuals involved, the organisation, and the broader socio-political context. The NASSS framework has been used to guide the design and implementation of the TOP UP intervention. The framework is useful to address important barriers and factors across several domains, each representing a different aspect of the implementation process.

1. The condition: Aged care users have complex medical presentation often with multiple co-morbidities living with a complex care environment.[125] The NASSS framework helps researchers understand the challenges aged care services users need to navigate telehealth.

2. The technology: Telehealth interventions encompass technological applications, posing challenges aged care services users who may lack familiarity with or access to digitally enabled devices.[126] The NASSS framework serves as a valuable tool for the researchers, enabling the identification of technological barriers and challenges associated with the adoption of telehealth solutions within aged care.
3. The value proposition: Examining the perceived benefits and advantages of the technology for various stakeholders, including aged care services users, is crucial to support successful implementation.[127] Understanding how these beliefs might influence the adoption of the telehealth intervention is important.
4. The adopter system: Understanding the skill, behaviours and actions of both aged care and physiotherapy providers and aged care service users is essential to implmentatoin.[128] The NASSS framework helps in exploring factors such as resistance to change, attitudes toward technology, and the willingness of healthcare providers and patients to adopt and sustain telehealth practices.
5. Long-term organisational sustainability: Telehealth programs need to be sustainable in the long run to provide consistent care to the ageing population.[129] The NASSS framework allows researchers to assess the potential challenges that might arise in the scaling up and spread of telehealth initiatives, ensuring that these programs can be maintained over time considering the organisational policies resources and support mechanisms for implementing the technology.
6. The wider system: By focusing on nonadoption and abandonment, the NASSS framework encourages researchers to learn from failures and unsuccessful elements of the intervention and its implementation.[130] Understanding why certain telehealth initiatives were not adopted or were abandoned provides valuable insights that can inform future research and implementation strategies.

7. The adaption over time: The framework provides a wholistic view of the telehealth implementation process, considering not only technological aspects but also social, organisational, and policy-related factors.[124] This comprehensive approach is essential for designing effective and sustainable telehealth interventions in aged care settings.

Chapter Five presents the TOP UP protocol - a Hybrid Type 1 effectiveness and implementation randomised controlled trial of telehealth physiotherapy to improve mobility, reduce falls and enhance quality of life in older people receiving aged care services in community or residential settings. Chapter Five presents in-depth insights into its methodology and planned analysis. Furthermore, it intricately explores the utilization of the NASSS framework and the COM-B model, conceived by Susan Michie and her colleagues.[131] The COM-B model, encapsulating "Capability, Opportunity, Motivation, and Behaviour," furnishes a comprehensive and systematic approach to comprehending behaviour and instigating behavioural change. The amalgamation of the NASSS framework and the COM-B model serves as a valuable tool for the research team and collaborators, aiding in the anticipation of challenges in the trial's implementation. This amalgamation will facilitate the formulation of strategies crucial for ensuring the successful adoption, scale-up, spread, and sustainability of telehealth services in aged care, contingent upon the effectiveness of the TOP UP intervention.

Chapter Six details the co-design methodology employed in TOP UP trial. This chapter details the consultation process that engaged stakeholders in open communication, providing opportunities for shared insights to design the intervention and implementation processes. It also details the trial progress.

1.5 Exploring the qualitative dimensions of telephysiotherapy in aged care

Qualitative research is crucial for understanding the experiences, needs and preferences of older people, and for understanding the challenges of implementing complex interventions such as telehealth.[132] It helps inform the development, implementation and improvement of telehealth services to ensure that they are age-appropriate, accessible and deliver person-centred care.[133]

A 2023 Australian qualitative study investigated the barriers and enablers experienced by physiotherapists while delivering community and outpatient services during the COVID-19 pandemic and found several major themes that could be used to inform future physiotherapy telehealth exercise programs.[134] These themes included: 1. Adaptation of existing skills and integration of new skills; 2. Supportive senior leadership to help program transition; 3. Adoption of specific environmental factors such as stable internet connection and access to suitable equipment; 4. Identification of appropriate patients and future hybrid models of care; and 5. Development of telehealth educational resources consolidated knowledge. Key enablers were also identified, and these included: 1. Conducting telehealth sessions in a confidential and quiet place; 2. Training to develop telehealth skills; and 3. Telehealth allows for better transferability of high-quality home exercise.

In a recent mixed-methods study focusing on adults in primary care during the COVID-19 pandemic, the experiences of physiotherapists and patients utilising telehealth were comprehensively examined.[135] Physiotherapists generally reported moderate-to-high ratings for videoconferencing effectiveness and satisfaction. A substantial majority intended to persist with individual consultations (81%) and group classes (60%) via videoconferencing post-pandemic. Patient perceptions indicated predominantly positive views on technology ease

(94%, 91%), privacy/security satisfaction (98%, 95%), safety (99% both), and effectiveness (83%, 89%) for both individual consultations and group classes. However, a lower percentage of patients (47%) expressed likelihood to choose videoconferencing for future individual consultations compared to group classes (68%). The study highlighted technology as both a facilitator and a barrier in the telehealth context, providing valuable insights into the nuanced dynamics of telehealth adoption among physiotherapists and patients in primary care settings.

In a systematic review conducted in 2022, researchers examined the adoption of telehealth for providing medical care to older adults with Alzheimer's disease residing in the community. The study revealed that the uptake of telehealth services was primarily influenced by its perceived efficiency concerning accessibility, reduced travel, and cost-effectiveness.[136] The review identified key facilitators that healthcare providers should take into account when developing future telehealth services. These factors encompassed the incorporation of a support person, a preference for an initial face-to-face assessment, the availability of high-speed internet, access to video conference-enabled devices, and educational initiatives aimed at alleviating concerns related to security and privacy.

These research findings suggest that videoconferencing is a viable option for delivering physiotherapy care in the future. However, further exploration of the barriers and facilitators is essential to gain a deeper understanding of how to support the sustainability of telehealth physiotherapy in aged care settings.

Addressing telehealth research gaps through qualitative methods by understanding users' perspectives is instrumental in crafting targeted strategies for the seamless integration of telehealth services. The adoption of qualitative methodologies is required to develop more inclusive, accessible, and effective telehealth programs in aged care, thereby enhancing the overall quality of care provided to users of aged care services.

Chapter Seven presents the qualitative findings of the TOP UP trial, delving into the barriers and facilitators entailed in employing telephysiotherapy for exercise delivery in aged care settings. This chapter also places emphasis on the implementation of telehealth to bolster the potential for widespread adoption and sustainability within this context.

1.6 Aims of the thesis

Chapter One has revealed that aged care service users require support to access evidence-based exercise to improve mobility, reduce falls and enhance their quality of life. There is promising evidence that telephysiotherapy can be an effective way to deliver exercise to older people in acute settings but its effectiveness, feasibility and acceptability in aged care is uncertain.

The aim of this research thesis is to address the critical imperative of enhancing healthcare accessibility for older individuals engaged in aged care services. The primary focus of the thesis is to explore innovative approaches that amplify healthcare access, with a particular emphasis on minimising health outcome disparities between metropolitan and rural/remote areas and individuals with disabilities within the ageing population. The research seeks to contribute to the evidence base surrounding effective fall prevention programs, prioritising precise and efficient fall data collection, and the proficient implementation of exercises in aged care settings. A pivotal aspect of this thesis involves integrating the experiences of older individuals into collaborative research design, ensuring the development of interventions tailored to their specific needs. Additionally, the thesis aims to fill gaps in research related to telehealth physiotherapy, with a specific focus on delivering exercise programs to enhance mobility, reduce falls and enhance quality of life among users of aged care services.

While telephysiotherapy feasibility has shown promise for hospital and community-dwelling older individuals, there is a lack of research on its implementation in aged care settings. The study intends to employ mixed methods research, considering users' perspectives, to develop co-designed strategies for effective exercise and the successful integration of telephysiotherapy programs into aged care. By embracing qualitative methodologies, the research aims to contribute to the development of inclusive and accessible fall prevention and telephysiotherapy interventions, ultimately enhancing the quality of care provided to aged care service users and informing aged care reform initiatives. A more complete picture of the thesis's impact will be clearer when the effectiveness results are published mid year.

The specific objectives are as follows:

1. Undertake a study to investigate the level of agreement between incident reports and progress notes as data sources for falls in residential aged care facilities (Chapter 2).
2. Conduct an Intervention Component Analysis of fall prevention exercise in residential aged care and develop a theory of the effective implementation of exercise in this population (Chapter 3).
3. Perform a systematic review and meta-analysis to examine both the effectiveness and the determinants influencing the implementation of telehealth exercise interventions for older individuals in aged care services, specifically those who have frailty, mobility or cognitive disabilities (Chapter 4).

4. Outline a protocol for the TOP UP trial, a hybrid type 1 effectiveness-implementation randomised controlled trial focusing on telehealth physiotherapy. The TOP UP intervention aims to enhance mobility, decrease fall incidents, and elevate the overall quality of life for older individuals in aged care services within community or residential settings (Chapter 5).
5. Conduct a concise exploration of the existing literature on co-design principles to provide insights for the development and implementation of the TOP UP trial (Chapter 6).
6. Conduct a qualitative process evaluation for the TOP UP trial, elucidating the experiences of older adults, physiotherapists, and aged care staff participating in the trial. The primary objectives include assessing the acceptability of telehealth physiotherapy and acquiring a comprehensive understanding of the implementation strategies for telehealth programs aimed at enhancing physical functioning in the future (Chapter 7).

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CHAPTER TWO

Monitoring falls in residential aged care facilities: agreement between falls incident reports and progress notes

Preamble

Participants included in the following study were drawn from the TOP UP trial. Aa a result people with severe cognitive, physical and sensory impairments were not included in this falls agreement study and the findings are not generalisable to this high fall risk population.

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2.1 Statement of co-authorship

As co-authors of the manuscript Monitoring falls in residential aged care facilities: agreement between falls incident reports and progress notes", we confirm that Rik Dawson is the lead corresponding author and has made the primary co-contribution to this study in each of the following areas:

- Conception and design of the research
- Data Collection
- Data analysis and interpretation of findings
- Co-writing of the manuscript and critical appraisal of content with Annie Feng

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TITLE PAGE

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ABSTRACT

Objectives Accurate fall reporting is essential for assessing the effectiveness of fall prevention strategies. This study aimed to investigate the level of agreement between incident reports and resident progress notes as data sources for falls monitoring in residential aged care facilities.

Methods A retrospective observational study was conducted involving 46 older people from six residential aged care facilities who had consented to join the broader TOP UP trial. Fall events documented in the incident report system and resident progress notes over 12 months before randomisation were extracted by two independent reviewers using a standardised Excel form. Agreement between the two data collection methods was calculated using Cohen's kappa coefficient.

Results A total of 75 falls were recorded from 27 (59%) of the 46 participants who were 65% female, with an average age of 83 [SD 9] years. The incident reports captured 68 (90.7%) falls, while the progress notes captured 73 (97.3%) falls. Overall, there was a 75% agreement between falls recorded in progress notes and incident reports. Perfect agreement was identified for five facilities (n=35), while one facility had a lower agreement rate of 29% (n=11) which appeared to be attributable to staff shortages linked to the COVID-19 pandemic.

Conclusion There was substantial agreement between incident reports and progress records. These findings support the use of incident reports for identifying falls in research or to investigate the effectiveness of fall prevention strategies in residential aged care facilities.

1. INTRODUCTION

The prevalence and impact of falls on older populations are recognised as a global health issue. Internationally, 27 to 34% of community-dwelling older people fall each year.[1] In residential aged care facilities (RACFs), older adults' risk of falling is twice as high compared to those living in the community.[2] Falls in RACFs have been linked to increased morbidity, mortality and loss of functional independence.[2,3] In the United States alone, healthcare services for falls cost approximately $20 billion dollars annually.[3] In Australia, the annual cost of falls is $4.3 billion.[4]

Accurate fall data is essential to effectively assess the impact of fall prevention strategies. Falls can be collected retrospectively where the individual is expected to recall their fall history over a time period or prospectively via progress notes or incident forms.[5] In Australia, fall reporting was established in 2021 as mandatory through the National Aged Care Mandatory Quality Indicator program.[6] Incident reports are often used to describe fall rates at a facility level as they can be more quickly generated via online documentation systems compared to retrospective time-consuming manual audits of progress notes.[7] However, discrepancies in falls data collected through incident reports and progress notes were identified in hospitals highlighting the need to investigate the agreement between these reporting methods in RACFs.[8]

The study aimed 1) to assess the agreement between fall incident reports and progress notes in RACFs, and 2) explore potential variations in agreement across different aged care facilities. This study sought to determine whether incident reports alone can effectively serve as a reliable and efficient way of identifying falls in RACFs. Information about the incidence, characteristics and outcomes of falls over a 12-month period was also summarised.

2. METHODS

2.1 Study design

This was a quantitative study investigating the level of agreement between progress notes and incident reports to monitor falls data in RACFs. This study was conducted within the TOP UP trial, a randomised controlled trial that aims to examine the effectiveness of telehealth physiotherapy and exercise on mobility performance and falls for older people in aged care. (ANZCTN:12621000734864).

2.2 Setting

The first six RACFs that were recruited to the TOP UP trial were included in this study. One metropolitan site in Sydney in the Australian state of New South Wales – Facility A, and five rural sites across New South Wales (Facilities B to F).

2.3 Participants

All TOP UP study participants from the six RACFs were included in this study. Eligibility included older people (65 years and over), possessing sufficient neurological, cognitive, and sensory skills to participate in the program with individual consent or consent from their person responsible. Those with terminal or unstable illness, severe dementia as measured by a score of ten or less on the Modified Telephone Interview for Cognitive Status (TICS);[9] who had participated in a similar physiotherapy program in the last year, or who were unable to walk ten metres were excluded from the study.

2.4 Data collection

An Excel data extraction sheet was developed by the research team and pilot-tested on 10 participants. Authors (Author 1, Author 2) made modifications based on pilot results. One author (Author 2) remotely accessed online incident reports and progress notes to extract fall data (fall date, time, activity, equipment involved, injuries, hospital admission and follow-up) and participant characteristics (age, gender, cognitive status, comorbidities, and mobility). The information was collected from available data 12 months before randomisation to the TOP UP trial which commenced in September 2021. If data was unavailable for the preceding 12 months, the surveillance period was recorded in months. The time it took to collect data from the two incident methods was also collected. The audits used the World Health Organization's (2021) definition of a fall, which is an event resulting in a person inadvertently coming to rest on the ground or a lower level.[10] Injurious falls (skin tears, head injuries or fractures) were also recorded.

2.5 Data analysis

Participant and falls characteristics were presented using descriptive statistics (number and percentage where applicable). The sum of independent falls captured by either the incident reports or progress notes was calculated. The level of agreement between the two data collection methods for the total sample and for each of the six facilities was assessed by Cohen's kappa (k) coefficient, where values of 0 would indicate no agreement, 0.01–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement.[11] IBM SPSS Statistics version 28 (IBM Inc., USA) was used to analyse the data.

3. RESULTS

3.1 Participant characteristics

There were 46 participants recruited out of a total of 420 older people living at the 6 RACFs. Participants had a mean age of 83 (Standard deviation [SD] 9) years, 65% were female (n=30), 78% (n=36) had cognitive impairment of which 78%, (n=28) were mild, a mean of 6 comorbidities and 74% (n=34) required a walking frame for mobility. The time it took to review participants' progress notes was approximately one to two hours compared to 5 minutes for incident reports. Further participant characteristics are displayed in Table 1.

There were 75 falls recorded using either incident reports and/or progress notes with a mean falls' incidence of 1.84 falls per person-year. Twenty-seven participants (59%) fell. Most falls (39 out of 75, 52%, 3.89 falls per person-year) were recorded from Facility B. Falls were less common during the night (12 a.m.-5:59 a.m.) with the other times during the day showing similar levels. Falls most occurred in the resident's room (45%) or their bathroom (17%) and occurred when walking (37%) or transferring (36%). Forty-two (56%) of fall incidents were recorded by a registered nurse and 31 (41%) were recorded by a care staff assistant. Further fall characteristics are presented in Supplementary Table 1.

3.2 Level of agreement

The agreement level (kappa value) is displayed in Table 2. Sixty-six out of 75 (88%) falls were captured in both methods, with 7 falls found only in the progress notes and 2 falls found only in the incident reports. Incident reports identified 68 falls (90.7%) whilst progress notes recorded 73 falls (97.3%). The level of agreement between incident reports and progress notes across all facilities was classified as a *substantial agreement* (0.75; 95% CI 0.59 to 0.90). We found perfect agreement for all facilities (k = 1.00), except for Facility B, classified as a fair agreement (0.29; 95% CI -0.05 to 0.62)

4. DISCUSSION

Accurate reporting of falls is crucial in RACFs to identify risk, implement preventive measures and provide the safety of older people. The results of this study demonstrate a substantial agreement between monitoring falls data in RACFs from incident reports and progress notes. Both methods identified most falls. All facilities achieved perfect agreement except Facility B. Workforce shortages could explain this lack of agreement at Facility B. Given the labour-intensive nature of collecting falls data from progress notes, these findings suggest that incident reports can be used as an accurate and more efficient method of falls data monitoring for research purposes.

The incidence rates and fall characteristics of this study are consistent with previous research in RACFs.[12 1]3 A recent epidemiological study of falls in Australian RACFs found that 58% of residents experienced falls[10] and, in Germany, the mean fall incidence rate was 1.74 falls per person-year.[13] Both studies showed that the highest risk of falls was associated with residents unsupervised in their bedrooms. Future research that can lead to better monitoring of residents in their bedrooms is warranted to help inform future fall prevention strategies.

Facility B exhibited the highest rate of falls (n = 39) and exhibited only fair agreement between the 2 fall collection methods. The facility also had the highest incidence of repeat non-injurious fallers, with five residents experiencing three or more falls. Workforce challenges, including difficulties employing registered nurses due to rural location and sustained sick leave exacerbated by repeat COVID outbreaks, may have contributed to the discrepancies in falls data and limit the capacity to implement effective fall prevention strategies leading to their higher rates of falls.[14] Previous research suggests nursing staff tend to underreport non-injurious falls especially when they perceive to be time poor.[15] To address this issue, further research involving mixed methods is recommended to understand staff workload and attitudes toward fall reporting, enabling the development of targeted interventions for resident safety.[16]

While both methods of falls reporting are used in aged care, they offer differing levels of efficiency and convenience.[7] Progress notes are an important tool as they allow registered nurses to communicate the fall incident to all care staff and allow for immediate fall follow-up and care plan evaluation.[17] However, incident reports have shown to be much more time-efficient and offer a comprehensive review of falls than progress notes.[18]

5. CONCLUSION

This study highlights that there is substantial agreement between incident reports and progress notes with perfect agreement found in all facilities except for one site. Incident reports offer a convenient method for falls monitoring for clinical and research purposes in RACFs compared to progress notes. However, the discrepancies between the two fall reporting methods exist, highlighting the need to develop strategies to improve fall reporting practices and address barriers such as adequate staffing in the management of falls.

ETHICS APPROVAL Human Research Ethics Committee at The Sydney Local Health District, Concord, Australia (approval number approval CH62/6/2021-009)

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CONFLICT OF INTEREST STATEMENT None declared.

DATA AVAILABILITY STATEMENT Data are available on reasonable request. Proposals for data should be directed to the corresponding author (rik.dawson@sydney.edu.au).

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Impact statement

This study demonstrated substantial agreement between falls in residential aged care recorded via incident reports and progress notes. It appears that incident reports can be used as a convenient but valid method for monitoring falls data, where staffing is sufficient to allow for the effective use of incident reporting systems.

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Table 1 Participant characteristics

	Total (n = 46)	Fallers (n = 27)	Non-fallers (n = 19)
Sex female, n (%)	30 (65.2)	17 (63.0)	13 (68.4)
Age, years, mean (SD); range	83.3 (9.2); 63-101	82.7 (9.8); 63-96	84.2 (8.4); 68-101
Age category in year			
60-69	7 (15.2)	5 (18.5)	2 (10.5)
70-79	7 (15.2)	3 (11.1)	4 (21.1)
80-89	20 (43.5)	12 (44.4)	8 (42.1)
90-99	11 (23.9)	7 (25.9)	4 (21.1)
≥100	1 (2.2)	0 (0.0)	1 (5.3)
Cognitive impairment, n (%)			
Present	36 (78.3)	22 (81.5)	14 (73.7)
Mild	28 (77.8)	15 (68.2)	13 (92.9)
Moderate	8 (22.2)	7 (31.8)	1 (7.1)
Number of comorbidities (0-18), mean (SD); range	6.0 (2.1); 2-11	6.3 (2.4); 3-11	5.8 (1.9); 2-10
Indoor mobility, n (%)			
No aid	9 (19.6)	4 (14.8)	5 (26.3)
Walking stick	3 (6.5)	2 (7.4)	1 (5.3)
Frame	34 (73.9)	21 (77.8)	13 (68.4)
Wheelchair	0 (0.0)	0 (0.0)	0 (0.0)
Outdoor mobility, n (%)			
No aid	8 (17.4)	4 (14.8)	4 (21.1)
Walking stick	3 (6.5)	2 (7.4)	1 (5.3)
Frame	31 (67.4)	18 (66.7)	13 (68.4)
Wheelchair	4 (8.7)	3 (11.1)	1 (5.3)
Facility, n (%)			
A	7 (15.2)	3 (11.1)	4 (21.1)
B	11 (23.9)	8 (29.6)	3 (15.8)
C	9 (19.6)	3 (11.1)	6 (31.6)
D	7 (15.2)	4 (14.8)	3 (15.8)
E	8 (17.4)	6 (22.2)	2 (10.5)
F	4 (8.7)	3 (11.1)	1 (5.3)

Table 2 Agreement between falls reported in progress notes and incident reports

TOTAL SAMPLE					
		Reported in progress notes			**Kappa value (95% CI)**
		Yes	No	Total	
Reported in incident reports	Yes	66	2	68	0.75*** (0.59 to 0.90)
	No	7	19	26	
	Total	73	21	94	
FACILITY B					
		Reported in progress notes			**Kappa value**
		Yes	No	Total	
Reported in incident reports	Yes	30	2	32	0.29* (-0.05 to 0.62)
	No	7	3	10	
	Total	37	5	42	

*: p <0.05; **: p <0.01; ***: p <0.001

Supplementary Table 1 Fall characteristics

Total falls, n = 75	n (%)
Surveillance period, months, mean (SD); range	10.6 (2.8); 1.1-12
Facility, number of falls, n (%); falls per person-years	
A (136 beds, 7 participants)	4 (5.3); 0.61
B (76 beds, 11 participants)	39 (52.0); 3.89
C (40 beds, 9 participants)	7 (9.3); 0.95
D (60 beds, 7 participants	6 (8.0); 0.86
E (96 beds, 8 participants	14 (18.7); 2.12
F (12 beds, 4 participants	5 (6.7), 1.60
TOTAL falls, falls per person-years	75, 1.84
Incident time of day (6 h)	
12 a.m.-5:59 a.m.	8 (10.7)
6 a.m.-11:59 a.m.	28 (37.3)
12 p.m.-5:59 p.m.	20 (26.7)
6 p.m.-11:59 p.m.	19 (25.3)
Incident location	
Resident's room	34 (45.3)
Bathroom/toilet	13 (17.3)
Shared indoor area	8 (10.7)
Dining room	3 (4.0)
Garden/outdoor area	7 (9.3)
Outside facility	4 (5.3)
Other	6 (8.0)
Activity leading to fall	
Walking	28 (37.3)
Transfers	27 (36.0)
Other	20 (26.7)
Author of documentation	
Registered nurse	42 (56.0)
Care staff	31 (41.3)
Falls outcome	
Injurious falls	32 (42.7)
Skin tear	21 (65.6)
Head injury	3 (9.4)
Fracture	1 (3.1)
Hospital admission	12 (37.5)
Post-fall review	
Physiotherapist	54 (72.0)
General practitioner	54 (72.0)

CHAPTER THREE

Features of effective fall prevention exercise in residential aged care:

An intervention component analysis

Chapter Three is under review as:

Dawson R, Suen J, Sherrington C, Kwok W, Pinheiro M, Haynes A, McLennan C, Sutcliffe K, Kneale D, Dwyer. Features of effective fall prevention exercise in residential aged care: An intervention component analysis. *British Journal of Sports Medicine.*

3.1 Statement of co-authorship

As co-authors of the manuscript "Features of effective fall prevention exercise in residential aged care: An intervention component analysis", we confirm that Rik Dawson is the lead corresponding author and has made the primary contribution to this study in each of the following areas:

- Conception and design of the research
- Data Collection
- Data analysis and interpretation of findings
- Writing of the manuscript and critical appraisal of content

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Figures: 2

Summary Box

What is already known on this topic
• Exercise reduces the risk of falls for older people in the community with tailored balance and functional exercise having the strongest fall prevention effect. • The evidence concerning effects of fall prevention exercise in residential aged care (RAC) is less clear so there is limited guidance for clinicians working in RAC.
What this study adds
• This Intervention Component Analysis (ICA) used a mixed method approach to develop a theory of potential features of effective fall prevention exercise in RAC that can be explored and validated in future analyses. This theory indicates that: - Exercise interventions for fall prevention in RAC should include balance and strength exercise delivered at a moderate intensity and tailored to the individual. - Exercise programs in RAC are more likely to be successful if structured, supervised and resourced to deliver an adequate dose.
How this study might affect research, practice or policy
• Findings from this ICA will: - assist implementation of fall prevention programs in RAC; - guide a Qualitative Comparative Analysis and subgroup meta-analysis in RAC; - inform the design of interventions to be tested in future large clinical trials in RAC.

ABSTRACT

Introduction The effect of fall prevention exercise in residential aged care (RAC) is uncertain. This paper reports on an Intervention Component Analysis (ICA) of randomised controlled trials (RCTs), from an update of a Cochrane review, to develop a theory of features of successful fall prevention exercise in (RAC).

Methods Trial characteristics were extracted from RCTs testing exercise interventions in RAC identified from an update of a Cochrane review to December 2022 (n=32). Eligible trials included RCTs or cluster RCTs in RAC, focusing on participants aged 65 or older, assessing falls outcomes with stand-alone exercise interventions. ICA was conducted on trials with >30 participants per treatment arm compared to control (n=17). Two authors coded trialists' perceptions on intervention features that may have contributed to the observed effect on falls. Inductive thematic analysis was used to identify the key differences between the trials which might account for positive and negative outcomes.

Results 32 RCTs involving 3,960 residents including people with cognitive (57%) and mobility (41%) impairments were included. ICA on the 17 eligible RCTs informed the development of a theory that: (1) effective fall prevention exercise delivers *the right exercise* by targeting balance and strength, tailored to the individual and delivered simply at a moderate intensity; and (2) successful implementation needs to be *sufficiently resourced* to deliver structured and supervised exercise at an adequate dose.

Conclusions ICA suggests delivering the right exercise sufficiently resourced is vital for RAC fall prevention. This preliminary clinical guidance needs confirmation in larger trials.

INTRODUCTION

Falls are prevalent in residential aged care (RAC), affecting half of residents annually, diminishing independence, increasing care burden, and imposing economic costs (1, 2). Implementing effective interventions holds potential to benefit older individuals and alleviate healthcare burden (3).

The 2019 Cochrane Review in community-dwelling older adults reported exercise prevents falls, particularly with balance and functional exercises, reducing rates by 24% (RaR 0.76, 95% CI 0.70 to 0.81; 7920 participants, 39 studies; I^2=29%, high-certainty evidence) (4). Programs combining balance, functional, and resistance exercises reduced the rate of falls by 34% (RaR 0.66, 95% CI 0.50 to 0.88; 1374 participants, 11 studies; I^2=65%, moderate-certainty evidence). Conversely, the 2018 Cochrane Review for residents in aged care reported uncertain effects of exercise on falls (RaR = 0.93, 95% CI 0.72 to 1.20; 2002 participants, 10 studies; I^2=76%, very low-quality evidence) (5). Sub-group analyses couldn't explain high outcome heterogeneity, challenging clinicians in selecting effective exercise programs (6).

In this study, we conducted an Intervention Component Analysis (ICA), a method utilising inductive qualitative analysis to collate trialists' reflections on the factors influencing the success or failure of an intervention. ICA becomes necessary when a systematic review and meta-analysis cannot deliver certain results or adequately explain high heterogeneity. ICA provides a deeper understanding how interventions work, why they work and allows researchers to explore the complexities of intervention in real world settings (7).

Our objective is to answer three research questions. 1) What are the characteristics of trials included in the updated Cochrane Review (5)? 2) Using ICA, what are the essential intervention and implementation features that are indicated in these trials as necessary for successful fall prevention exercise in RAC? and 3) What explanatory theory does the information in the first two questions suggest for supporting knowledge translation of fall prevention programs and informing future research in RAC (7)?

METHODS

Our systematic review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (8). The ICA was developed according to the methodology detailed in an existing published theory (7).

Selection of studies

Eligibility criteria and trial searches were consistent with Cameron and colleagues' 2018 Cochrane Review 'Interventions for preventing falls in older people in care facilities and hospitals' (5). New trials published from 2017 to December 2022 were identified by searching CENTRAL, MEDLINE, Embase and CINAHL databases using this Cochrane Review's search strategies (5). Conference abstracts and trial records were not systematically searched or included. Trials eligible for inclusion were all randomised controlled trials (RCTs) and cluster RCTs which enrolled participants living in RAC with a mean age of 65 years or over; reporting either the number of falls (rate of falls) or risk of falling (number of people falling); and tested exercise as a single intervention compared to usual care or a control exercise program. Only trials that had 30 or more participants in each treatment arm were included in the ICA to decrease the risk of small sample bias (9). This ICA included trials with fall outcomes that were either positive (reduced falls), neutral (no effect) or negative (increased falls).

Data extraction

Trial features

Two aged care physiotherapists (RD, WK) extracted the trial and participant characteristics (trial design, sample size, age, gender, level of cognitive and mobility impairment), exercise features (type, duration, dose, delivery mode, supervision level, tailoring, intensity) and fall outcomes based on the trial's final endpoint from new trials or as reported in the Cochrane Review (5). Trial adherence was classified as good if the participant exercise session attendance rate exceeded 50% and/or 75% or more of the participants attended 50% or more of the exercise sessions. The exercise intervention features were classified based on an exercise taxonomy developed by the Prevention of Falls Network Europe (ProFANE) group (10), standardised exercise ratings such as the Borg Rating of Perceived Exertion (RPE) Scale (11) and trialist's self-classification. Disagreements were resolved through discussion and involvement of a third author as required (SD, JS). The fall outcome data were presented as a rate ratio or risk ratio with a 95% confidence interval (95% CI) and coded as positive (fall risk or rate ratio < 0.75), neutral (fall risk or rate ratio 0.75 to 1.25), or negative (fall risk or rate ratio < 1.25). These cut-points were informed by the GRADE group's general guidance for consideration of "appreciable benefit or harm" (12). Data were stored and analysed using Excel.

Trial quality

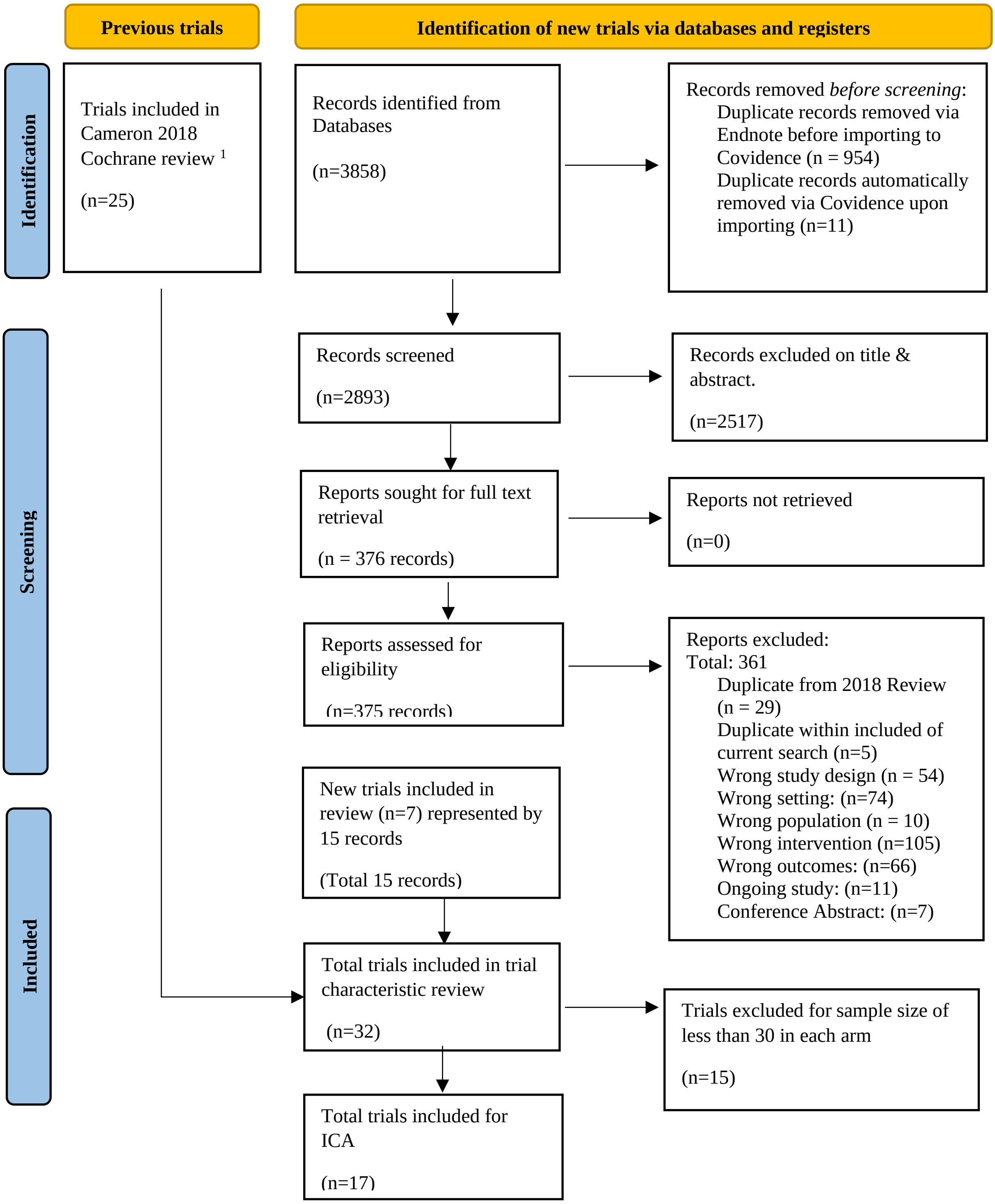
Two trained independent physiotherapists (RD, WK) evaluated study quality using the 11 items of the Physiotherapy evidence Database (PEDro) scale*:* inclusion criteria and source, random allocation, concealed allocation, similarity at baseline, subject blinding, therapist blinding, assessor blinding, completeness of follow-up, intention-to-treat analysis, between-group statistical comparisons, and point measures and variability (13). Any disagreements were resolved through discussion. The first item refers to external validity and does not contribute to the score, thus the final score ranges from 0 to 10. Scores of 0-4 are considered ‘poor’, 4-5 are considered ‘fair’, 6-8 are considered ‘good’ and 9-10 are considered ‘excellent’ but are not possible in trials of exercise as participant and therapist blinding cannot be achieved (14).

Intervention Component Analysis

ICA was conducted over four stages:

1. Authors (RD, WK) described the trial features, quality and classified fall outcomes in Excel (12).
2. Authors (RD and JS) coded trialists' reflections on effective and ineffective features in the discussion and conclusion sections of eligible publications, including any additional trial-related documents (e.g., protocols, process evaluations) identified through systematic search, pearling, and hand searching. A selection of publications was coded independently in duplicate, the remainder were extracted by RD and checked by JS with disagreements resolved through discussion. Codes were stored in NVivo 12 (15).
3. RD conducted an inductive thematic analysis in NVivo on included trials, grouping codes to develop themes and subthemes on successful intervention features and implementation (16). Groupings were reviewed by JS and SD to ensure thematic agreement. Both JS and SD, experienced qualitative and falls researchers respectively, offered critical perspectives to the thematic analysis as non-exercise professionals.
4. RD reviewed the themes in combination with the trial outcomes and the intervention features to develop a theory regarding the types of intervention features and implementation strategies most likely to be effective in preventing falls in RAC. All authors were involved with developing the final theory.

Figure 1: PRISMA trial selection



Equity, diversity and inclusion statement

The author group consists of junior, mid- career and senior researchers from different countries and disciplines. Our study population included both male and female older adults from different socioeconomic and geographical backgrounds.

RESULTS

Trial and participant characteristics from an updated systematic review

Thirty-two trials across 16 countries involving 3,960 participants with 35 exercise intervention arms. Many trials were small, with a median number of 71 trial participants ranging from 16 (17) to 682 participants (18). Participant ages ranged from 68 (19) to 92 years (20, 21), with a median of 82 years; 74% were female. Eighteen (57%) trials included people with cognitive impairment and 13 (41%) trials those with mobility disabilities. Trial length varied from 4 (22) to 104 weeks (23), with a median of 12 weeks (IQR 12–26). Total intervention hours ranged from 1.5 (24) to 112 hours (25), with a median trial dose of 22 hours (IQR 14–36) or 1.8 hours per week, comprising median 3 sessions per week (IQR 2-3) with a median session duration of 33 minutes (IQR 25-48). Sixteen (52%) trials met good exercise adherence criteria. Ten (32%) trials reported the occurrence of adverse events, including two falls during exercise (26, 27). Most trials compared an exercise intervention with usual care, defined as seated low-intensity range of movement exercise programs, self-directed or social programs. (Supplementary Material A)

Intervention components

The most common primary intervention component was gait, balance and functional training combined with strength training in 18 (51%) intervention arms. The most common single intervention was gait, balance and functional training in five (14%) arms. Exercise

Table 1: Development of intervention and implementation themes in the ICA

Subtheme	Trials (n)	Examples of informal evidence	Correspondence between themes and trial outcome[a]
THEME 1: THE RIGHT EXERCISE			
1. Target balance and strength (22 codes)	11	"Multicomponent exercise program focusing primarily on strength and balance training found to be the most effective strategy in the management of falls in the elderly." (Dhargave et al, 2020, p 57)	6/8 trials with positive findings tested the effect of exercise interventions that combined progressive standing strength and balance. 2/9 trials with ineffective or negative findings involved balance and strength exercise.
2. Tailored to the individual (38 codes)	11	"This pattern (fluctuating adherence) of commitment to exercise interventions, suggests that exercise programs may need to be specially tailored for individual seniors' changing needs, interests, physical, and cognitive capabilities." (Nowalk, 2001, p 864)	7/8 positive trials tailored their exercise program to the individual and progressed it accordingly. 4/9 trials with neutral or negative findings did not tailor the program.
3. Moderate intensity (21 codes)	11	"6 months of individualised and progressive multicomponent exercise at moderate intensity composed of strength, balance and walking recommendations in long term nursing home residents was effective to prevent falls." (Arrieta, 2019, p 1149)	6/8 trials with positive findings tested exercise interventions at a moderate intensity. The other trials tested low intensity exercise. 0/9 trials with neutral or negative findings tested moderate intensity exercise.
THEME 2: SUPPORTING EXERCISE ENGAGEMENT			
1. Sufficiently resourced (17 codes)	8	"The study identified an overall reduction in the risk of falls in individuals to underwent structured exercise program, whereas we identified that those who were not provided with any of the supervised training had an increase in risk of falls after the study period". (Dhargave, 2020, p 57) "A dose of 30 or more hours of this type of exercise over a 25-week time frame may therefore produce outcomes similar to those with the higher doses previously recommended" (Hewitt, 2018, p 7)	4/8 positive trials sufficiently resourced via funding the trials to deliver structured and supervised balance and strength exercise interventions > 30 hours compared to 2/9 trials with neutral to negative findings.
2. Group exercise to allow for socialisation (6 codes)	3	"Elderly people can reduce their risk of falling by participating in moderate intensity group-exercise programs. Another reason for preferring moderate intensity exercise is that a key element in sustaining exercise participation of older people is the opportunity to socialize." (Faber, 2006, p 893)	5/8 trials delivered their exercise interventions in a group that supported participant socialisation. 5/9 trials with neutral or negative findings also delivered group exercise.
3. Staff and resident education (7 codes)	4	"Educating staff and residents on the potential benefits of progressive resistance training (PRT) and balance training may have resulted in higher participation rates." (Hewitt, 2018, p 7)	3/8 trials with positive findings employed educational strategies to increase adherence – one trial highlighted staff education, one resident education and one both. 1/9 trials with neutral or negative findings provided staff and resident educational strategies.

[a] trial was included in the thematic table if they included 100% of the intervention component

Table 2: Presence of themes and subthemes in falls prevention exercise trials (effectiveness synthesis)

First author, year	Target strength & balance	Exercise tailored to individual	Mode-rate intensity exercise	SUPP-ORT RIGHT EXER-CISE	Suffi-ciently resour-ced	Group exercise allowing socialis-ation	Staff and resident educa-tion.	SUPPORT EXER-CISE ENGAGE-MENT	Falls outcome (95% CI)
TRIAL INTERVENTIONS THAT REDUCED FALLS[b]									
Arrieta, 2019	Yes	Yes	Yes	Yes	Yes	Yes	No	Partial	0.45[c] (0.29, 0.69)
Dhargrave 2020	Yes	Yes	Yes	Yes	Partial	No	Yes	Partial	0.72[c] (0.44, 1.17)
Fu 2015	No	Yes	No	Partial	Partial	NR	No	No	0.35[c] [0.19, 0.63]
Hewitt 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0.45[c] (0.17,0.74)
Irez 2011	Yes	Yes	Yes	Yes	Yes	Yes	No	Partial	0.28[c] [0.15, 0.54]
Jahanpeyma 2020	Yes	Yes	Yes	Yes	Partial	Yes	Yes	Yes	0.39[c] (0.23,0.66)
Kovacs 2013	Yes	Yes	Yes	Yes	Yes	Yes	No	Partial	0.77[c] (0.37,1.62)
Yokoi 2015	No	No	No	No	Partial	No	No	No	0.3[d] (0.07,1.28)
TRIAL INTERVENTIONS THAT HAD NO EFFECT ON FALLS[b]									
Buckinx 2014	No	No	No	NO	NO	No	No	No	0.96[c] (0.58,1.60)
Faber 2006	Partial	Yes	No	Partial	Yes	Yes	No	Partial	1.13[c] (0.95,1.35)
Kerse 2008	No	Yes	No	Partial	Partial	No	No	No	1.11[c] (0.84.1.45)
Nowalk 2001	Partial	Partial	No	Partial	Partial	Yes	Yes	Partial	NR; No sig. difference
Rosendahl 2008	Yes	Yes	No	Partial	Partial	Yes	No	Partial	0.82[c] (0.44,1.55)
Sakamoto 2006	No	No	No	No	Partial	No	No	No	0.82[c] (0.65,1.04)
Toots 2019	Yes	Yes	No	Partial	Yes	Yes	No	Partial	0.9[c] (0.5,1.61)
TRIAL INTERVENTIONS THAT INCREASED FALLS[b]									
MULROW, 1994	Partial	Yes	No	Partial	Partial	No	No	No	1.32[c] (0.95,1.85)
SITJA RABERT 2015	No	No	No	No	Partial	Yes	No	Partial	1.28[d] (0.71,2.31)

a We used the definition based on 2 quotes for sufficient resourcing for trials that allocated funding to deliver structured and supervised exercise at a dose of 30+ hours, excludes trials that incorporated exercise into usual care.
b We sought to identify whether the trials that reported positive fall outcomes (fall risk or rate ratio <0.8) were qualitatively different to those with neutral (fall risk or rate ratio 0.8 to 1.2) or negative outcomes (fall risk or rate ratio < 1.2).
c Fall rate ratio
d Fall risk ratio

interventions in 20 (63%) trials were tailored to the individual. Fifteen (47%) trials delivered exercise at moderate intensity, 14 (44%) at low intensity and three (9%) at high intensity. Thirteen (41%) trials were led by physiotherapists, three (9%) by other health professionals, and 14 (44%) trials were led by trained non-exercise professionals; five trials (16%) did not report who led the intervention. There was a mix of supervised and unsupervised individual and group exercise, with supervised groups being the most common in 19 trials (59%) with a median of 5 participants per group (IQR 5-8). (Supplementary Material B)

Quality assessment

The PEDro study quality summary is displayed in supplementary material C. The median PEDro quality score for the trials included in the ICA was 'good' (6/10).

Intervention Component Analysis

The ICA included 17 trials involving 3,293 participants with a median age of 82 years (ranging from 75 to 86 years); 73% female participants. Ten trials (59%) included people with cognitive impairment and 7 trials (41%) included people with mobility disability (table 1). The participant characteristics of the ICA trials were reflective of the 32 trials included in the updated Cochrane Review. ICA identified two major themes related to exercise features and implementation, each with three subthemes (table 2). ICA Codebook outlining the coding framework is displayed in Supplementary Material D. The correspondence between the themes and the trial's effectiveness synthesis are summarised in table 3. The ICA also identified some study design features that could be associated with intervention effects.

The right exercise

The most common theme supported by trialist's commentary focused on providing the *right exercise* to reduce falls. The results of our thematic analysis suggesting that the right exercise is a combination of exercise that targets balance and strength, tailored to the individual's physical and cognitive comorbidities and delivers moderate-intensity exercise (table 2). Ten trials targeted progressive standing balance and strength exercise (27-36), twelve studies delivered tailored exercise prescription (18, 27-35, 37, 38) and six studies delivered moderate intensity exercise sub-theme (27-32) (table 2). Six of eight effective trials (27-32) supported the right exercise theme whilst zero of nine neutral or negative trials did not (table 3).

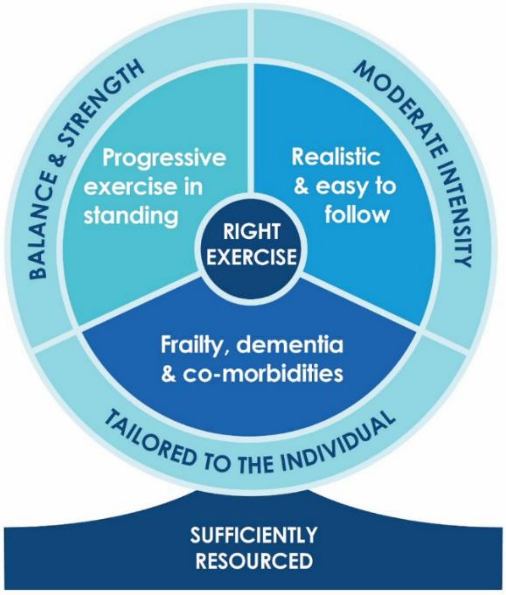
Supporting Exercise Engagement

The second theme centered on *supporting exercise engagement*. However, there was less trialist commentary on this theme (table 2) and only two of eight effective trials included all the subthemes (27, 31). Only the first subtheme had sufficient evidence to progress to the ICA theory (table 3). Four of eight effective trials provided sufficient resourcing as defined as trials that delivered structured and supervised exercise at a dose greater than 30 hours (27, 28, 30, 32) compared to two of nine neutral or negative trials (34, 38). Group exercise that offers socialisation opportunities was offered in five of eight effective trials (27, 28, 30-32) but was also offered in four of nine neutral or ineffective trials (33, 34, 36, 38). Fall prevention education was a feature in three of eight effective trials (27, 29, 31) and one of nine neutral or negative trials (23). The effectiveness synthesis demonstrated that there was insufficient evidence to involve the group exercise and fall education sub-themes in the final ICA theory displayed in Figure 2.

Trial methodological design features

Two features emerged as themes relating to trial design and their impact on effective fall prevention trials. Seven authors commented that some trials are too small to detect significant changes in falls (23, 28, 30, 33, 34, 36, 38) Five authors commented that trial designs that involved an active control which diluted the fall effect (30-33, 36).

Figure 2: ICA theory of effective fall prevention exercise in residential aged care



DISCUSSION

ICA is a valuable tool for researchers, clinicians and policy makers, enabling the optimisation of essential intervention components and their implementation strategies. Through ICA methodology, trialist perspectives are plotted against trial outcomes, culminating in the development a theory of effectiveness. This ICA theory indicates that effective fall prevention programs within RAC center upon the delivery of the *right exercise* when *sufficiently resourced.* However, larger trials are required to expand the evidence base for effective fall prevention exercise programs in RAC.

Hill and colleagues reported that there is considerable variability in the types of exercise programs investigated in the community to reduce falls in older people (39). However, Sherrington and colleagues' sub-group analysis revealed that balance and functional exercises with or without resistance exercises had the greatest fall prevention effects in the community (4). Cameron and colleagues 2018 sub-group analysis for combination exercises in RAC including balance and strength exercise (30, 32, 33, 35, 38) or physical activity plus strength (17) did not find a significant reduction in falls (RaR 0.94, 95% CI 0.6 to 1.47), however there were only six trials in this subgroup analysis (5). Our ICA was based on an update of Cameron et al.'s Cochrane Review, which reported that balance and strength exercises were the most commonly prescribed interventions in effective trials (88%) compared to those trials with neutral or negative fall outcomes (33%). This finding is also supported by Becker and colleagues' multifactorial trial in RAC. They reported that progressive standing balance and strength exercises reduced rate of falls by 45% (40).

Our review of trial characteristics revealed that 20 of 32 trials were tailored to the individual. In the ICA 88% of positive trials tailored the exercise programs compared to 56% of trials with neutral or negative fall outcomes. Several trialists stated that exercise needs to be tailored throughout the program to cater for participants' changing physical and cognitive capabilities to learn the program and to maintain exercise adherence which is a key factor in reducing falls (33, 35, 38, 41).

Six effective trials delivered exercise at a moderate intensity (27-32) compared to two effective trials that delivered exercise at a low intensity (37, 41). All the trials with neutral or negative fall outcomes tested low or high intensity models. Kerse et al. revealed that low-intensity exercise delivered in small doses throughout the day by care workers as part of the resident's usual activities was ineffective (18). Faber et al. reported that high-intensity individual training was not effective or sustainable for long-term exercise due to the resident's high level of comorbidities (38). Nowalk, Yokoi and Sakamoto and colleagues all commented that successful exercise interventions should be delivered in a way that is simple and easy to learn to maximise exercise compliance in RAC and increase exercise intensity over time (23, 41, 42).

There were fewer comments from trialist's regarding ideal implementation strategies. However, ICA indicated that trials need to sufficiently resourced to support exercise structure, supervision and adequate dose. The trial characteristic analysis revealed that the median weekly dose for all 32 trials identified in the updated Cochrane search was 1.8 hours/week. This is considerably lower than Sherrington and colleagues' meta-regression which suggests that effective fall prevention exercise in the community should include more than 3 hours/week of exercise (43). Kerse et al concluded that effective fall prevention programs need to be funded to deliver a 'more intensive intervention' and more supervision (18). Kovacs et al. stated that funding sufficient physiotherapy resources is required to lead effective fall prevention exercise (32). More research is required to better understand the implementation of an ideal fall prevention exercise program in RAC. This could include investigating different engagement strategies, exercise delivery modes, trial length and dose, as well as who should prescribe and supervise the exercise programs in RAC.

This ICA indicates that future RCTs fall prevention exercise in RAC need to expand their sample size and enhance study quality by minimising bias in their design and improve reporting. For trials evaluating multifaceted interventions such as exercise, a total PEDro score of 8 is optimal compared to the median trial score of 6 (44). In the 32 trials identified in the

Cochrane Review update, fifteen trials enrolled fewer than 60 participants, requiring a larger sample size to detect differences in fall rates (9). Additionally, many trials did not meet the standards of the Consolidated Standards of Reporting Trials statement (CONSORT) (45). The reporting of almost two-thirds of trials did not describe allocation concealment, with some not clearly describing their control group. This poor reporting made coding exercise features difficult and reduces the generalisability of the ICA.

Hewitt and colleagues' Sunbeam trial is an example of a fall prevention trial that delivered *the right exercise* with an optimal PEDro score of 8 (27). They were able to achieve a 55% reduction in fall rates and improve mobility outcomes by delivering progressive standing balance and strength moderate intensity exercise programs, tailored and progressed by a physiotherapist. This trial also implemented *exercise engagement supports* as detailed in our thematic analysis (table 3). It resourced a mean exercise dose of 36 hours and used sophisticated exercise equipment that was simple for the residents to use. High levels of program adherence were supported by staff and resident education and supervised group exercise training that allowed for socialisation.

Research implications

The ICA theory will inform a Qualitative Comparative Analysis (QCA), which statistically examines the consistency of ICA theory and identifies essential conditions that contribute to effective falls prevention programs (7). Recent ICA and QCA on multifactorial fall prevention interventions highlight the importance of engaging aged care staff and managers in implementing tailored exercise strategies for each resident (46).

Future trials should adhere to recognized trial reporting guidelines such as the CONSORT statement (45), Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) statement (47), Template for Intervention Description and Replication (TIDieR) checklist (48), and Consensus on Exercise Reporting (CERT) guidelines (49) to enhance reporting.

Strengths and Limitations

This updated systematic review, incorporating ICA, ensures rigorous methodology and confidence in outcomes. Nonetheless, limitations include exclusion of conference abstracts, trial records, and studies on exercise within multifactorial interventions. Some trials excluded older adults with high cognitive and mobility impairments, potentially limiting result generalisability. Additionally, exercise descriptions were often broad, lacking specificity like sensorimotor training. Incomplete reporting may have compromised ICA quality, hindering a more comprehensive explanatory theory.

CONCLUSION

Examining trial characteristics in the updated Cochrane Review on fall prevention exercise in RAC reveals intervention heterogeneity. This ICA enriches trial descriptors, aiding theory development and practical applications. Trialists suggest sufficiently resourced, tailored balance and strength exercises delivered at a moderate intensity may prevent falls. Future larger trials should scrutinise this ICA theory, delivery mode, dose, different implementation and engagement strategies, and adhere to reporting guidelines.

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Supplementary material A: Characteristics of the included trials

Clinically and statistically significant reduction in falls (point estimate is less than 0.80 and the confidence interval does not cross 1)															
Author, year, Trial Design	**Cont[1]**	**RACF**	**N, Rand**	**Trial Location**	**Age, mean**	**Gender % women**	**Mean number co-morb.**	**Cognitive Impair. at baseline**	**Mobility criteria at enrollment**	**Adhe-rence[2]**	**Severe Adverse events[3]**	**Summary of exercise intervention (frequency, session length, planned trial dose)**	**Falls rate ratio**	**Falls risk ratio**	**Other effect data**
Arrieta, 2019, RCT, 2 arms	Y	HC	112	Spain	84.9	71	2	Mild	Ambulant without staff assistance	Yes	Nil	26/52 tailored, progressive strength, gait, balance and functional group program, EP led, moderate intensity. (2/wk, 60min/session, 52hrs)	26/52 0.45 (0.29, 0.69)	26/52 0.86 (0.52, 1.41)	NR
Brett, 2021, RCT, 3 arms	Y	HC	60	Australia	85	65	9	Mild, moderate or severe	All level of mobility	Yes	Nil	12/52 tailored, progressive group strength, balance, endurance and flexibility program., PT led, moderate intensity. Intervention A: (1/wk, 45 min/session, 9 hrs.) Intervention B: (3/wk, 15min/session, 9hrs)	12/52 0.23 (0.14, 0.37	12/52 0.48 (0.27, 0.87)	NR
Fu, 2015, RCT, 2 arms	N	HC	60	China	82.3	65	NR	NR	Ambulant with staff assistance	Yes	NR	6/52 progressive Wii Fit balance program, PT led, intensity NR. (3/wk, 60min/session, 18 hrs)	52/52 0.35 [0.19, 0.63]	NR	NR
Hewitt, 2018, Cluster RCT, 2 arms	Y	HC	221	Australia	86	65	3	Mild to moderate	Stand with staff assistance	Yes in 6/12 active section No in main-tenance	Nil	25/52 tailored and progressive strength using HUR Health and Fitness equipment, functional and balance group program, PT led, moderate intensity. (2/wk, 60min/session,50 hrs); followed by 6/12 maintenance program	52/52 0.45 [0.17, 0.74]	52/52 0.66 (0.47, 0.93)	Fall-related fracture risk ratio: 0.76 (0.21 to 2.74
Irez, 2011, RCT, 2 arms	Y	IC	60	Turkey	75.4	100	NR	NR	NR	Yes	NR	12/52 tailored, progressive group Pilates program, TNP led, moderate intensity. (3/wk, 60min/session)	12/52 0.28 [0.15, 0.54]	NR	NR
Jahanpeyma, 2020 RCT,	Y	HC	71	Turkey	75.2	75	NR	Nil	Ambulant without	NR	NR	12/52 tailored, progressive Otago Exercise Program, TNP led, moderate intensity	12/52	NR	NR

2 arms									staff assistance			(3/wk,45min/session, 27 hrs) + walking prescription (3/wk, 30 min/session, 18 hrs)	0.39 [0.23, 0.66]		
Saravanakumar, 2014, RCT, 2/3arms Yoga	Y	M	11 / 33	Australia	85.2	88	10	Mild to moderate	Stand with support	Yes	Yes	14/52 group yoga program, TNP led, low intensity. (2/wk, 30min/session, 14 hrs)	26/52 0.47 [0.24, 0.91]	NR	NR
Saravanakumar, 2014, RCT, 2/3arms Tai Chi	Y	M	11 / 33	Australia	83.3	63.6	10	Mild to moderate	Stand with support	Yes	Yes	14/52 group tai chi program, TNP led, low intensity. (2/wk, 30min/session, 14 hrs)	26/52 0.52 [0.28, 0.98]	NR	NR
Sihvonen, 2004, RCT, 2 arms	NR	IC	28	Finland	81.7	100	2.6	Nil	Stand without staff assistance	Yes	NR	4/52 individual tailored and progressive balance exercise program using force platform. Moderate intensity. Program lead NR. (3/wk,30min/session, 6 hrs)	52/52 0.40 (0.17, 0.93)	52/52 0.77 (0.42, 1.42)	NR
Clinically but not statistically significant reduction in falls															
Cadore, 2014, RCT, 2 arms	Y	M	32	Spain	91.9	70	NR	Nil	Ambulant with and without staff assistance	Yes	NR	12/52 Individual, tailored, progressive strength, gait, balance and functional program. TNP led, moderate intensity. (2/wk, 40 min/session, 16 hrs)	NR	NR	IG: 0 fall, CG: 0.8/pt/ mnth Time*group interaction P<.001
Serra-Rexach, 2011, RCT, 2 arms	Y	HC	40	Spain	92	80	1.4	Mild to moderate	Ambulant with or without staff assistance	Yes	Nil	8/52 individual tailored, progressive strength, flexibility, cycling exercise, EP led, low to moderate intensity. (3/wk, 45min/session, 18 hrs)	NR	NR	IG:1.2 95% CI: 0.-3 fewer than control P.03
Toulotte, 2003, RCT, 2 arms	Y	M	20	France	81.4	NR	NR	Mild to moderate	Ambulant with or without staff assistance	NR	NR	16/52 progressive, tailored balance and seated strengthening, flexibility group program. GP led, low intensity. (2/wk, 45min/session, 24 hrs)	NR	NR	IG 0 fall, CG Part. 6 falls, no p value

Clinically significant but statistically non-significant reduction in falls (point estimate is 0.8 or less but the confidence interval crosses 1)															
Choi, 2005, Quasi RCT, 2 arms	Y	IC	59	Korea	77.	75	NR	Mild to moderate	Ambulant with and without staff assistance	Yes	NR	12/52 Tai Chi group exercise program. TNP led, low intensity. (3/wk, 35min/session, 21 hrs)	NR	52/52 0.6 (0.19, 1.87)	NR
Dhargrave 2020, RCT, 2 arms	Y	IC	163	India	74.6	53	NR	Mild	Ambulant without staff assistance	NR	NR	12/52 Individual progressive flexibility, gait, balance, functional program and walking, PT led, moderate intensity. (7/wk., 30min/session, 42 hrs.)	12/52 0.72 (0.44, 1.17)	12/52 0.72 (0.39, 1.32)	NR
Imaoka, 2016, RCT, 4 arms	N	HC	91	Japan	84.3	76	NR	NR	NR	NR	NR	12/52 (1) strength and balance ex, x2/wk of individualised exercise, x1/wk group exercise (14 hrs) (2) the low exercise group control group minus group program (8 hrs) (3) nutrition group was given oral vitamin D, no ex. (4) low-level exercise and received vitamin (8 hrs)		12/52 0.48, (0.17, 1.3)	NR
Kovacs, 2012, 2 arms	N	IC	41	Hungary	69.2	100	2.3	NR	Ambulant with staff assistance	Yes	Nil	26/52 progressive tailored multimodal exercise program. PT led, moderate intensity (x2/wk, 30 min/session, 26 hrs)	NR	26/52 0.54 [0.29, 1.01]	NR
Kovacs, 2013, RCT, 2 arms	Y	IC	86	Hungary	77.8	81	2.4	Mild to moderate	Ambulant without staff assistance	Yes	NR	52/52 tailored, progressive gait, balance, functional and strength group program. PT led, moderate intensity. (2/wk,30min/session, 52 hrs)	52/52 0.77 [0.37, 1.62]	52/52 0.67 (0.37, 1.23)	NR
Shimada 2004, RCT, 2 arms	N	IC	32	Japan	83.4	78	NR	Nil	Ambulant without staff assistance	NR	NR	26/52 Ind treadmill program lead NR, mod intensity (2/wk, 10min/session, 9 hrs)	26/52 0.42 (0.08, 2.06)	NR	NR
Tuunainen, 2013, RCT, 2/3 arms Gait, Bal., functional	N	HC	18 / 55	Finland	85	89	3.8	Mild, moderate, severe	Stand without staff assistance	NR	NR	13/52 Progressive gait, balance and functional group program, PT led, intensity NR. (2/wk, 60min/session, 26 hrs)	156/52 0.65 [0.4, 1.06]	NR	NR
Tuunainen, 2013, RCT, 2/3 arms Strength	N	HC	18 / 55	Finland	84.7	67	3.8	Mild, moderate, severe	Stand without staff assistance	NR	NR	13/52 Progressive strengthening group exercise program. PT led, intensity NR. (2/wk, 60min/session, 26 hrs)	156/52 0.74 [0.5, 1.1]	NR	NR

Varela, 2018, RCT, 2 arms	Y	HC	74	Spain	81.1	38	NR	Nil	Ambulant without staff assistance	No	NR	64/52 self-selected intensity cycling. Supervised by physio (7/wk, 15min/session, 112 hrs)	64/52 0.67 [0.3, 1.21)	NR	NR
Yokoi, 2015, Cluster RCT, 2 arms	Y	IC	105	Japan	79.3	60	3.9	Nil	Ambulant without staff assistance	Yes	Nil	26/52 individual seated physical activity exercise with traditional Japanese 'stick', TNP led, low intensity. (2/wk, 25min/session)	NR	52/52 0.3 [0.07, 1.28]	NR
Significant effect on falls not detected or not present (point estimate between 0.8 and 1.2 regardless of confidence interval)															
Buckinx, 2014, RCT, 2 arms	Y	IC	62	Belgium	83.2	76	3	Mild to moderate	Stand with or without staff assistance	Yes	NR	26/52 individual whole body vibration program. PT/TNP led, low intensity. (3/wk, 1.25min/session, 1.6 hrs)	52/52 0.96 [0.58, 1.60]	52/52 0.88 [0.54, 1.43]	NR
Faber, 2006, RCT, 3 arms Tai Chi	Y	M	168	Nether-lands	84.4	79	NR	Mild to moderate	Ambulant without staff assistance	Yes	NR	20/52 Tai Chi group program TNP led, moderate intensity. (2/wk, 60min/session, 36 hrs)	52/52. 0.96 [0.77, 1.19]	52/52 1.19 (0.79, 1.79)	NR
Kerse, 2008, Cluster RCT, 2 arms	Y	IC	682	New Zealand	84.3	74	4.9	Mild	Ambulant without staff assistance	No	Nil	26/52 functional exercise program. TNP led, low intensity. (7/wk, 15min/session)	52/52 1.11 [0.84, 1.45]	52/52 1.19 (0.94, 1.5)	NR
Nowalk, 2001, RCT, 3 arms	Y	M	110	USA	84	86	NR	NR	Ambulant without staff assistance	No	NR	52-72/52 Progressive, strength ex. and physical activity (cycling, treadmill) or low intensity Tai Chi groups classes led by TNP (3/wk, ?/session, ? dose)	NR	NR	No signif-icant differ-ence p=0.27
Rosendahl, 2008, Cluster RCT, 2 arms	Y	M	191	Sweden	84.7	73	3.1	Mild to moderate	Stand with staff assistance	Yes	NR	12/52 progressive, strength, functional ex. and balance group ex. program based on high-intensity functional ex. PT led, high intensity. (2.5/wk, 45min/session, 22 hrs)	26/52 0.82 [0.44, 1.53]	26/52 1.05 (0.77, 1.44)	NR
Sakamoto, 2006, RCT, 2 arms	Y	IC	533	Japan	81.6	74	≥ 1	Mild to moderate	Stand without staff assistance	NR	NR	26/52 unipedal standing balance exercise. PT led, low intensity. (7/wk, 6min/session, 18 hrs)	26/52 0.82 [0.65, 1.04]	26/52 0.9 [0.65, 1.23]	NR
Toots, 2019, RCT, 2 arms	Y	HC	186	Sweden	85.1	76	3	Mild to moderate	Stand with or without staff assistance	Yes	Nil	16/52 progressive, strength, functional, balance group ex., high intensity, PT led. (2.5/wk, 45min/session, 30 hrs)	64/52 0.9 (0.5, 1.61)	64/52 0.97 (0.76. 1.22)	NR

Clinically and statistically significant increase in falls: point estimate greater than 1.2 and the CI does not cross 1															
Schoenfelder, 2000, RCT, 2 arms	NR[1]	HC	16	USA	82.8	75	NR	Mild	Ambulant without staff assistance	NR	NR	12/52 ankle strengthening and walking, NP led, low intensity. (3/wk, 20min/session, 12 hrs)	26/52 2.72 [1.42, 5.19]	NR	NR
Clinically significant but statistically non-significant increase in falls: if the point estimate is 1.2 or more but the CI crosses 1															
Faber, 2006, RCT, 3 arms Gait, balance, functional ex.	Y	M	154	Nether-lands	85.4	79	NR	Mild to moderate	Ambulant without staff assistance	Yes	NR	20/52 gait, balance and functional group program, TNP led, moderate intensity. (1-2/wk, 60min/session, 36 hrs)	52/52. 1.32 (1.09, 1.61)	52/52 1.31 (0.87, 1.98)	NR
Mulrow, 1994, 2 arms	Y	HC	194	USA	80.6	71	5.1	Mild to moderate	Ambulant with and without staff assistance	Yes	Nil	16/52 individual, tailored, progressive strength, balance and functional ex. PT led, mainly low intensity (3/wk,30 min/session, 24 hrs)	16/52 1.32 [0.95, 1.85]	16/52 1.16 (0.83 to 1.62)	NR
Sitja Rabert, 2015, RCT, 2 arms	N	M	159	Spain	82	67	NR	nil	Stand with assistance	Yes	Nil	6/52 individualised, tailored and progressive strength exercise program with vibration platform therapy, low Intensity, program lead NR (3/wk, 30min/session)	NR	1.28 (0.71, 2.31) NB: 6/12 FU	NR
Uncertain: insufficient data to make judgement															
Buettner 2002, RCT. 2 arms	Y	M	27	USA	83.3	48	NR	Severe, moderate or mild	Ambulant with staff assistance	NR	NR	12/52 group strengthening, balance and gait program. Recreation therapist led, low intensity. (3/wk, 60min, 36 hrs)	NR	NR	NR
Da Silva Borges, 2014, RCT, 2 arms	Y	IC	59	Brazil	67.5	NR	NR	Nil	Ambulant without staff assistance	NR	NR	12/52 group ball room dancing program. TNP led, high intensity. (3/wk, 50min/session, 30 hrs)	NR	NR	NR

NR = not reported, HC = high care facility, IC = intermediate care facility, M = mixed (IC and HC)

1: Routine or usual care Y =authors described the control group as usual or routine care such as seated range of movement exs, N= authors described the control group as physical activity and exercise programs that include active exercise beyond routine or usual care

2: Attendance rate exceeded 50% and/or 75% or more of the participants attended 50% or more sessions

3: TNP = trained non-professional, EP = Exercise Professional, PT = Physiotherapist, GP = general practitioner

Supplementary material B: ProFaNE Components of the included trials

First author, year	Type of exercise (ex.) according to ProFaNE classification a							Duration in weeks	Total hours b	Delivery Mode c	Ex. supervised	Part. per group d	Program leader	Exercise tailored to individual	Exercise progressed	Exercise Intensity
	Gait, Balance functional	Strength/ resistance training	Flexibility training	3D ex.	General Physical Activity	Endur-ance exer.	Other exer.									
Arrieta, 2019	P	P	S					26	52	1	Y	NR	EP	Y	Y	Mod
Brett, 2021	P	P	S		S			12	9	1	Y	5	PT	Y	Y	Mod
Buckinx, 2014	S	S					P	26	1.5	2	Y	NA	PT	N	N	Low
Buettner 2002	P	P			P		S	12	24	1	Y	4	TNP	N	N	Low
Cadore 2014	P	P	S					12	16	2	Y	NA	TNP	Y	Y	Mod
Choi 2005				P				12	21	1	Y	29	TNP	N	N	Low
Da Silva Borges 2014			S	P				12	30	NR	Y	NR	NR	Y	Y	High
Dhargrave 2020	P	P	S		S			12	42	2	Partial	NA	PT	Y	Y	Mod
Faber 2006 – Functional walking	P	P						20	36	1	Y	12	TNP	Y	Y	Mod
Faber 2006 – In balance group				P				20	36	1	Y	12	TNP	Y	Y	Mod
Fu 2015	P							6	18	NR	Y	NR	PT	Y	Y	Low
Hewitt 2018	P	P	S					52	76	1	Y	5	PT	Y	Y	Mod
Imaoka 2016	P	P						12	6	1	Y	NA	PT	Y	NR	Mod
Irez,2011	P	P	S					12	36	1	Y	NR	TNP	Y	Y	Mod

First author, year	Type of exercise (ex.) according to ProFaNE classification a							Duration in weeks	Total hours b	Delivery Mode c	Ex. supervised	Part. per group d	Program leader	Exercise tailored to individual	Exercise progressed	Exercise Intensity
	Balance, Gait or functional	Strength/ resistance Training	Flexibility training	3D ex.	General Physical Activity	Endur-ance ex.	Other ex.									
Jahanpeyma 2020	P	P	S		S			12	27	1	Y	9	TNP	Y	Y	Mod
Kerse 2008	P							26	91	2	Y	NA	TNP	Y	Y	Low
Kovacs 2012	P	P	S		P			26	52	1	Y	6	PT	Y	Y	Mod
Kovacs 2013	P	P	S		P			52	104	1	Y	4	PT	Y	Y	Mod
Mulrow 1994	P	P	S		P			16	24	2	Y	NA	PT	Y	Y	Low
Nowalk 2001 LL/TC				P				104	NR	1	Y	NA	TNP	N	Partial	Low
Nowalk 2001 FNBF		P						104	NR	2	Y	NA	EP	Partial	Partial	Low
Rosendahl 2008	P	P						12	22	1	Y	9	PT	Y	Y	High
Sakamoto 2006	P							26	17	2	Y	NA	PT	N	N	Low
Saravanakumar 2014 Yoga				P				14	14	1	Y	11	TNP	Partial	N	Low
Saravanakumar 2014 Tai Chi				P				14	14	1	Y	11	TNP	Partial	N	Low
Schoenfelder 2000		P			P			12	12	2	Y	NA	TNP	N	Y	Low
Serra-Rexach 2011		P	S			P		8	18	2	Y	NA	TNP	Y	Y	Low to mod
Shimada 2004	P							6	10	2	Y	NA	NR	Y	Y	Mod
Sihvonen 2004	P							4	26	2	Y	NA	NR	Partial	N	Mod
Sitja Rabert 2015	P	P					P	16	24	1	Y	5	NR	N	Y	Low

First author, year	Type of exercise (ex.) according to ProFaNE classification a							Duration in weeks	Total hours b	Delivery Mode c	Ex. supervised	Part. per group d	Program leader	Exercise tailored to individual	Exercise progressed	Exercise Intensity
	Balance, Gait or functional	Strength/ resistance Training	Flexibility training	3D ex.	General Physical Activity	Endur-ance ex.	Other ex.									
Toots 2019	P	P						16	30	1	Y	NR	PT	Y	Y	High
Toulette 2003	P	P	P					16	24	1	Y	5	GP	N	N	Low
Tuunainen 2013	P	P	P					13	26	1	Y	5	PT	N	Y	High
Varela 2018						P		64	112	2	N	NA	Self	N	N	Low
Yokoi 2015					P			26	22	2	Y	NA	TNP	N	N	Low

a Classification (P = Primary; S = Secondary);
b Minimal dose
c Delivery mode (1 = Group, 2 = Individual, 3= combined);
d Maximum participants in a group
N = No, Y = Yes, NA = Not applicable, NR = Not reported, TNP = trained non-exercise professional, EP = exercise physiologist, PT = physiotherapist, GP = general practitioner

Supplementary Material C: Pedro Risk of Bias of included trials

First author Year	**Pedro Score/ 10**	**Eligibility Criteria**	**Random allocation**	**Concealed Allocation**	**Baseline Compara-bility**	**Blind subjects**	**Blind therapists**	**Blind assessors**	**Adequate follow up**	**Intention to treat analysis**	**Between group compar.**	**Point est. & variability**
Arrieta 2019	6	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes
Brett 2021	6	Yes	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes
~~Buckinx 2014~~	6	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Yes	Yes
Buettner 2002	1	Yes	Yes	No	No	No	No	No	No	No	No	No
Cadore 2014	6	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes
Choi 2005	5	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes
Da Silva Borges, 2014	5	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes
Dhargrave 2020	5	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes
Faber 2006	6	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes
Fu 2015	7	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Hewitt 2018	8	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Imaoka 2016	6	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes
Irez 2011	6	Yes	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes
Jahanpeyma 2020	6	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes
Kerse 2008	5	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes
Kovacs 2012	8	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes

Kovacs 2013	8	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Mulrow 1994	6	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes
Nowalk 2001	4	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes
Rosendahl 2008	7	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes
Sakamoto 2006	4	No	Yes	No	No	No	No	No	Yes	No	Yes	Yes
Saravanakum 2014	6	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes
Schoenfelder 2000	4	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	No
Serra-Rexach, 2011	7	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes
Shimada 2004	4	No	Yes	No	Yes	No	No	No	No	No	Yes	Yes
Sihvonen 2004	5	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes
Sitja Rabert 2015	7	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes
Toots 2019.	8	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Toulotte 2003	3	No	Yes	No	No	No	No	Yes	No	No	No	Yes
Tuunainen 2013	4	Yes	Yes	No	No	No	No	No	Yes	No	Yes	Yes
Varela 2018	6	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Yes	Yes
Yokoi 2015	7	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes

Note: Eligibility criteria item does not contribute to total score

CHAPTER FOUR

Exercise Interventions Delivered Through Telehealth to Improve Physical Functioning for Older Adults with Frailty, Cognitive, or Mobility Disability: A Systematic Review and Meta-Analysis

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4.1 Statement of co-authorship

As co-authors of the manuscript "Exercise Interventions delivered through Telehealth to Improve Physical Functioning for Older Adults with Frailty, Cognitive, or Mobility Disability: A Systematic Review and Meta-Analysis", we confirm that Rik Dawson is the lead corresponding author and has made the primary contribution to this study in each of the following areas:

- Conception and design of the research
- Data Collection
- Data analysis and interpretation of findings
- Writing of the manuscript and critical appraisal of content

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Exercise Interventions Delivered Through Telehealth to Improve Physical Functioning for Older Adults with Frailty, Cognitive, or Mobility Disability: A Systematic Review and Meta-Analysis

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Abstract

Introductions: *This study assessed the effects of telehealth-delivered exercise interventions on physical functioning for older adults and explored implementation measures related to program delivery.*

Methods: *We conducted a systematic review of studies investigating effects of exercise interventions delivered through telehealth in adults 60+ years of age with frailty, mobility, or cognitive disability on mobility, strength, balance, falls, and quality of life (QoL). Electronic databases (MEDLINE, CINAHL, SPORTSDiscus, and Physiotherapy Evidence Database) were searched from inception until May 2022. Evidence certainty was assessed with Grading of Recommendations, Assessment, Development, and Evaluation and meta-analysis summarized study effects.*

Results: *A total of 11 studies were included, 5 randomized controlled trials, 2 pilot studies, and 4 feasibility studies. The overall certainty of evidence was rated as "low" or "very low." Pooled between-group differences were not statistically significant, but effect sizes suggested that telehealth produced a moderate improvement on mobility (n = 5 studies; standardized mean difference [SMD] = 0.63; 95% confidence interval [CI] = −0.25 to 1.51; p = 0.000, I^2 = 86%) and strength (n = 4; SMD = 0.73; 95% CI = −0.10 to 1.56; p = 0.000, I^2 = 84%), a small improvement on balance (n = 3; SMD = 0.40; 95% CI = −035 to 1.15; p = 0.012, I^2 = 78%), and no effect on QoL. Analysis of implementation measures suggested telehealth to be feasible in this population, given high rates of acceptability and adherence with minimal safety concerns.*

Discussion: *Telehealth may provide small to moderate benefits on a range of physical outcomes and appears to be well received in aged care populations.*

Keywords: *physical therapy, aged care, rehabilitation, telemedicine, telehealth*

Introduction

Older adults, 60 years of age and older, are the most sedentary age group in our community.[1] Aged care service recipients, who usually have frailty, and/or mobility or cognitive disability, are particularly inactive.[2] Physical inactivity is associated with negative health outcomes such as increased risk of falls, frailty, mobility disability, and death.[3] Exercise interventions have been found to improve mobility and reduce falls in frail community-dwelling older adults and in aged care populations, who have high levels of mobility and cognitive disability.[4–6] The Australian 2021 Royal Commission into Safety and Quality in Aged Care identified falls and mobility decline as a serious problem in residential aged care, exacerbated by poor access to exercise health professionals such as physiotherapists.[7] Similar issues have been identified in other countries.[8]

World Health Organization has defined telehealth as the delivery of health care services, where patients and providers who are separated by distance use information communication technologies to diagnose and treat diseases and injuries.[9] Telehealth is a rapidly growing service delivery model that could enhance access and facilitate delivery of exercise programs to older adults receiving aged care services in their home or in residential care. Uptake of telehealth has been accelerated in response to the COVID-19 pandemic, especially in aged care settings.[10]

Little is known about the effectiveness of telehealth use to deliver exercise programs in aged care settings or how best to implement telehealth exercise in this complex population. A recent rapid review investigating the use of websites and apps to assist older adults engage with balance and strength training found low to moderate evidence that the use of digital technology improved physical activity and reduced fall risk.[11] However, this review excluded studies that targeted aged care populations. A discrete choice experiment in 2017 concluded that telehealth was acceptable among older adults receiving rehabilitation, but excluded aged care populations.[12]

This systematic review sought to investigate the use of telehealth exercise for older adults who are receiving aged care services or have frailty, mobility, or cognitive disability. This review aimed to summarize (1) the effects of exercise interventions delivered through telehealth on mobility, strength, balance, falls, and quality of life (QoL) and (2) implementation outcomes and determinants related to the delivery of telehealth exercise programs in this population.

Methods

Our systematic review with meta-analysis followed the methods described in the Cochrane Handbook for Systematic Reviews of Interventions and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[13,14] This review was registered through the PROSPERO international prospective register of systematic reviews on May 1, 2022 (CRD42022322469).

SEARCH STRATEGY

Optimized searches were completed through four electronic databases (MEDLINE, CINAHL, SPORTDiscus, and Physiotherapy Evidence Database [PEDro]) from inception to May 1, 2022. Four reviewers (I.M.R., C.Y.C., A.S., and M.B.) searched one database each. Keywords, MeSH, and other index terms were used to construct the search strategy (see online *Supplementary Table S1* for examples of search terms). Articles sourced by hand searching were included. Articles were independently screened in two stages: screening of title and abstracts and screening of full-text articles by two pairs of reviewers (I.M.R./A.S. or C.Y.C./M.B.) using the eligibility criteria. Disagreements regarding the eligibility of studies were resolved through discussion. Conference abstracts and dissertations that reported data suitable for analysis were included.

ELIGIBILITY CRITERIA

Type of study. For our first aim, we included randomized controlled trials (RCTs), and for our second aim, we also included quasi-randomized, feasibility, and qualitative studies.

Participants. We included studies investigating participants with a mean age of 60+ years with frailty, mobility, or cognitive disability, or who were aged care service users. Any type of health condition was included. Studies involving participants being treated in hospital were excluded as these participants receive more support than older people receiving aged care services in their home or in residential aged care.

Interventions. Studies were included if they evaluated exercise interventions delivered through synchronous telehealth (virtual interactions between a participant and a health professional that occurs in real time) or asynchronous telehealth (sharing of data, educational materials, or online programs to assist a participant to exercise at a time of their choosing) that aimed to increase balance, strength, and/or physical functioning.[15] We excluded studies involving no telehealth, that did not include participants with frailty, mobility, or cognitive disability or aged care service users, or involved only wearable technology. Interventions of any length and any follow-up period were included.

Comparator. For our meta-analysis, we included RCTs that compared telehealth to any comparator.

Outcomes. Our outcomes to address aim 1 included measures of mobility, balance, strength, falls, and QoL. Outcome data were extracted for baseline and post-intervention periods. Studies were included in meta-analysis if their data were presented as or could be converted into mean/standard deviation (SD) pre-intervention and post-intervention scores to facilitate quantitative pooling. To enable inclusion of as many studies as possible in the meta-analysis, we pooled results across multiple assessment tools for the same outcome.

For studies that reported results for more than one assessment tool for the same outcome, we selected one tool per outcome using a pre-defined order of priority.[16] The order of priority was as follows: for mobility (Short Physical Performance Battery, Physical Performance Test, Timed Up and Go test, and walking speed); for balance (Berg Balance Scale, 4-Stage balance test, and timed step test); strength (only timed sit to stand was used); and QoL (no priority was required as there was only one tool used in each study). Falls were assessed separately using the risk of falling that is, number of adults who experienced one or more falls and rate of falls that is, falls per person-year.

Outcomes to address aim 2 included any implementation-related outcome and determinant identified through an analysis of studies' results relating to the intervention's reach (proportion of participants who were successfully screened and consented to participate),[17] feasibility (proportion of participants who completed the follow-up assessment),[18] adherence (proportion of participants who completed the agreed number of planned intervention sessions),[19] acceptability (measure of satisfaction), dose (hours of exercise completed over study period), and safety (reporting of adverse events [AE] such as falls and pain directly related to the intervention), as well as barriers and facilitators determined using mixed methods.[20]

DATA EXTRACTION

A data extraction sheet was developed, pilot-tested, and modified accordingly. For each study, two pairs of investigators (I.M.R./A.S. or C.Y.C./M.B.) extracted the data, and two investigators (R.D./W.S.K.) checked the data. Information extracted from each study comprised a description of participants, details of the intervention, and outcome measures (baseline and at first follow-up). Preintervention and post-intervention scores were used when available. Authors of the included studies were contacted by email if the study reports were incomplete, or data were missing. If the author did not reply, then the available data were used. For our meta-analysis, the pooled difference was calculated as a mean and 95% confidence intervals (CIs) for each outcome in the simple stratified analysis.

METHODOLOGICAL QUALITY ASSESSMENT FOR RCTS

Data pertaining to the risk of bias were extracted by two pairs of investigators (I.M.R./A.S. or C.Y.C./M.L.) and assessed using the PEDro scale.[21] The PEDro scale evaluates 11 items: inclusion criteria and source, random allocation, concealed allocation, similarity at baseline, subject blinding, therapist blinding, assessor blinding, completeness of follow-up, intention-to-treat analysis, between-group statistical comparisons, and point measures and variability.[21] Item 1 refers to external validity and does not contribute to the final score; thus, the final scores ranged from 0 to 10.

ASSESSMENT OF CERTAINTY OF THE EVIDENCE

The Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) was used to assess the certainty of evidence for the primary outcomes of our meta-analyses for aim 1.[22] We used the GRADE system for all outcomes, which pooled results from three or more studies. We evaluated the quality of the body of evidence as "High," "Moderate," "Low," or "Very Low" based on the presence or extent of four factors: study limitations, inconsistency of the effect, imprecision, and publication bias.[23]

DATA ANALYSIS

Meta-analyses were completed using Stata Meta-Analysis software using the random-effects model for each outcome (mobility, strength, balance, and QoL).[24] We gathered pre-intervention and post-intervention mean/SD and the sample size per group. We used the controlled trials that compared the telehealth intervention group with either usual care that included no active exercise (four trials)[25–28] or face-to-face in-person exercises (one trial).[29] We calculated treatment effects using standardized mean differences (SMDs) (Hedges' g), standardized by post-score SD (or its estimate) with 95% CIs. SMD was calculated using the pre-mean and post-mean and SD or, when this was unavailable, we used the mean change score. Effect sizes were categorized as small (0.2–0.49), medium (0.5–0.79), or large (0.8 or greater).[30] We visually inspected forest plots for evidence of heterogeneity with consideration of the I^2 and χ^2 tests. For the implementation data, we collected median and range scores and conducted a thematic analysis of the authors' reported barriers and facilitators to implementing telehealth.

Results

After duplicates were removed, the electronic search retrieved 370 references. We completed full-text screening on 118 articles. We included 11 studies for the review, which included 5 RCTs, 4 feasibility studies, and 2 pilot studies. The five trials contributed to our meta-analysis (aim 1) and all the studies contributed to our implementation analysis (aim 2). Search results are presented in *Figure 1*.

TRIAL DESIGN AND PARTICIPANT CHARACTERISTICS

Participant characteristics are displayed in *Table 1*. A total of 546 subjects participated across all studies (302 in

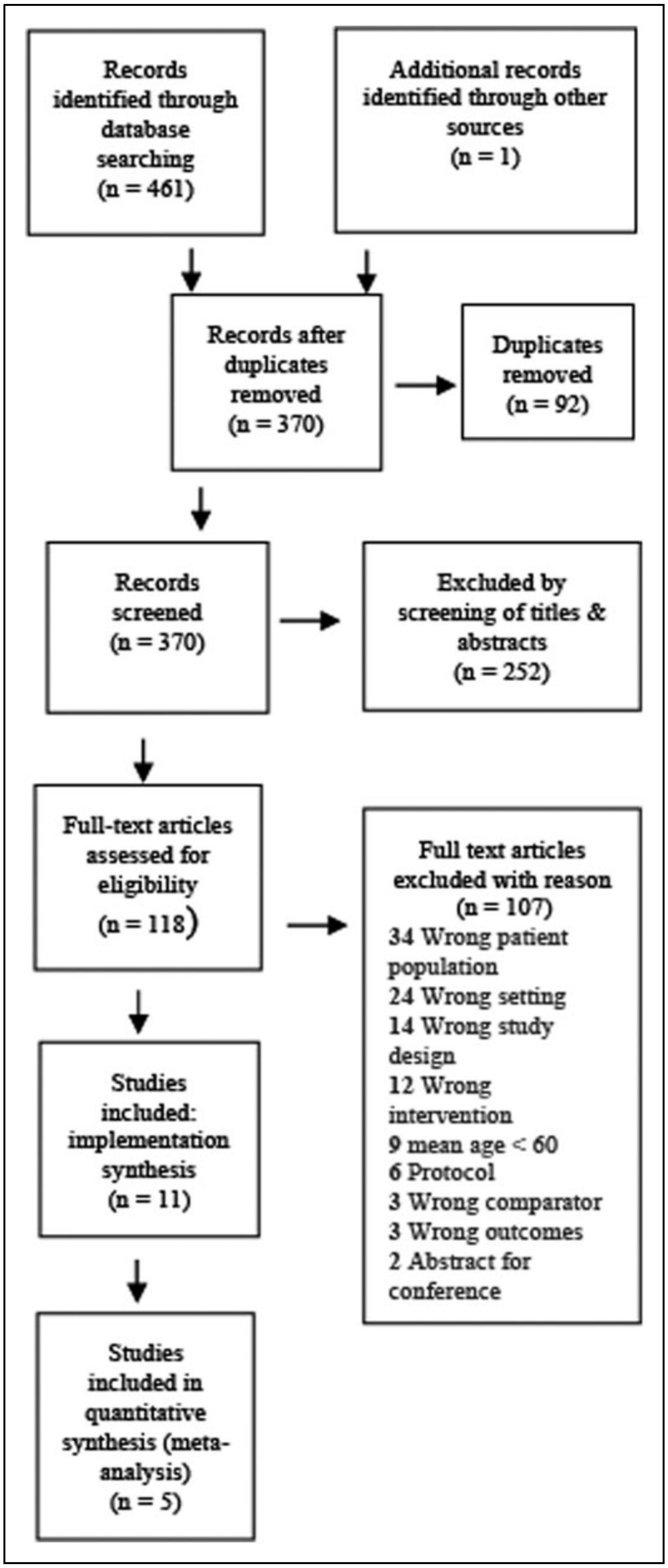

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart.

controlled studies and 244 in feasibility or pilot studies). Mean age was 77.4 ± 4.7 years and 65% of participants were female. Three studies recruited from residential aged care facilities[27,31,32] and one study recruited participants receiving aged care services in their home.[28] Eight studies recruited participants with a mobility disability,[25–28,32–35] five studies included participants with cognitive impairment,[25–27,31,35] and three studies recruited frail participants.[25,27,36] In the controlled studies, two compared telehealth to usual care,[27,28] with one study compared to usual care plus fall education,[25] one study compared to seated stretching,[26] and one study compared to in-person balance training.[29] The mean PEDro total score of the RCTs was good at 6.4.

TELEHEALTH AND EXERCISE INTERVENTION COMPONENTS

Telehealth and exercise intervention components are displayed in *Table 2*. Five studies evaluated programs that included synchronous videoconferencing to deliver exercise session,[26,29,31,32,34] while six studies used asynchronous telehealth to deliver exercise components.[25,27,28,33,35,36] Seven studies evaluated programs led by a physiotherapist,[25,29,32–36] six studies incorporated interventions with tailoring of the exercise program,[25,27,29,32,34,35] and seven studies delivered a combination of strength and balance exercises.[25,27,28,32–35] Six studies delivered low-intensity exercise,[26,27,29,31,33,36] with three studies delivering moderate-intensity exercise.[25,34,35] The median frequency of exercise sessions was three per week (range = 1–7), median session duration was 26 min (range = 7–60), median planned exercise dose over trial was 18 h (range = 3–48), and median intervention length was 17 weeks (range = 4–26). There were three group-based interventions.[26,31,34]

EFFECTS OF INTERVENTIONS

The results of outcomes measured are summarized in *Supplementary Table S2* with the forest plots and mean differences presented in *Figures 2–5*. The overall certainty of evidence for the effect of telehealth intervention on physical outcomes was rated as very low quality (*Supplementary Table S3*) and the pooled results for all outcomes did not reach statistical significance as all the CIs crossed the null line of effect. The pooled estimates (Hedges' g) of suggested effect size are as follows: a moderate improvement in mobility (5 studies; SMD = 0.63; 95% CI = –0.25 to 1.51; 302 participants, $p = 0.000$, $I^2 = 86\%$, very low certainty),[25–29] a moderate improvement in strength (4 studies; SMD = 0.73; 95% CI = –0.10 to 1.56; 226 participants, $p = 0.000$, $I^2 = 84\%$, very low certainty),[25–28] and a small improvement in balance

Table 1. Trial Design and Participant Characteristics ($N = 11$)

AUTHOR (YEAR), COUNTRY, PEDRO SCORE[a]	STUDY DESIGN, LENGTH IN WEEKS	SAMPLE SIZE (I & C)	AGE (YEARS, MEAN ± SD)	FEMALE (%)	SETTING	CONDITION AND SEVERITY	CONTROL	OUTCOMES (END OF INTERVENTION)
Bernard et al. (2009),[31] Canada, NA	Pilot study, 10 weeks	$n = 22$	81 ± 7	53%	Aged care facility	Comorbidities, mild to moderate CI	No control group	Strength
Bruns et al. (2019),[33] The Netherlands, NA	Pilot study, 3.7 weeks (median)	$n = 14$	79 IQR = 74–76	64%	Home	Frailty, cancer	No control group	Strength, mobility, balance, QoL
Callisaya et al. (2021),[25] Australia, 7/10	RCT, 26 weeks	$n = 93$ ($I = 44$, $C = 49$)	$I = 73 \pm 7$ $C = 73 \pm 7$	$I = 61\%$ $C = 55\%$	Home	Mild CI, falls, moderate mobility disability, frailty, comorbidities	Usual care + fall education	Strength, mobility, balance, falls
Crotty et al. (2014),[32] Australia, NA	Feasibility study, 8 weeks	$n = 104$	73 ± 10	42%	Home and aged care facility	Moderate mobility disability, falls, comorbidities	No control group	Implementation measures
Gandolfi et al. (2017),[29] Italy, 6/10	RCT, 7 weeks	$n = 76$ ($I = 38$ $C = 38$)	$I = 67 \pm 7$ $C = 70 \pm 9$	$I = 39\%$ $C = 26\%$	Home	PD, falls	In person balance training	Mobility, balance, QoL, implementation measures
Lauzé et al. (2017),[27] Canada, 5/10	RCT, 12 weeks	$n = 42$ ($I = 28$ $C = 14$)	$I = 80 \pm 8$ $C = 83 \pm 7$	$I = 71\%$ $C = 91\%$	Aged care facility	Mild to moderate mobility disability, falls, frail, mild CI, comorbidities	Usual care	Strength, mobility, QoL, falls, implementation measures
Li et al. (2021),[26] USA, 8/10	RCT, 24 weeks	$n = 30$ ($I = 15$ $C = 15$)	$I = 76 \pm 6$ $C = 76 \pm 6$	$I = 60\%$ $C = 80\%$	Home	Mild CI, falls comorbidities, mild mobility disability	Stretches	Falls, strength, mobility, balance, implementation measures
Mansson et al. (2020),[34] Sweden, NA	Feasibility study, 16 weeks	$n = 67$ ($I = 29$ $C = 38$)	$I = 76 \pm 5$ $C = 77 \pm 3$	$I = 62\%$ $C = 79\%$	Home	Falls, balance impairment, mild mobility disability	Otago exercise program booklet	Implementation measures
Taylor et al. (2020),[36] Australia, NA	Feasibility study, 12 weeks	$n = 15$	83 ± 8	47%	Home	Mild to moderate CI, mobility disability, falls comorbidities	No control group	Strength, mobility, balance, implementation measures
Vestergaard et al. (2013),[28] Denmark, 6/10	RCT, 20 weeks	$n = 61$ ($I = 30$ $C = 31$)	$I = 81 \pm 3$ $C = 83 \pm 4$	$I = 100\%$ $C = 100\%$	Home	Moderate mobility disability, comorbidities	Usual care	Strength, mobility, QoL, implementation measures
Wong et al. (2005),[35] China, NA	Feasibility study, 12 weeks	$n = 22$	75 ± 7	90%	Communtiy center and home	OA, mild mobility disability	No control group	Strength, mobility, balance, QoL, implementation measures

[a]Physiotherapy Evidence Database (PEDro) Score only for RCTs.[46]

C, control; CI, cognitive impairment; *I*, intervention; IQR, interquartile range; mod, moderate; NA, not applicable; OA, osteoarthritis; QoL, quality of life; PD, Parkinson's disease; RCT, randomized controlled trial.

Data are mean ± SD, unless otherwise stated.

Table 2. Telehealth and Exercise Intervention Components ($N = 11$)

REFERENCES	STUDY LEAD	TELEHEALTH	TAILORED	PRIMARY PROFANE EX. CATEGORY	EX. INTENSITY	EX. FREQENCY (SESSIONS/WEEK)	SESSION DURATION (MIN)	EX. DOSE (H)	GROUP OR IND.	TELEHEALTH SUPPORTS
Bernard et al. (2009)[31]	Kinesiologist	Synchronous videoconferencing exercise classes	NR	Strength – seated	Low	1–2 Times/week	60 min	13 h	Group	Local F2F support
Bruns et al. (2019)[33]	PT	Asynchronous exercise videos	No	Strength – seated and standing	Low	7 Times/week	7 min	3 h	Ind.	NR
Callisaya et al. (2021)[25]	PT or EP	Asynchronous exercise videos	Yes	Strength/balance – standing	Moderate	Flexible	10–30 min	48 h	Ind.	One-hour F2F initial ax for setup and 2 FU visits & monthly phone calls
Crotty et al. (2014)[32]	PT	Synchronous videoconferencing	Yes	Strength/balance – standing	NR	2 Times/week	NR	NR	Ind.	Initial F2F training with telehealth
Gandolfi et al. (2017)[29]	PT	Synchronous exercise games	Yes	Balance – standing	Low	3 Times/week	50 min	18 h	Ind.	Remote super-vision & caregiver support
Lauzé et al. (2017)[27]	Kinesiologist	Asynchronous exercise games	Yes	Strength/balance – standing	Low to moderate	2 Times/week	45 min	18 h	Ind.	Initial F2F training with telehealth
Li et al. (2021)[26]	ET	Synchronous videoconferencing exercise class	No	3D ex (Tai Ji Quan) – standing	Low	2 Times/week	60 min	48 h	Group	NR
Mansson et al. (2020)[34]	PT	Asynchronous exercise videos	No	Strength/balance – standing	Low	3 Times/week	30 min	24 h	Ind.	Two hour F2F initial support
Taylor et al. (2019)[36]	PT	Asynchronous exercise videos	Yes	Strength/balance – standing	Moderate	Flexible	10–30 min	17 h	Ind.	F2F initial home visit and 2 FU visits + caregiver support
Vestergaard et al. (2008)[28]	ET	Asynchronous exercise video	No	Strength/balance – standing	NR	3 Times/week	26 min	26 h	Ind.	Initial F2F training, 2 times/week follow-up phone calls
Wong et al. (2005)[35]	PT	Synchronous videoconferencing exercise classes	Yes	Strength/balance – standing	Moderate	4 Times/week (Telehealth 1 time/week)	NR	NR	Group for telehealth	NR

ax, assessment; EP, exercise physiologist; ET, exercise trainer; ex, exercise; F2F, face to face/in person; FU, follow-up; Ind., individual; NR, not reported; PT, physiotherapists.

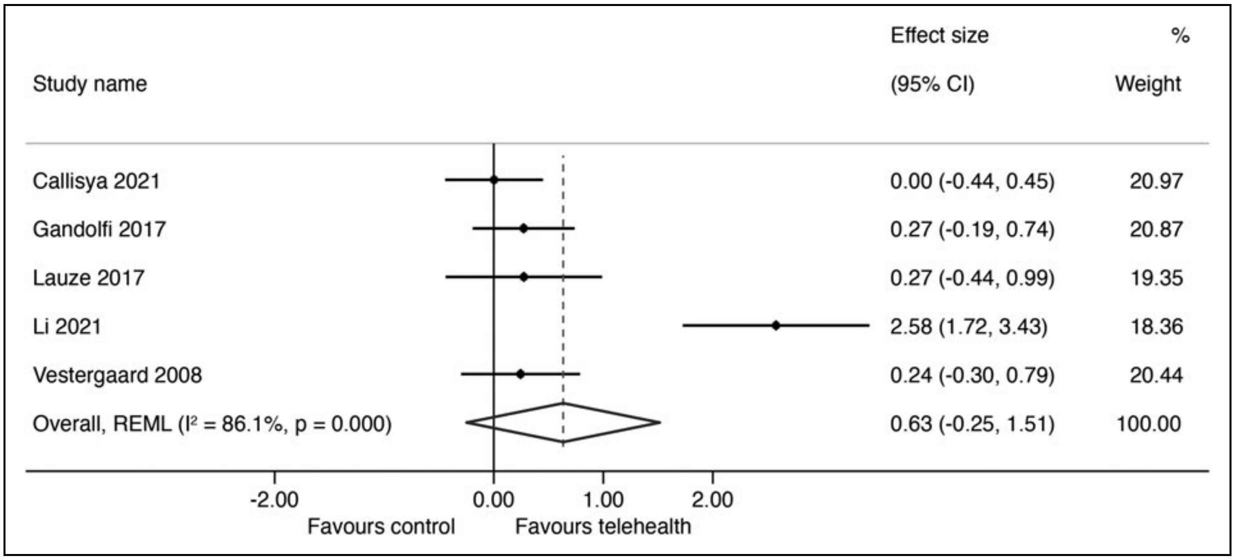

Fig. 2. Effect size (95% confidence interval) of telehealth versus control on mobility using random-effects meta-analysis.

(3 studies; SMD = 0.40; 95% CI = −035 to 1.15; 199 participants, $p = 0.012$, $I^2 = 78\%$, very low certainty).[25,26,29] There was no indication of an effect of telehealth on QoL (3 studies; SMD = −0.09; 95% CI = −0.23 to 0.40; $p = 0.77$, 179 participants, $I^2 = 0\%$, low certainty).[27–29] We were unable to conduct a meta-analysis of fall outcomes as there were only two studies that could have their reported data translated into a fall rate ratio[27,29] and only one study was able to translate their fall data into risk ratio.[26]

IMPLEMENTATION ANALYSIS

The results of the implementation analysis are summarized in *Table 3*.

Reach: Seven studies reported on the proportion of participants who were successfully screened and consented to participate, and their median reach was 55% (range = 9–82).[25,26,28,29,32,34,36]

Feasibility: All studies reported the proportion of participants who were included in the follow-up data collection with a median score of 87% (range = 67–100).

Adherence: Nine studies reported a measure of intervention adherence with median exercise attendance to planned exercise sessions as 86% (range = 54–91).[25–28,31,33–36]

Dose: Eight studies reported the time spent exercising over the study period with a median exercise dose of 17 h (range = 3–41).[25–28,31,33,35,36]

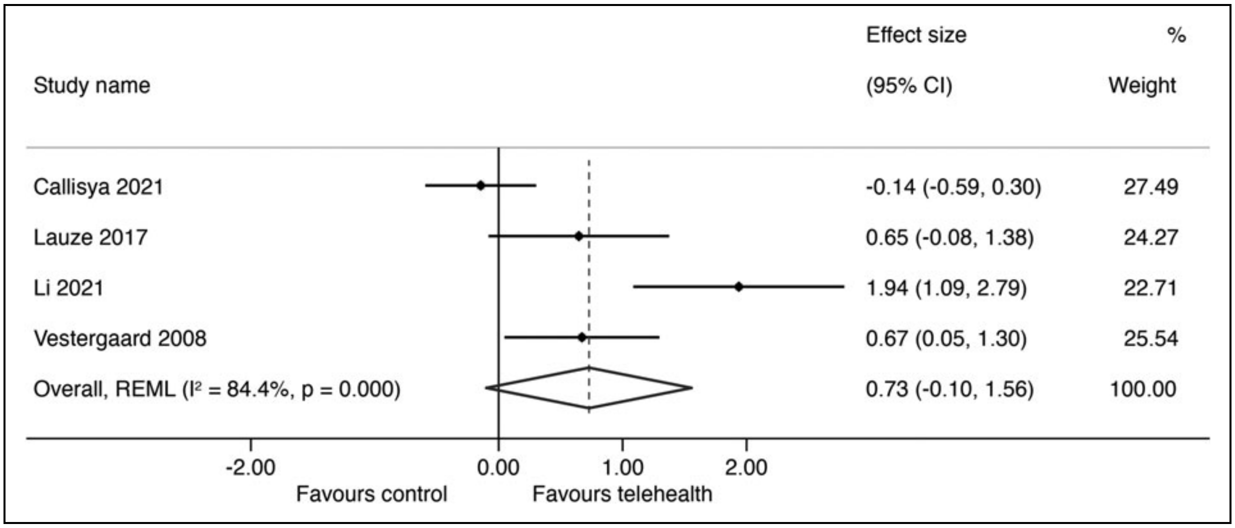

Fig. 3. Effect size (95% confidence interval) of telehealth versus control on strength using random-effects meta-analysis.

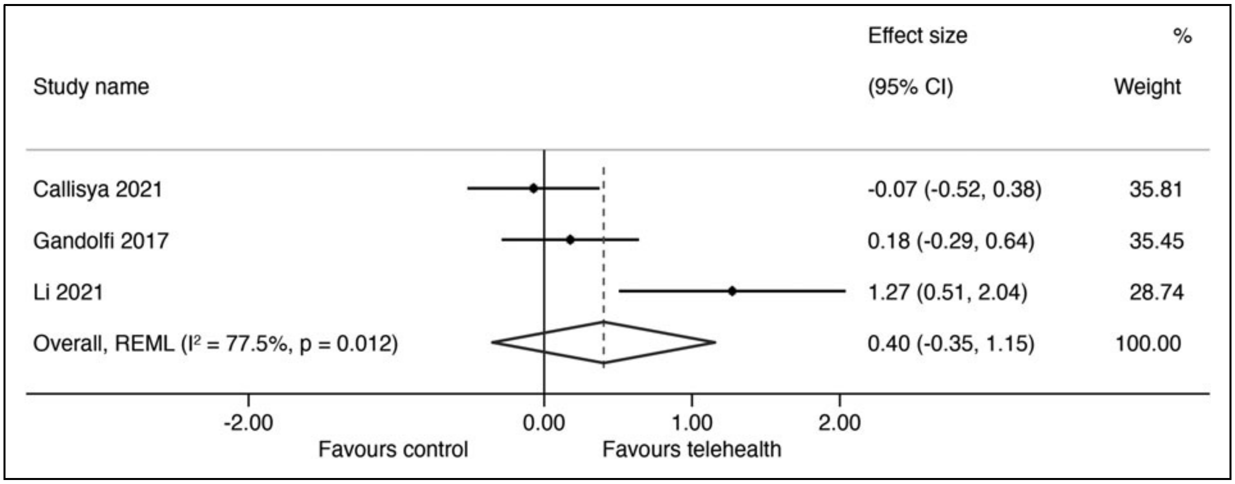

Fig. 4. Effect size (95% confidence interval) of telehealth versus control on balance using random-effects meta-analysis.

Safety: AE (falls and adverse musculoskeletal pain directly resulted to the telehealth intervention) were reported to some degree in seven studies.[25–29,33,35] Four studies reported no AE.[26,28,29,33] Falls ($n=4$) were reported in three studies from participants exercising, while using asynchronous telehealth.[25,27,35] One study reported musculoskeletal pain events ($n=3$) linked to the intervention.[25]

Acceptability: Eight trials included a measure of participants' overall satisfaction with the intervention.[25,27,29,31,33–36] The median satisfaction rate was 86% (range = 68–100).

Facilitators: Three factors that supported high program adherence rates were reported by the authors in the "Discussion" section of the article. The importance of initial participant technology training with ongoing support through face-to-face visits or phone calls to troubleshoot any problem and enhance exercise adherence was highlighted by seven authors.[25,27,28,31–33,35] Participant appreciation of the convenience of telehealth exercise programs being delivered in their own home was reflected on by five authors.[28,29,31,32,36] Positive effects of program flexibility on exercise adherence using asynchronous telehealth exercise programs as it allowed participants to choose the timing of when they exercised were observed by four authors.[25,27,32,33]

Barriers: Authors' reports regarding the impact of the participant's technology hesitation and age on the outcomes of telehealth exercise programs were mixed. One study reported that high technology hesitation reduced recruitment rates.[31] Two studies observed that higher levels of technology hesitation correlated with reduced telehealth satisfaction rates[26,35] and another study found that older participants had lower satisfaction rates.[35] However, one study observed that technology hesitation or age was not related to the feasibility or acceptability of the telehealth intervention.[32] Bernard et al. commented that delivering synchronous exercise classes to

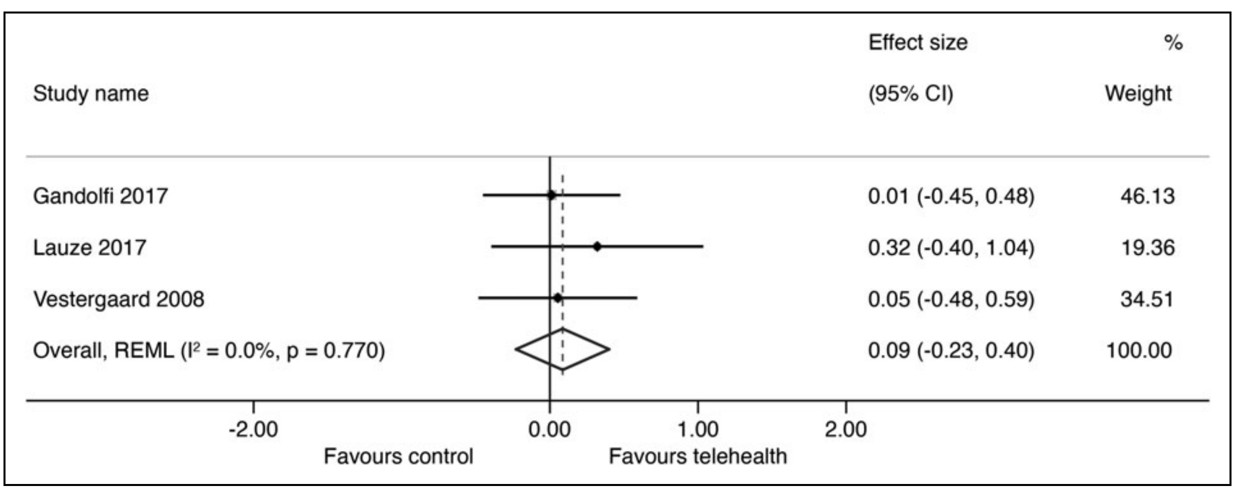

Fig. 5. Effect size (95% confidence interval) of telehealth versus control on quality of life using random-effects meta-analysis.

Table 3. Implementation Outcomes

AUTHOR	REACH	FEASIBILITY	ADHERENCE	DOSE ACHIEVED (H)	SAFETY (N=AE)	ACCEPTABILITY (% SATISFIED)
Bernard[31]	NR	67%	57%	10	NR	91%
Bruns[33]	13%	100%	86%	3	NR	80%
Callisaya[25]	69%	83%	85%	41	4	77%
Crotty[32]	51%	92%	NR	NR	NR	NR
Gandolfi[29]	56%	100%	NR	NR	0	91%
Lauzé[27]	NR	79%	89%	16	2	94%
Li[26]	55%	87%	80%	38	0	NR
Mansson[34]	NR	72%	63%	17	0	100%
Taylor[36]	NR	87%	54%	9	1	68%
Vestergaard[28]	9%	87%	89%	23	0	NR
Wong[35]	82%	91%	91%	NR	NR	80%
Total (median) (range)	55% 9–82%	87% 67–100%	85% 54–91%	17 3–41	0 Events 0–4	86% 68–100%

AE, adverse events.

multiple sites is challenging and may inhibit the ability to deliver adequate exercise dose and intensity required to improve other physical outcomes.[31] Brun et al. stated that asynchronous exercise programs did not enable sufficient exercise tailoring to enhance physical outcomes.[36]

Discussion

This systematic review with meta-analysis assessed the effectiveness and implementation of exercise interventions delivered through telehealth for older adults, 60 years and older, who are receiving aged care services or have mobility, cognitive, or frailty disability. It is the first review of this approach in this population, to our knowledge. Pooled effects did not reach statistical significance outcomes, but suggested favorable effects of telehealth interventions to improve mobility, strength, and balance in older adults, which are likely to be clinically meaningful. Our analysis of implementation measures suggested that telehealth is feasible, as evidenced by high rates of acceptability and adherence with few safety concerns.

The utilization of telehealth to promote physical activity and improve physical functioning in aged care is emerging as an effective and acceptable mode of health care delivery.[37] A 2020 systematic review (n = 17 controlled studies) into community-dwelling older adults, 60 years of age and older, receiving a variety of health care interventions using synchronous telehealth found similarly high levels of feasibility, safety, and acceptability.[38] Three of the included studies that focused on falls, exercise, or strength-based measures demonstrated significant improvements.[39–41] A scoping review in 2022 found that synchronous and asynchronous telehealth physiotherapy is safe, feasible, and acceptable to adults with complex comorbidities and has comparable effects to in-person care activity.[42] Both reviews suggest that telehealth delivery increases access to exercise programs, especially for those who cannot travel to a treatment facility due to distance or disability.[38,42] Hawley et al. concluded that telehealth physiotherapy may increase adherence to exercise by providing increased prompts reminding patients when and how to exercise.[42]

The positive effects emerging in our meta-analysis favoring telehealth-led exercise intervention could be explained by their alignment with some behavior change techniques known to facilitate exercise adherence.[43] Several studies involved elements of monitoring and feedback where they were able to provide real-time feedback on individuals' levels of performance and offered clear instructions on how to perform the exercise.[26,27,29,32] These elements combined with professional support have been shown to increase exercise adherence.[43]

A set of key components for successful fall prevention exercise programs has been identified in community-dwelling adults.[4] Interventions that included an exercise dose of more than 3 h per week and included balance and strength exercises reduced falls by 34%.[4] However, adherence to in-person fall prevention exercise programs has previously been reported to be ∼50%.[44] In our review, we found that the adherence of exercise interventions delivered by telehealth was high (86%), but the exercise dose achieved was low (1.3 h/week). Future research could investigate how to utilize telehealth's high adherence to support increased exercise dose to improve physical outcomes.

This review highlighted the importance of providing staff and participant training to improve the chances of successful program implementation. The importance of technology training was also reported in a recent qualitative study where telehealth was used to enhance mobility and physical activity for older adults receiving rehabilitation services.[45] They found that patients engaged optimally with telehealth when they received sufficient training and support to use the technology and understood the potential benefits from using telehealth. Their study also reported the importance of sufficient therapist training to increase telehealth technology competence and overall program implementation.

Conclusions

This is the first systematic review and meta-analysis that provides a summary of the impact of telehealth on physical outcomes for older adults, 60 years of age and older, with mobility, frailty, and cognitive disabilities. We conducted this systematic review in accordance with PRISMA guidelines and followed a pre-specified protocol registered on PROSPERO. Furthermore, the controlled studies included were of sound methodological quality. However, due to the study heterogeneity and low number of controlled studies in this area, we were unable to uncover any significant finding. There was also insufficient follow-up data, which limited our ability to assess the long-term effects and sustainability of exercise interventions delivered through telehealth in this population.

Future RCTs are required to investigate the use and effects of synchronous different exercise programs delivered through telehealth, trials that investigate use effects of asynchronous telehealth versus asynchronous telehealth, trials that include cost-effective analyses, and trials that explore the implementation and sustainability of these telehealth interventions to ensure that wide scale uptake of telehealth in aged care is as safe, effective, and cost-effective as possible. Telehealth used to deliver evidence-based exercise intervention to our most vulnerable older adults has the potential to be an effective and acceptable addition to in-person exercise interventions.

Authors' Contributions

R.D., J.S.O., I.M.R., A.S., C.Y.C., M.B., and C.S. contributed to the study design, methods, and the refinement of the study protocol. All authors interpreted the results, and revised and approved the final article. All the authors fulfilled the ICMJE criteria for authorship.

Disclaimer

The funders had no role in the trial design and will not have any role during its execution, analyses, interpretation of data, or decision to submit results.

Disclosure Statement

No competing financial interests exist.

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Supplementary Material

Supplementary Table S1
Supplementary Table S2
Supplementary Table S3

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Supplementary Table 1: Search terms for Medline

#	Query	Results
1	aged.mp.	5,804,099
2	Aged/	3,334,085
3	older adults.mp.	35,090
4	older adult*.mp.	101,558
5	elderly.mp.	283,605
6	geriatric.mp.	84,093
7	Geriatrics/	30,971
8	seniors.mp.	8,407
9	(old* adj2 (men or women or female* or mal* or adult* or adults*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	391,100
10	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9	6,060,642
11	fall* prevention.mp.	4,369
12	balance exercise*.mp.	739
13	balance training.mp.	1,678
14	strength exercise*.mp.	1,003
15	strength training.mp.	6,043
16	(strength and balance exercise*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	261
17	resistance training.mp.	16,100
18	Resistance Training/	10,947

19	(strength and balance training).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	445
20	11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19	26,012
21	telehealth.mp.	9,761
22	telemedicine.mp.	41,402
23	Telemedicine/	32,611
24	telerehabilitation.mp.	1,645
25	Telerehabilitation/	736
26	telecare.mp.	858
27	ehealth.mp.	5,589
28	mhealth.mp.	7,208
29	tele-health.mp.	231
30	tele-medicine.mp.	169
31	tele-rehabilitation.mp.	254
32	tele-care.mp.	36
33	e-health.mp.	3,572
34	m-health.mp.	753
35	((remote* or distant or video) adj3 (consult* or monitor* or treat* or therap*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	20,843
36	21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35	70,231
37	10 and 20 and 36	111

Supplementary Table 2: RCT Trial results (n = 5)

Author	Outcome	Intervention		Control	
		Baseline	Post-trial	Baseline	Post-trial
Mobility					
Callisaya **(25)**	*Gait speed (m/sec)*				
		1.3±0.2	1.3± 0.2	1.22±0.17	1..21±5.8
Gandolfi **(29)**	*10m walk test (m/sec)*				
		1.6±-0.49	1.6±0.43	1.46±-0.42	1.60±1.01
Lauze **(27)**	*Short Performance Physical Battery test (n/12points)*				
		Change	1.0±1.3	Change	0.3±3.6
Li **(26)**	*Timed Up and Go - single task (m/sec)*				
		13.38±0.55	11/86±0.56	13.41±0.73	13.04±0.89
Vestergaard **(28)**	*Physical Performance test (n/36)*				
		16.3±5.6	18.1±5.8	17±4.8	17.4±5.5
Strength					
Callisaya **(25)**	*5 sit to stands (secs)*				
		11.2±4	11.9±6.4	9.9±3.4	9.7±5.8
Lauze **(27)**	*5 sit to stands (secs)*				
		Change	-2.1±2.3	Change	0.3±3.6
Li **(26)**	*30 sec sit to stands (n)*				
		11±1.0	13.07±0.8	11.4±1.12	11.6±1.06
Vestergaard **(28)**	*5 sit to stands (secs)*				
		19.3±11.6	14.1±8.5	16.4±5.3	16.3±6.2
Balance					
Callisaya **(25)**	*Step test (n)*				
		17.7±4.0	17.59±5.3	16.4±3.4	15.8±5.8
Gandolfi **(29)**	*Berg Balance Scale (n/56points)*				
		48.63±6.31	52.4±3.29	45.61±7.97	49.82±1.01
Li **(26)**	*4 Stage balance test (n/4points)*				
		2.39±0.49	3.13±0.52	2.47±0.52	2.53±0.52
QoL					
Gandolfi **(29)**	*Parkinson's Disease Questionnaire (PDQ)-8: lower score higher QoL*				
		30.7±15.5	24.2±14.8	30.5±16.0	24.2±15.9
Lauze **(27)**	*36 Item Short Form Health Survey (SF-36): higher score higher QoL*				
		Change	-0.7±7.7	Change	2.4±6.5
Vestergaard **(28)**	*EuroQol-visual analogue scales (EQ-VAS): higher score higher QoL*				
		59.8±21	59±16.2	62.1±17.4	60.4±16.7
Falls					
Gandolfi **(29)**	*Rate*				
		0.58	0.38	1.84	0.61
Lauze **(27)**	*Number*				
		NR	4	NR	0
Li **(26)**	*Number*				
			15		26

NR=not reported

Supplementary Table 3: Summary of the certainty of evidence (GRADE Quality assessment)

Meta-analysis	Downgraded				Overall
	Study limitations[1]	Inconsistency[2]	Imprecision[3]	Publication bias[4]	
Mobility	-	↓ (I^2 = 86%)	↓	↓	Very Low
Strength	-	↓ (I^2 = 84%)	↓	↓	Very Low
Balance	-	↓ (I^2 = 78%)	↓	↓	Very Low
QoL	-	- (I^2 = 0%)	↓	↓	Low

↓Downgraded
[1] >25% of participants from studies with low methodologic quality: PEDro score <6
[2] Heterogeneity > 60%
[3] Wide confidence intervals around the effect estimate
[4] Risk of publication bias due to small number of small trials
NB: We did not consider the indirectness criterion in this review as it encompasses a specific population with relevant outcome measures and direct comparisons

CHAPTER FIVE

Physiotherapy-led telehealth and exercise intervention to improve mobility in older people receiving aged care services (TOP UP): protocol for a randomised controlled hybrid type 1 effectiveness-implementation trial.

Chapter Five is published as:

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5.1 Statement of co-authorship

As co-authors of the manuscript "Physiotherapy-led telehealth and exercise intervention to improve mobility in older people receiving aged care services (TOP UP): protocol for a randomised controlled hybrid type 1 effectiveness-implementation trial", we confirm that Rik Dawson is the lead corresponding author and has made the primary contribution to this study in each of the following areas:

- Conception and design of the research
- Data Collection
- Data analysis and interpretation of findings
- Writing of the manuscript and critical appraisal of content

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Physiotherapy-led telehealth and exercise intervention to improve mobility in older people receiving aged care services (TOP UP): protocol for a randomised controlled type 1 hybrid effectiveness-implementation trial

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For 'Presented at statement' see end of article.

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ABSTRACT

Introduction Deteriorating mobility and falls reduce independence and quality of life for older people receiving aged care services. This trial aims to establish effectiveness on the mobility of older people, and explore cost-effectiveness and implementation of a telehealth physiotherapy programme.

Method and analysis This type 1 hybrid effectiveness-implementation randomised controlled trial will involve 240 people aged 65+ years receiving aged care services in community or residential settings. Participants will be randomised to either: (1) the Telehealth Physiotherapy for Older People (TOP UP) Program or (2) a wait-list control group. The 6-month intervention includes 10 physiotherapy sessions delivered by videocall (Zoom). The intervention will include the local support of an aged care worker and online exercise resources. Primary outcome is mobility at 6 months post randomisation measured by the Short Physical Performance Battery. Secondary outcomes include rate of falls, sit-to-stand, quality of life, and goal attainment at 6 months after randomisation. Regression models will assess the effect of group allocation on mobility and the other continuously scored secondary outcomes, adjusting for baseline scores. The number of falls per person over 6 months will be analysed using negative binomial regression models to estimate between-group differences. An economic analysis will explore the cost-effectiveness of the TOP UP programme compared with usual care. Implementation outcomes and determinants relating to the intervention's reach, fidelity, exercise dose delivered, adoption, feasibility, acceptability, barriers and facilitators will be explored using mixed methods.

Conclusion This is the first trial to investigate the effectiveness, cost-effectiveness and implementation of a physiotherapy intervention in aged care delivered solely by telehealth internationally. The study has strong aged care co-design and governance and is guided by steering and advisory committees that include staff from aged care service providers and end-users. Trial results will be disseminated via peer-reviewed articles, conference presentations and lay summaries.

Trial registration number The trial is registered with the Australian New Zealand Clinical Trials Registry (ACTRN 12621000734864).

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Telehealth physiotherapy is an effective health service in primary care.
⇒ Exercise programmes improve mobility for older people.

WHAT THIS STUDY ADDS

⇒ Establish the effectiveness of telehealth physiotherapy in aged care on mobility.
⇒ Explore the impact of online resources on exercise dose.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our implementation analysis will guide the adoption of telehealth physiotherapy in aged care.

INTRODUCTION

Older people receiving aged care services have a high prevalence of multimorbidities, dependency in activities of daily living and mobility limitations.[1] Mobility disability (ie, difficulty or inability to walk and transfer) is a common and a serious form of physical disability.[2] Mobility disabilities affect approximately 35% of people aged 70 years and older, and the majority of people aged over 85 years.[3] Mobility disability is predictive of adverse health outcomes, including death.[4]

Exercise is recommended for those who have mobility disability.[5] The 2020 update of the World Health Organisation's (WHO) physical activity guidelines call for older people to undertake 150–300 min/week of moderate-intensity activity, muscle strengthening and exercises targeting balance.[6] This 2020 update marked the release of specific guidelines for people living with disability.[7] These guidelines specify that people living with disability should, where possible, undertake the same amount and types of physical activity (including balance, functional strength and endurance activities) as is recommended for the general population.

Physiotherapists are well placed to deliver suitable exercise programmes for older people with mobility disability. Exercise-based interventions designed and delivered face to face by physiotherapists in aged care settings have been found to improve mobility.[8] However, in Australia, there is a lack of suitably-trained exercise professionals to deliver these interventions, particularly in regional areas.[9]

Telehealth could provide a cost-effective way to increase older people's access to physiotherapists and has been successfully used in other populations and contexts.[10] The WHO defines telehealth as the delivery of healthcare services where patients and providers are separated by distance and where health professionals use information communication technologies for the exchange of information for the diagnosis and treatment of diseases and injuries, education, research and evaluation.[11] The COVID-19 pandemic has rapidly accelerated familiarity with, and infrastructure required for, telehealth provision in aged care.[12] However, no randomised controlled trials to date have been designed to examine the effect or implementation of telehealth physiotherapy on mobility and falls for older people receiving aged care services.

To address this evidence gap, we will conduct a type 1 hybrid effectiveness-implementation randomised controlled trial to evaluate the effectiveness, cost-effectiveness and implementation of the Telehealth Physiotherapy for Older People (TOP UP) Program. The TOP UP Study tests a 6-month telehealth physiotherapy-led exercise programme, which aims to improve mobility compared with a wait-list control of usual care on older people aged 65+ years receiving aged care services in their home or in residential aged care. Additionally, we aim to measure the effects of telehealth physiotherapy on secondary outcomes of fall rate, sit-to-stand ability, health-related quality of life and goal attainment at 6 months. We will also evaluate the cost-effectiveness of the telehealth physiotherapy programme and if proven effective, explore implementation to guide future scale-up.

METHODS AND ANALYSIS

Study design and setting

We will conduct a two-arm parallel, pragmatic, type 1 hybrid effectiveness-implementation randomised controlled trial. Trial design is illustrated in figure 1. Trial and protocol reporting will be guided by the CONsolidated Standards Of Reporting Trials statement,[13] the Standard Protocol Items: Recommendations for Interventional Trials statement,[14] the Template for Intervention Description and Replication checklist)[15] and the Consensus on Exercise Reporting (CERT) guidelines.[16]

Participants

Inclusion criteria

People eligible for inclusion are aged 65 years and over; living in the community or residential aged care receiving Commonwealth-funded aged care services; willing to use a mobile tablet device to video-conference with a physiotherapist; willing to exercise for 2 hours/week; and have sufficient sensory, neurological, cognitive and English language skills for exercise and video-based interventions as determined by their aged care service provider.

Exclusion criteria

Potential participants will be excluded if they have severe cognitive impairment as measured by a score of ten or less on the Modified Telephone Interview for Cognitive Status[17]; are unable to walk 10 m with or without a walking aid; are currently participating in a balance and strengthening exercise programme designed by a physiotherapist; and have life expectancy less than 6 months as determined by their aged care service providers.

Recruitment and consent

The aged care services will generate a list of potential participants using a standardised screening form. Potential eligible participants will receive information about the study through written participant information sheets and will have the opportunity to talk to their aged service provider and/or research team. Eligible participants will be enrolled once they have signed the consent form. If a potential participant is considered by their aged care provider not to have full capacity to provide consent, the potential participant's person responsible will be asked to provide consent. Participants' General Practitioner will be sent a letter explaining their participation in the trial allowing the doctor to discuss any concerns with the research team and suggest withdrawal of participants from the study.

Randomisation

Participant baseline data will be collected before randomisation. Two hundred and forty participants will be randomly assigned (1:1) to either the telehealth physiotherapy TOP UP exercise programme or to the wait-list control group. The trial will use a centralised web-based randomisation system using Research Electronic Data Capture (REDCap) within The Sydney Local Health District license to ensure concealment of group allocation. A research investigator not involved in baseline assessment measures or recruitment of facilities will develop a randomisation schedule. They will use a computer-generated random number schedule with randomly permuted block sizes of two and four. Allocation to either the intervention group or the control group will be stratified according to the participants' place of

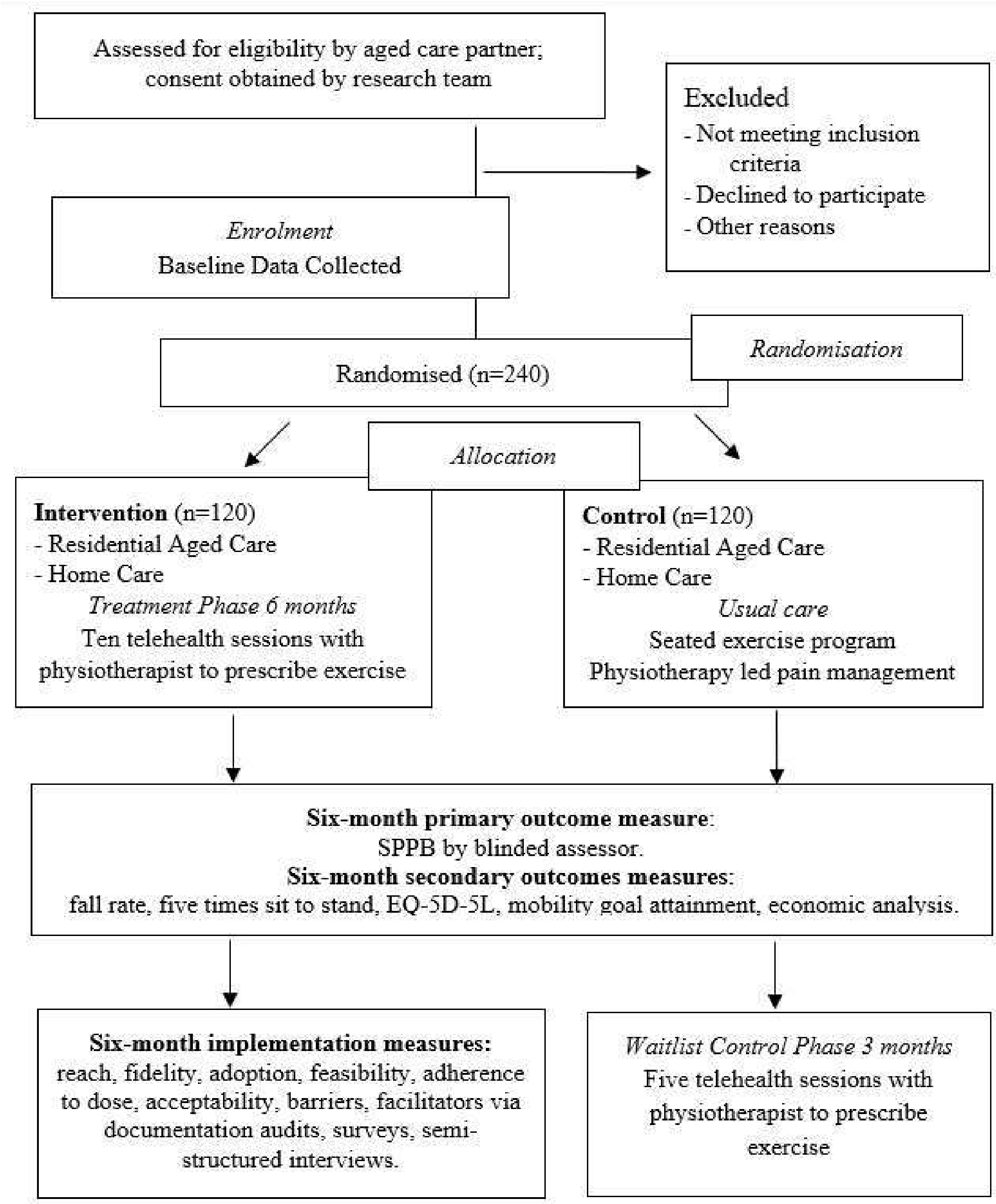

Figure 1 Trial design.

residence (at home receiving aged care services or living in residential aged care).

Intervention

The TOP UP Study will use telehealth to prescribe an individualised exercise programme, deliver health coaching and technology training by a physiotherapist supported and supervised by a trained care worker called TOP UP Coaches (TCs). A computer or tablet will be used in the physiotherapist sessions using the Zoom videoconference application, for access to the TOP UP a website where participants can follow several progressive strengthening and balance exercise videos produced by the research team, and access to the *StandingTall* exercise app that delivers progressive balance exercise.[18]

Participants allocated to the TOP UP exercise programme will be invited to participate in ten 30-to-60-minute physiotherapy assessments using Zoom over 6 months. The initial assessment occurs in week 1 with the subsequent assessments scheduled to occur weeks 3, 5, 7, 9, 12, 16, 20, 22 and 24. The sessions will be conducted by Australian registered physiotherapists who have a minimum of 3 years aged care experience. The physiotherapists will create an individualised, progressive exercise programme based on the Otago Exercise Program (OEP).[19] It will be delivered in the participant's

Table 1 TOP UP strengthening and balance exercises and programme levels

Seated warm up and cool down: seated marching 1 min, neck and trunk gentle rotations, upper limb gentle range of movement exercise including ×10 repetitions (reps) shoulder elevation, elbow and wrist flexion and extension, ankle dorsiflexion and plantarflexion ×10 reps				
Strengthening exercises				
Seated knee extension	All 4 levels Ankle cuff weights used to provide resistance to the muscles and 10 reps of each exercise per set: building up to 3 sets of 10, hold support as required			
Standing knee flexion				
Standing hip abduction				
Standing ankle plantarflexion	Level 1: 10 reps, hold support Level 2: 2×10 reps, hold support		Level 3, 2×10 reps, hold support	Level 4, 2×10 reps, no support
Standing ankle dorsiflexion	Level 3 10 repetitions, hold support, 2 sets		Level 4 2×10 reps, no support, 2 sets	
Standing balance exercises				
	Level 1	Level 2	Level 3	Level 4
Backwards walking		10 steps, 2 reps, hold support	10 steps, 4 reps, minimal support	10 Steps, 4 reps, no support
Walking and turning around		Walk in a figure 8 twice, use walking aid if required	Walk in a figure 8 twice, minimal support	Walk in a figure 8 twice, no support
Sideways walking		10 steps, 2 reps, hold support	10 steps, 4 reps, minimal support	Walk 10 steps, no supports, 4 sets
Tandem stance	10 s, hold support	10 s, hold support	10 s, minimal support	10 s, no support
Heel-toe walk			Walk 10 steps, minimal support, 2 sets	Walk 10 steps, no support, 2 sets
One-leg stand		10 s, hold support	10 s, minimal support	30 s, no support
Heel walking			Walk 10 steps, hold supports, 4 sets	Walk 10 steps, no support, 4 sets
Toe walking			Walk 10 steps, hold support, 4 sets	Walk 10 steps, no support, 4 sets
Heel-toe walking backward			Walk 10 steps, hold support, 2 sets	Walk 10 steps, no support, 2 sets
Sit to stand	5 reps, 1 to 2 sets, 2 hands for support	10 reps, 2 hands for support	10 reps, 1 hand leading to no hands, 2 sets	10 reps, no support, 2 sets

home or their residential aged care facility. The OEP is a series of progressive balance and lower limb resistive strengthening exercises that allows the treating physiotherapist to prescribe the level of intensity and pace of the programme. See table 1 for details of the exercise programme reported according to the CERT guidelines.[16]

Participants will be advised to complete up to 2 hours of exercise per week for the study based on previous research shown to improve mobility and reduce falls.[8] Exercise dosage will be prescribed to accommodate comorbidities and cognitive impairments to minimise the risk of harm and will be tailored at the initial and each subsequent assessment. Participants will be asked to complete 2–3 sets of 10 repetitions for each exercise at a self-determined 'moderate' intensity, defined as 12 to 14 out of 20 using the Borg Scale of Perceived Exertion and the intensity will be progressed by the physiotherapist accordingly.[20] The balance exercises will also be progressed by reducing hand support, reducing the base of support in standing, increasing the number of repetitions, and/or increasing the time in certain balance positions. Participants and TCs will record adherence to their exercise programme in an exercise diary that forms part of the participant booklet. More detail is provided in table 2.

Participants' exercise dose is supported using different exercise resources prescribed by the physiotherapist. These include following their exercise programme with an exercise booklet, following online pre-recorded 15–30-min exercise videos on the TOP UP website, participate in individual or group exercise programmes led by TCs or follow their exercise programme on the *StandingTall* app. Access to online exercise programmes and unsupervised exercise will be introduced after the treating physiotherapist has completed a risk assessment.

Behavioural change support

A key component of this intervention will be the behavioural change support delivered by the treating physiotherapist and TCs to each intervention participant over the trial period.[21] The research team will conduct a

Table 2 Intervention description using the Template for Intervention Description and Replication (TIDieR) checklist

Brief name	Telehealth physiotherapy-led exercise (TOP UP) Study to improve mobility in older people receiving aged care services.
2.Why	Older people receiving aged care services have a high prevalence of mobility disability and a high rate of falls. Physiotherapy-led exercise programmes that increase leg strength and challenge balance are proven to improve mobility and reduce falls. Telehealth is emerging as an effective method to deliver physiotherapy to improve access in regional areas and during COVID-19.
3.What materials	Participants allocated to the TOP UP exercise programme will be provided with a mobile tablet with internet connectivity to access Zoom, online exercise videos and the StandingTall app. Participants will receive a booklet comprising descriptions of their home exercise programme based on the Otago exercise programme, an exercise and falls calendar, ankle weights (1 and 2 kg), details on how to access and connect to the online exercise programmes, and balance support such as a sturdy dining chair, kitchen bench, parallel bars or wall bar.
4.What procedures	TOP UP physiotherapists will deliver balance and strength exercise prescription advice and health coaching using telehealth. Participants will be supported to access zoom to videoconference with a physiotherapist and aim to exercise for 2 hours/week supported by TOP UP Coaches (trained care staff of the participant's aged care service provider). The research team will provide the physiotherapists and TOP UP Coaches with a 2-hour training session on the study protocol at the beginning of the study.
5.Who provides	The intervention will be conducted by either the research team's physiotherapists or other registered physiotherapists employed by the study's aged care partners. All physiotherapists will have 3 years+ experience in working in aged care supervising care staff. TOP UP Coaches will be selected by the aged care service providers from their interested pool of care workers.
6.How	TOP UP Coaches will support the participant to gain access to the technology for the Zoom physiotherapy sessions, lead group exercise classes in residential aged care, and supervise weekly the individual exercise programmes using the participant exercise booklet, online exercise videos, and StandingTall app. Participants allocated to the wait-list control group will receive a similar 3-month intervention once the trial is completed.
7.Where	The TOP UP Study will be delivered in the participant's home or in the residential aged care facility where they live. Participants will be recruited from aged care service providers that deliver residential and home care services across metropolitan and regional areas in Australia.
8.When and how much	The 6-month intervention will include 10 Zoom sessions where the physiotherapists will devise moderate-intensity exercise programme and use health coaching principles to encourage participants to exercise for 2 hours/week. The participants can follow their exercise programme via exercise sheets in the participant booklet, follow 20–30 min exercise videos on the TOP UP website, attend group exercise programmes, or follow the StandingTall app. The programme will focus on standing balance and strength exercises. Participants will be provided with 30 min of supervised exercise with their TOP UP Coach each week to support the programme dose and safety.
9.Tailoring	The exercise programme will be tailored to the individual's capabilities and comorbidities by a physiotherapist at assessment and at subsequent assessments. The physiotherapist will introduce supervised and unsupervised exercise and introduce online exercise resources that challenge balance and lower limb strength when appropriate.

2-hour preintervention protocol training to treating physiotherapists and TCs informed by Michie's COM-B model (table 3) and relevant Behaviour Change Taxonomy techniques[22 23] to enhance participant's motivation to adhere to their prescribed exercise programme.

Wait-list control group

Participants allocated to the wait-list control group will continue with usual care regarding their exercise and physiotherapy programmes in the first 6-month phase of the trial. This will include any pain management programmes delivered as part of the Aged Care Funding Instrument, any seated group exercise classes or mobility programmes delivered by the aged care service. These participants will be offered a similar 3-month intervention after the follow-up assessment.

Data collection

Demographic data, questionnaires and physical assessments will be recorded by research physiotherapists blinded to group allocation at baseline and 6 months after randomisation. All outcomes will be assessed by research physiotherapists who will be trained in the conduct of the outcome assessment and are unaware of group allocation. Where face-to-face data collection is not possible, Zoom will be used with non-blinded TCs acting as local support under the supervision of the research physiotherapist to ensure safe and accurate data collection. Prior to the follow-up assessments, participants and TCs will be instructed not to inform the assessor of the their group assignment.

All intervention delivery costs including staff and equipment costs and all health service utilisation will be

Table 3 Trial intervention and the Capability,Opportunity and Motivation - Behavioural system (COM-B) for enhancing behaviour change[22 23]

Component	Definition	Behaviour change techniques
Capability	Individual's psychological and physical capacity for engaging with exercise and telehealth including knowledge and skills.	Goal setting: development of SMART goals (specific, measurable, achievable, relevant, and timely). Action planning: encourage participants what, when, how, where they will exercise to assist with habit formation. Self-monitoring: encourage participants to keep track of their exercise programmes through use of diaries. Graded exercise: ensure that programme is achievable and progressive.
Opportunity	Factors outside the individual that enable or prompt behaviour.	Behavioural rehearsal/prompt cues/repetition: provision of exercise videos to follow with repetitive and detailed physiotherapy exercise advice. Instructions on how to perform a behaviour: provision of telehealth equipment and training to access physiotherapy advice. Social support and reward: TCs to assist with safe exercise delivery and socialisation opportunities.
Motivation	Cognitive processes that energise and direct behaviour, that is, goals, decision-making, habits, emotional responses.	Feedback on exercise performance and behaviours/ celebrate programme success: physiotherapists to provide feedback on participants' performance, help them understand their progress and assist them to make necessary adjustments to their routine. Modelling: use of older people in printed and online exercise resources. Motivational interviewing/verbal persuasion: physiotherapist and TCs engage participants in a collaborative and empathetic conversation to strengthen their motivation and commitment to the exercise programme.

collected during the study period. The health service utilisation, falls and exercise data will be recorded by home care participants in their self-reported exercise diary and falls and health utilisation calendars. This data will be posted back to the research team by our aged care partners at the completion of the trial. In residential aged care this data will be recorded by TCs in the online documentation system. All data will be collected and uploaded into the REDCap database by a blinded member of our research team via auditing the participant's online medical records and calendars.

All qualitative data will be collected by experienced research assistants using questionnaires and semistructured interviews via zoom. The implementation data collection related to the intervention's reach, fidelity, dose delivered, adoption, feasibility and exercise adherence measures will be conducted by research assistants via audits of participants' exercise diaries and physiotherapy notes.

Outcomes

All outcomes will be measured in the intervention and control groups at baseline and 6 months after randomisation.

Primary outcome

Mobility will be measured by the 12-point *Short Physical Performance Battery (SPPB)* test score. The SPPB measures standing balance, gait (2.44 m timed walk), and timed sit-to-stand (five repetitions). The SPPB has predictive validity showing a gradient of risk for mortality, nursing home admission and disability.[24]

Secondary outcomes

The secondary outcomes will include: (1) rate of falls using the internationally recognised fall definition: 'an unexpected event in which the participant comes to rest on the ground, floor, or lower level, as a result of a loss of balance"[25]; (2) five times sit-to-stand test will be analysed as an standalone predictor of future disability in older people[26]; (3) quality of life will be measured by the EuroQol 5 dimensions five level health questionnaire (EQ-5D-5L) enabling participants to rate their level of impairment across mobility, self-care, usual activities, pain/discomfort, and anxiety/depression and give a global health rating on a visual analogue scale (EQ-VAS), the EQ-5D-5L was found to be a highly reliable and valid measure of the quality of life in older people with mild to moderate dementia[27]; and (4) individualised mobility goal attainment will be measured with the Goal Attainment Scale (GAS) where participants and/or their 'person responsible' will identify a key goal related to physical functioning, the GAS is recommended as a measure of relevant person-centred outcomes in the evaluation of complex interventions in older people.[28]

Cost-related outcomes will include intervention delivery costs (from study records, including staff salary, travel and equipment costs) and health service utilisation costs (from calendars and aged care documentation records) during the trial period.

Implementation outcomes and determinants will use quantitative and qualitative methods to gather data on the implementation of the intervention and to inform future implementation and scale-up if found to be successful. Implementation outcome measures included are: (1) reach (proportion of aged care recipients who were successfully screened, consented to participate and received the intervention with an exploration of their representativeness), (2) fidelity (the extent to which the different components of the telehealth intervention are delivered per protocol and monitored through audits of study-specific checklists), (3) dose delivered (the number and duration of physiotherapy telehealth and coach sessions provided to participants plus total exercise dose over the trial period), and (4) adoption (proportion of facilities who participate and factors associated with uptake). Implementation determinants related to feasibility are: (1) proportion and representativeness of participants that completed the intervention at 6 months; (2) proportion and representativeness of available participants that completed the primary outcome at 6 months, and (3) adherence to the prescribed dose (percentage of participants recording 2 hours of exercise per week on their exercise diaries over the trial period).

The acceptability, barriers and facilitators for implementing this telehealth exercise and education programme for older people will be explored with participants, physiotherapists, aged care workers and aged care service managers via surveys and semistructured interviews.[29] Up to 20 participants receiving the TOP UP intervention will be invited to participate in the interviews. We will sample participants purposively for maximum variation in (1) residence: home or residential aged care, metropolitan and regional, (2) age, (3) engagement with the intervention (as judged by the TOP UP coaches), and (4) sex: aiming for a distribution that reflects the male/female ratio in the intervention arm of the trial. We will interview up to 10 TOP UP coaches, 6–8 aged care managers and 6–8 physiotherapists involved in intervention delivery based in a range of aged care services and locations.

Adverse events such as a fall, musculoskeletal injury, or cardiovascular event that may, or may not, be related to the intervention but occurs while the person is participating in the intervention will be monitored via records kept by our aged care partners and by the participants in their self-report exercise diaries at 6 months. This information will be reported in any publications. A serious adverse event (SAE) will be defined as an incident that occurs while the person is participating in the intervention resulting in serious injury, hospitalisation or death.

If a SAE occurs, the research manager will notify the Data and Safety Monitoring Board (DSMB). The DSMB, consisting of two independent clinical experts and a statistician, will be convened to monitor SAE within 48 hours, where policies and procedures around the programme will be reviewed, and recommendations implemented. This assessment will guide the continuation of the research, including a temporary halt or early termination of the trial, ensuring ethical conduct of the study.

Data management

We will use a custom-built and secure REDCap database. All study documentation will be stored securely in either locked filing cabinets (paper files) or electronically (electronic database files) with access granted only to authorised study team members. Logic and range checks will be used to minimise data entry errors and to identify missing data and other problems. To ensure confidentiality, the final dataset will contain deidentifiable information only. All publications associated with the study results will involve deidentified data to maintain participant confidentiality. Demographic information linking the participant to the data will be stored in a separate file. Only the principal investigator will have access to this information after the study.

Sample size

A total of 240 participants (120/group) will provide 80% power to detect a 0.9 point between-group difference in 12-point SPPB scores at 6 months (assuming SD of 2.8, p=0.05, and 20% dropouts). A 0.5 point between-group difference in SPPB is considered to be clinically significant.[30] This sample size is expected to be sufficient to detect between-group differences of 10–15% for the secondary outcome measures. These calculations used the *sampsi* command in Stata V.13 and PASS V.13 and allow for a 20% loss to follow-up.

Data analysis

The primary analysis will be based on an intention-to-treat approach. The primary effectiveness outcome will be assessed as a change in participants' mobility using the SPPB. It will be treated as a continuous variable. The effect of group allocation on the outcome at 6-month follow-up will be analysed using linear regression models with baseline scores entered into the linear regression model as a covariate. Alternatively, if distributions are overly skewed (on visual inspection of histograms), the change scores (post-pre) will be analysed. The number of falls per person year will be analysed using negative binomial regression models to estimate the between-group difference in fall rates after 6 months with exposure entered as the offset variable.[31] The other secondary continuous outcomes (five times sit-to-stand test and EQ-5D-5L) will be analysed using regression models with baseline variables as covariates as described for the primary outcome.[31] Ordinal regression will be used to compare groups on the GAS.

Prespecified subgroup analyses will use interaction terms (group × outcome) in the model to explore whether there is a differential effect of the intervention in residential aged care facilities versus community-dwelling residents and in those with more marked cognitive impairment. Secondary analyses using causal modelling maybe conducted to establish intervention effects in people with greater exercise dose.[32]

Cost-effectiveness will be explored as the cost per extra person avoiding mobility deterioration as defined as an improvement or no change in the 12-point SPPB score between baseline and 6 months. Cost-effectiveness analysis may also be conducted on falls (ratios will be calculated relative to the control group for the incremental cost per fall avoided per person) and the quality-adjusted life year (QALY) gained (calculated from EQ-5D-5L). Bootstrapping will estimate a distribution around costs and health outcomes and calculate the CIs around the incremental cost-effectiveness ratios. The results will be plotted on the cost-effectiveness plane, and as cost-effectiveness acceptability curves. These methods have been used previously when calculating the incremental cost-effectiveness ratios for exercise programmes for older people.[33]

A detailed analysis of the implementation outcomes relating to the intervention's reach, fidelity, dose delivered, adoption, feasibility and exercise adherence measures will be conducted. This data will be presented numerically and descriptively.[34] Thematic analysis will be conducted for interview data.[35] We will use the NASSS framework (Nonadoption, Abandonment and Challenges to the Scale-Up, Spread and Sustainability of Health and Care Technologies) to provide a conceptual 'lens' that will inform our implementation analysis. NASSS consolidates multiple implementation frameworks and empirical studies, targeting key issues relating to implementation and uptake of telehealth at the microlevel of individual staff and consumers, the mesolevel challenges of organisational engagement and adoption, and macrolevel policy and regulatory factors.[36]

Patient and public involvement

The rationale, trial design and intervention content were informed by older people receiving aged care services and their advocates, aged care physiotherapists and aged care service providers via several online forums and many formal and informal meetings and conversations. Staff of aged care service provider organisations assisted with recruitment of participants for the research through direct communications within their organisations.

Governance

The trial will be governed by a project steering committee, consisting of representatives from our aged care partners not directly linked to research activities, an independent consumer advocate and the study investigators. The committee will be chaired by a member of the research team. This committee will facilitate consumer and aged care input into the study, oversee the study protocol and data analysis, support results translation and be involved in the development of the resources at the end of the study period.

CONCLUSION

This study addresses the international public health challenge of preventing mobility decline in older people. Deteriorating mobility is common and costly in older people receiving aged care services. The increasing cost of ageing and dementia care services means that there is an economic imperative for governments and service providers to support treatment innovations such as telehealth to ensure that older people have equitable access to appropriate and effective care.[37] This study is the first known randomised controlled trial to rigorously examine the evidence about the effectiveness, cost-effectiveness and implementation of a telehealth physiotherapy-led exercise programme to improve mobility, reduce falls and improve the quality of life in older people receiving aged care services in their home or residential aged care.

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Presented at
Not applicable.

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CHAPTER SIX

Engaging stakeholders: Co-design in the development of the TOP UP trial

Preamble

This chapter describes the co-design process of the TOP UP trial, including an overview of the collaborative input from stakeholders that contributed to the implementation of the TOP UP intervention.

6.1 INTRODUCTION TO CO-DESIGN

The ageing population is experiencing an increase in disability rates, with frailty often as a precursor to disability.[1] This was exacerbated by the COVID-19 pandemic during which social distancing measures led to increased physical inactivity in older adults, worsening frailty and disability progression.[2 3] Multicomponent lifestyle interventions that include exercise have been shown to be effective in reducing frailty and mobility disability.[4] However the availability and reach of these interventions is limited.[5]

Telehealth exercise programs have emerged as a viable alternative to traditional face-to-face approaches, showing promise in increasing physical activity levels among older adults.[6] However, barriers to the adoption of technology in older adults and in different care settings persist.[7] Implementing telehealth interventions for older adults is complicated by challenges such as limited digital literacy, variable access to technology and physical and sensory impairments.[7] Despite these challenges, there is scant research guiding the adoption and sustainability of telehealth programs aimed at promoting physical activity in aged care.

There are increasing calls for researchers to use co-design methods to bridge the digital divide and create sustainable telehealth programs that enhance the wellbeing and independence of older people.[8] Co-design with older people has shown to be critical for gaining a comprehensive understanding of their specific needs and challenges and for identifying solutions which can safely address age-related barriers to telehealth.

Co-design, as evidenced by a comprehensive 2020 systematic review, encompasses a spectrum of activities across research methodologies.[9] The review identified varied terminologies, scopes, and theoretical focuses within trials, yet common steps for stakeholder involvement emerged. These steps include stakeholder identification, partnership establishment, collaborative research question formulation, co-design forums, method development, feedback loops, ongoing monitoring and evaluation, data analysis, knowledge translation, dissemination, and sustained engagement for scale-up.

Co-design steps are as follows:

1. Identify stakeholders: Engage diverse stakeholders, including community members, partner organisations, and field experts, aligning their knowledge and resources to enhance research outcomes.[10]
2. Build partnerships: Foster genuine and active partnerships with stakeholders, establishing collaborative and respectful relationships throughout the research process.[11]
3. Define and test research questions: Collaboratively identify relevant research questions aligned with stakeholders' concerns and research goals.[12]
4. Host co-design forums: Organise workshops where researchers and stakeholders collaboratively shape research objectives, trial resources, and refine implementation strategies through open dialogue.[13]
5. Develop research methods: Co-design research methods, incorporating stakeholders' input in selecting appropriate data collection and analysis techniques for the specific research context.[14]
6. Create a feedback loop: Establish communication channels for ongoing stakeholder input on research implementation, responding to emerging findings and recommendations.[15]

7. Ongoing monitoring and evaluation: Implement mechanisms for continuous monitoring and evaluation of interventions, adjusting based on stakeholder feedback to ensure relevance and responsiveness.[15]
8. Data analysis: Involve stakeholders in data analysis and interpretation, deriving meaningful insights that resonate with their lived experiences.[16]
9. Knowledge translation: Involve stakeholders in data analysis and interpretation, deriving meaningful insights that resonate with their lived experiences.[17]
10. Dissemination: Discuss strategies for sharing research findings with the broader community, utilising co-authored publications, reports, presentations, workshops, or other suitable means.[18]
11. Sustain engagement for scale-up: Maintain ongoing stakeholder engagement beyond project completion, fostering continued collaboration and deeper understanding of evolving community needs.[19]

Co-design ensures participatory and inclusive research, yielding more relevant and impactful outcomes.[9] This chapter focuses on the co-design activities employed by the research team in developing the TOP UP intervention, with a specific emphasis on the co-design of the implementation mapping process.[20] Implementation mapping in co-design research refers to the systematic process of planning and detailing how a designed intervention or innovation will be put into practice.[21] It involves identifying the key components of the intervention, understanding the context in which it will be implemented, and mapping out the steps and strategies needed for successful execution. This mapping process ensures that the designed solution is effectively translated into real-world settings, considering the specific needs, resources, and challenges of the target environment. The objective of this chapter is to describe the application of co-design principles in the development of the TOP UP trial.

6.2 TOP UP'S CO-DESIGN ACTIVITIES

The TOP UP intervention and implementation plan was guided by Fernandez's implementation mapping process,[21] the Integrated Knowledge Translation (IKT) model[22] [23] and the Nonadoption, Abandonment, and Challenges to the Scale-Up, Spread, and Sustainability (NASSS) framework.[24]

Implementation mapping is used to improve adoption, implementation, sustainment, and scale-up of interventions.[25] Implementation mapping involves five tasks: (1) conduct an implementation needs assessment and identify program adopters and implementers; (2) state adoption and implementation outcomes and performance objectives, identify determinants, and create matrices of change objectives; (3) choose theoretical methods (mechanisms of change) and select or design implementation strategies; (4) produce implementation protocols and materials; and (5) evaluate implementation outcomes.

IKT is a collaborative approach that involves engagement of "knowledge users" or stakeholders as active participants in the research process. IKT aims to ensure that research findings are relevant, applicable, and useful to those who can benefit from them, leading to more effective and efficient knowledge translation from research into practice and policy. TOP-UP was co-designed by 1) older people with lived experience and their loved ones, who bring firsthand knowledge of how to create a model that meets their needs, 2) aged care provider managers and care staff who understand the barriers and facilitators of delivering high quality care, 3) clinicians who understand the benefits and technical requirements of exercise and the barriers to integrating it in the aged care setting, and 4) leading researchers in falls and ageing with strong track records in development, evaluation and implementation of exercise programs.

The NASSS framework is a comprehensive model developed to analyse and understand the complexities involved in the adoption and implementation of healthcare technologies. It provides a structured approach to assess the Non-Adoption, Abandonment, Scale-up, Spread, and Sustainability of technologies within healthcare systems. The framework considers various factors and contexts, including technological, social, organisational and policy-related aspects, to evaluate the success and challenges associated with implementing healthcare technologies. By addressing the messy multifaceted nature of technology adoption, the NASSS framework offers valuable guidance for researchers and healthcare professionals seeking to implement and sustain technology-based interventions in healthcare settings [24]

TOP UP used a co-design implementation mapping process that was a hybrid of Fernandez implementation mapping process and the NASSS framework and strengthened through the IKT approach.

Stage One: pre-trial

1. Implementation needs assessment to identify TOP UP adopters and implementers: The research team met to discuss potential stakeholders and developed an expression of interest letter for these possible stakeholders (Supplementary File 1). After an initial phone or Zoom conservation, aged care service providers including care workers staff, experienced aged care physiotherapists, members of the research institute's consumer forum including aged service users and their families from both the residential and home care settings, and other aged care researchers from different disciplines were invited to a series of Zoom workshops. The initial workshop was held in October 2020 and where Implementation Needs Assessment was conducted. This meeting discussed the research objectives and the potential requirements and challenges associated with implementing TOP UP. The goal of

this workshop was to understand the factors that may influence the successful adoption and integration of TOP UP. This assessment gave the research team useful insights into the specific needs (physiotherapists, aged care staff and aged care administration), resources (printed and online), and potential barriers (staffing shortages during COVID breakouts) that must be addressed during the implementation process.

2. Explore program barriers and facilitators and develop trial resources: Between November 2020 to May 2021 the research team had fortnightly meetings with potential aged care services providers (n=5) that included local facility managers and care staff and gave us the opportunity to develop viable research partnerships. We also convened four consultation workshops with physiotherapists (n=10), care workers (n=5) and people with lived experiences (n=10). The aim of these consultation processes was to use the principles of IKT to better understand the needs of the aged care community regarding the existing barriers and facilitators to existing mobility and fall prevention exercise program. We used these workshops to strengthen our relationship with our aged care research partners, further refine our research question, trial methodology, data collection/analysis and design, design and test our trial resources such as the Participant Information Sheet and Consent Form (Supplementary File 2), TOP UP Exercise Booklet (Supplementary File 3), Health Service Utilisation and Fall Diary (Supplementary File 4), exercise videos and website (https://www.physiotopup.com/).

3. Review of existing literature**:** The research team conducted a review of existing exercise and telehealth literature to identify evidenced-based interventions that have been successful in addressing similar health concerns in similar contexts with older people and those with disability. Findings from Chapter Two and Three were discussed with our stakeholders and

formed the foundation for the TOP UP intervention protocol in Chapter Six and our successful ethics application in May 2021. See Appendix 2.

4. Co-design implementation mapping**:** In the pursuit of enhancing intervention implementation strategies, the TOP UP intervention was developed following an in-depth mapping process utilising NASSS framework, a comprehensive model spanning seven distinct domains. This approach was undertaken during the pre-trial stakeholder workshops, where stakeholders actively contributed to identifying context-specific barriers and formulating facilitators. The objective was to enhance the feasibility of the intervention and ensure its successful implementation within the complex landscape of aged care, with particular emphasis on the challenges posed by the COVID-19 pandemic. Through iterative dialogue, these identified barriers were scrutinised, and potential facilitators were integrated into the TOP UP trial protocol. For detailed insights, please refer to Box 1**.**

5. Preparing for implementation outcomes evaluation and research translation: In the context of the TOP UP trial, stakeholders actively contributed to the development of our recruitment strategy and qualitative evaluation process methodology. Stakeholders agreed that a robust cost-effectiveness evaluation methodology is required to support strategic policy arguments in favour of telehealth physiotherapy interventions in aged care, and advocating for funding if the TOP UP intervention proves effective and acceptable. Moreover, stakeholders engaged in discussions regarding potential dissemination strategies and opportunities for scaling the intervention if it demonstrated acceptability, safety and effectiveness. Addressing these challenges is fundamental facilitate the widespread adoption and long-term sustainability of telehealth solutions post-research phase.[26]

Box 1: TOP UP intervention and implementation mapping using the NASSS framework

Domain	**Definition of domain**	**Implementation guidance derived from our knowledge stakeholders**
The condition	The suitability of the participant's attributes and their interaction with the intervention.	All stakeholders reviewed the development of information sheets, participant manual, exercise video scripts and video footage to ensure that it used senior-friendly text, language and visuals as well as being clinically feasible.
The technology	Technical features related to the usability of telehealth and its support requirements.	-Keep the website design simple and intuitive. -Use large, easy-to-read fonts and high contrast colors for better readability. -Organise content logically with clear navigation menus and labels. -Use clear headings and subheadings to break down content into easily digestible sections. -Provide clear instructions for each exercise, accompanied by step-by-step videos. -Include variations or modifications for different fitness levels and abilities.
The value proposition	The value proposition of telehealth for upstream end users (service providers) and downstream users (clinicians and their clients).	-Development of the participant information sheet to maximise the interventions uptake during recruitment -Development of educational videos stored on the TOP UP website and training videos for coaches to maximise intervention adherence
The adopter system	The ongoing investment required to support the telehealth intervention and the ongoing acceptability of stakeholders.	-Ensure sufficient time for coaches to support participants and receive training. -Support feasibility by identifying sites with >5 possible participants, ensure sites had sufficient capacity from support staff and registered nurses. -Ensured all participants had safe and secure space to conduct the Zoom physiotherapy assessments.
The organisation	An organisation's capacity to embrace the telehealth intervention and the supports required to establish and maintain it as a viable service offering.	-Stakeholders encouraged the research team to develop a research timeline that included organisational support for recruitment, baseline assessment, coach training and trial implementation ensuring that all steps were culturally safe for potential participants. -Aged care partners provided funds to purchase sufficient iPads and mobile connectivity to commence the trial
The wider context	The wider organisational and policy impacts on telehealth uptake and sustainability.	The stakeholders reviewed processes that: -Developed reimbursement processes, reviewed telehealth and privacy regulations, tested telehealth systems before commencement of trial. -Consulted with site management to ensure that there was no burden on staff and participants.

Stage Two – during the trial

The successful implementation of telehealth interventions in aged care settings demands continuous adaptation to the unique challenges within this context. Throughout the TOP UP trial, a proactive approach was taken to address emerging challenges and optimise trial fidelity. This process was guided by two key committees.

The Project Steering Committee (PSC) comprises of two representatives from aged care partners not directly involved in the research, one independent consumer advocate, and two study investigators, met quarterly via Zoom from May 2021. During these meetings, the research team provided updates on project milestones, comparing them with actual progress. Identified barriers were discussed, and implementation solutions were devised and documented. A dedicated agenda item focused on risk management and adverse event reporting was a standing feature of these sessions.

The Aged Care Partner Project Committee (ACPPC) consists of representatives from TOP UP's aged care and physiotherapy partners, working alongside TOP UP's lead researcher, Rik Dawson. This committee convened monthly via Zoom to deliberate on the trial's implementation strategies and data collection processes. Importantly, it served as a vital feedback loop,[15] enabling aged care partners to communicate challenges faced by participants engaging with the intervention. This platform allowed prompt reporting of adverse events to the PSC and also facilitated modifications to trial resources to enhance participant engagement and the development of novel trial resources. Examples of these outputs include:

i. Enhanced exercise videos: Both trial participants and physiotherapists expressed the need for additional exercise videos. Specifically, there was a demand for videos featuring seated options, slower exercise routines tailored to individuals with cognitive and neurological impairment such as Parkinson's Disease, and the incorporation of upper limb exercises. These suggestions aimed to create a more inclusive and comprehensive exercise program to cater to the diverse needs of the participants.

ii. Advanced training for TOP UP coaches: TOP UP coaches identified a requirement for further education in motivational interviewing techniques and behaviour change strategies. This input highlighted the importance of equipping coaches with advanced skills to effectively engage with participants, motivate them to exercise and facilitate positive behavioural changes. Additionally, staff in intervention sites noted that more coaches needed to be trained during the trial's implementation due to the impact of COVID-19 on staff availability to support the intervention.

iii. Co-design of trial results summary documents (Supplementary File 5): Aged care partners and various participants led the co-design of trial summary documents in order to ensure maximum clarity and comprehension for the participants involved in the trial. By involving multiple perspectives, these documents were more thoughtfully crafted to be accessible and informative (answering the questions that stakeholders, rather than researchers, prioritise), thereby enhancing participant understanding and engagement.

These committee consultations facilitated continuous dialogue between stakeholders which provided a structured mechanism for addressing challenges in real-time. This collaborative problem-solving approach significantly contributed to the successful implementation and fidelity of the TOP UP trial within the complex landscape of aged care settings, as well as the development of more tailored and participant-centred trial resources described above.

6.3 TRIAL PROGRESS

The recruitment for the TOP UP trial concluded in February 2023, with final follow-up data collection completed in November 2023. Throughout the trial, various challenges, including COVID-19 lockdowns and floods, tested recruitment and fidelity efforts. The research team attributes the trial's high level of acceptability and successful implementation outcomes to the co-design approach.

The co-design approach enabled the TOP UP research team to sign clinical trials agreements with eight aged care partners. Through these partnerships over 27 sites agreed to participate in the TOP UP trial. A total of 1348 aged care services across 27 sites were screened by TOP UP's aged care partners. The trial demonstrated robust adoption, with 242 services consenting to participate from an eligible pool of 512 participants. At the six-month primary outcome follow-up assessment, 191 participants remained available for follow-up, highlighting the high feasibility of TOP UP. Trial median exercise dose was 29 hours (range 8 to 75), which reflects the dose proposed in the ICA and QCA. There was only one recorded adverse event recorded during the trial with one participant experiencing a fall while exercising with no reported injuries. Participants were surveyed at the end the intervention, with a specific inquiry regarding whether they would endorse telephysiotherapy to individuals similar to themselves. Noteworthy is the fact that most participants, except for five, expressed a willingness to recommend telephysiotherapy (TOP UP) to others. Additional insights into implementation will be further investigated in 2024.

6.4 DISCUSSION

The development and implementation of the TOP UP intervention in aged care settings was grounded in a co-design approach, guided by the Integrated Knowledge Translation (IKT) [22 23] and Fernandez implementation mapping process.[21] This chapter explores the process of co-design that the research team undertook, led by Rik Dawson. It highlights the involvement of diverse stakeholders and the utilisation of established frameworks to address challenges and optimise the intervention's effectiveness. The co-design process involved older people with lived experiences, aged care providers, clinicians and leading researchers with multidisciplinary skills. Fernandez's implementation mapping process guided the co-design activities while the IKT framework was instrumental in promoting active engagement of stakeholders, facilitating collaboration, and aligning research questions with stakeholders' concerns while the. Similarly, the NASSS framework, encompassing technological, social, organisational, and policy-related aspects, provided a structured approach to considering the different dimensions of implementing and evaluating the complexities of telehealth interventions in aged care settings.

In the pre-trial phase, stakeholders were identified through consultations and workshops, fostering partnerships and were invited to participate in an intervention needs assessment and refine research questions and methodology. A comprehensive literature review informed the intervention protocol, ensuring evidence-based practices were embedded in the intervention. Utilising the NASSS framework, barriers and facilitators specific to aged care were identified and integrated into the implementation plan. Informed by the IKT model stakeholders actively contributed to the co-design process, resulting in the development of tailored trial resources such as enhanced exercise videos and extensive staff education.

The co-design process faced challenges, including technological usability and organisational readiness. Stakeholders collaborated to address these challenges and assisted to develop user-friendly telehealth interfaces, senior-friendly written resources and organisational support for recruitment and trial implementation. This commitment to the trial was grounded in sound partnerships. Feedback loops were established in the trial's governance committees, facilitating ongoing communication and adaptation based on stakeholders' inputs.

A recent mixed methods study, akin to TOP UP, employed co-designed implementation strategies to deliver a feasible digital community-based exercise and education program targeting frail older adults.[27] The study focused on optimising telehealth interventions for physical activity in community-dwelling older adults through a co-design process, using Zoom stakeholder workshops for collaborative dialogue. Their approach stressed the development of digital health-literacy training, educational sessions to enhance self-efficacy, and digital literacy for participants. Recommendations included training health professionals in digital skills, emphasizing the importance of social and community support for technology adoption among older adults, and addressing potential digital divides through local networks or family assistance.[27]

The adaptive co-design process employed by TOP UP played a pivotal role in optimising the acceptance of the intervention, as detailed in Chapter Seven's qualitative analysis. Moreover, the ongoing implementation, as indicated by emerging implementation outcomes, suggests the potential feasibility of this approach. We anticipate that the tailored co-designed methodology utilised by TOP UP across residential and home care settings will contribute to heightened acceptance and utilisation of its implementation strategies among prospective aged care service providers, physiotherapists, and older individuals, if the intervention proves effective.

6.4 CONCLUSION

This chapter highlights the necessity of ongoing collaboration and adaptability to address challenges and optimising outcomes in real-world settings. The acceptability and feasibility of the TOP UP trial in aged care settings was enhanced by a careful co-design process, engaging diverse stakeholders and utilising established implementation frameworks. The collaborative endeavours yielded a participant-centred approach, effectively addressing the complex needs of the aged care population. This cooperative approach has not only facilitated the implementation of TOP UP but also holds the potential to foster widespread adoption should the intervention prove effective. TOP UP demonstrates the pivotal role of co-design in crafting a telehealth solution that could truly make an impact.

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Supplementary File 1: Stakeholder Expression of Interest letter

Date:

Dear [Recipient's Name],

I hope this message finds you well. My name is Rik Dawson, and I am reaching out to you on behalf of the University of Sydney, specifically from the Sydney Musculoskeletal Health (Sydney MSK) at the Institute for Musculoskeletal Health (IMH). As a titled Gerontological Physiotherapist I have dedicated a significant portion of my career to improving the lives of older Australians in residential and aged care settings.

Our shared interest in enhancing the health and wellbeing of the elderly in our community has led myself and some other researchers to develop an innovative project called TOP UP. We envisage that the TOP UP project will be a co-designed telehealth program aimed at delivering virtual physiotherapy and health coaching services. Our goal is to enhance the safety, cost-effectiveness, and acceptability of physiotherapy and health coaching programs tailored for residents in aged care.

The TOP-UP app would like to address key concerns related to falls prevention and mobility improvement among older Australians who might face challenges accessing in-person services. We firmly believe that the TOP-UP project could address the accessibility issues faced by aged care residents, particularly those residing in rural areas or dealing with frailty. The evidence supporting the effectiveness of physiotherapist-prescribed exercises in preventing falls and injuries among aged care residents underscores the importance of our initiative.

I am writing to extend a warm invitation to you (your organisation) to meet with us. During this meeting, I would be delighted to share our vision for the TOP-UP project and discuss how it can significantly improve the lives of aged care services users. Moreover, I am keen to gain insights into aged care physiotherapy from your unique perspective.

We are flexible in terms of meeting arrangements and can meet in person at the University of Sydney Campus or via Zoom, whichever is more convenient for you. Additionally, we are more than happy to come to your offices or home if that proves to be more accessible for you.
I believe that by combining our expertise and resources, we can make a substantial difference in the lives of older Australians in residential aged care. I am looking forward to the opportunity to collaborate and create a positive impact together.

Please feel free to reach out to me at [Mobile] or [Email Address] to schedule a suitable time for our meeting. Thank you for considering our invitation, and I am excited about the prospect of working together for the betterment of our community.

Warm regards,

Rik Dawson

Gerontological Physiotherapist

Institute for Musculoskeletal Health (IMH) University of Sydney

BAppSc. (Phty), B.Ca., GAICD

Supplementary File 2: TOP UP Participant Information sheet and Consent From

Participant Information Sheet

Study Title	**A physiotherapy led telehealth and exercise intervention to improve mobility in older people receiving aged care services: an effectiveness and implementation randomised controlled trial**
Short Title	The TOP UP study
Project Sponsor	Sydney Local Health District and (insert ACP), this study is being funded by The Institute of Musculoskeletal Health.
Coordinating Principal Investigator	Professor Catherine Sherrington
Associate Investigator(s)	Mr. Rik Dawson, Dr Marina Pinheiro, Professor Vasi Naganathan, Dr Morag Taylor
Locations	TBA

1 Introduction

You are invited to take part in a research study looking at how telehealth can be used with physiotherapy to improve your walking, reduce your risk of falls, and improve your overall health. Telehealth means receiving a physiotherapist exercise program on-line via an iPad or a similar video-conferencing device.

We believe that you would be a suitable person to see if telehealth is effective and whether you would recommend it to anyone in the future. This Participant Information Sheet tells you about the research study. Knowing what is involved will help you decide if you want to take part in the research. Please read this sheet carefully or ask someone to read it out to you and ask questions about anything that you don't understand or want to know more about.

Participation in this research study is voluntary. By giving your consent to take part in this study you are telling us that you:

- Understand what you have read and agree to take part in the research study

- Agree to the use of your personal information as described.

2 What is the purpose of this research?

Research has shown that physiotherapy can improve older people's walking, reduce their risk of falls and improve their overall health. This study is designed to see if receiving physiotherapy while using an iPad or other devices is as effective as face-to-face sessions, has a cost benefit and helps older people do their exercise more easily.

The study is being carried out by the following researchers:

- Professor Cathie Sherrington, Dr Marina Pinheiro, and Professor Vasi Naganathan from the Insitute of Muscuolskeletal Health, The University of Sydney; Dr Morag Taylor from NSW University; and Mr. Rik Dawson.
- Rik is an experienced aged care physiotherapist and is conducting this study as the basis for his degree of Master of Philosophy at The University of Sydney. This will take place under the supervision of Professor Sherrington and Dr Pinheiro.

3 What does participation in this research involve?

Anyone aged 65 years or older who is able to walk at least 10 metres with or without a walking aid can join the study. We will ask you to exercise for 4 days per week for up to 30 minutes each time. We will help you to use the technology safely with confidence.

You will be asked to answer some questions to make sure you are the right fit for this study. For example: how old are you? Do you have any difficulty walking? You will also be asked to sign the consent form at the end of this form where you agree to participate in the study.

You will be asked to participate in some research activities that will take no longer than 60 minutes each time. These include:

- assessments of your ability to stand up, your standing balance, and, to walk short distances at the beginning and end of the study.
- answering a short survey about your general health called the EQ-5D-5L and your experience with telehealth at the end of the study.

- keeping a record of your exercise program, any falls, and any other side effects you may have throughout the study. Please let the research team know if you need help with this.

The study will go for 6 months and during that time you will be asked to:

- talk to a physiotherapist using an iPad or another device and get some advice about how you exercise and walk.

- follow some balance, walking and strengthening exercise programs that we will provide in a booklet and on-line that you can access via the TOP UP website.

- talk to one of our physiotherapist 10 times over the study. You will also have their phone number so you can call them anytime and ask them questions about your physiotherapy program.

- participate in a 60-minute interview once the study is over.

- there is no ongoing participation once the 6 months is completed.

You may be asked to have your photo taken and video recording of you exercising with the physiotherapist throughout the study, however this is not essential to be part of the study. The final interview will need to be audio recorded and transcribed by a computer transcription service and reviewed by members of the research team to review the interview later.

The results of the study will be included in newspaper articles, scientific journals and presented at National and International Conferences. You will not be identifiable in any of these publications.

If you agree to take part in the study, you will either start the telehealth intervention straight away in Group 1 or wait six months and start in Group 2. We will use a computer to randomly pick what group you will in. Random allocation is like the flip of a coin, there is an equal chance of you being allocated to either group.

The results of the telehealth intervention in Group 1 will be compared to the results of Group 2 who will continue with their usual care for the first 6 months.

There will be no additional costs associated with participating in the TOP UP Study, nor will you be paid. All physiotherapy will be provided to you free of charge as will the telehealth technology needed during the study if you don't already have a suitable device.

We will contact your Doctor to let them know that you have decided to participate in this research.

4 What do I have to do?

If you are allocated to Group 1 during the study, you will begin using the telehealth devices for your physiotherapy sessions and follow your physio exercise program using the Participant Booklet and the online exercise programs.

If you are allocated to Group 2, you will have to wait until the first six months has passed before you can start the TOP UP physiotherapy program.

Both groups will need to keep a record of their exercise habits and any falls in the first six months, and we will take some measurements on both groups to measure the effects of the study. There will be no other changes to your daily activities other than the specific TOP UP interventions.

You cannot join the study if you are already doing a similar exercise program. However, if you see a physiotherapist for regular massage or occasionally for other reasons than you are free to join. However, if you have poor hearing, vision or difficulty speaking clearly than this study is not suitable for you.

5 Other relevant information about the research project

We expect that over 240 older people living in a residential aged care or in their home receiving home care will participate in the TOP UP Study across Australia.

6 Do I have to take part in this research project?

Being in this study is completely voluntary, and you do not have to take part. Your decision whether to participate will not affect your current or future relationship with the researchers at the University of Sydney or your aged care service provider.

7 What are the possible benefits of taking part?

We cannot guarantee or promise that you will receive any benefits from this research. However, possible benefits of this program are that it could help you improve your walking, standing balance and reduce your risk of falls.

8 What are the possible risks and disadvantages of taking part?

Although the risks involved with participation in this research are low, there is a slight chance that you may experience muscle soreness at the start of the exercise sessions or have a fall. If you have any of these issues, please talk to your physiotherapist or your aged care service provider.

These risks will always be taken into consideration during the telehealth sessions, and we will adapt the exercise program to suit your medical needs. However, if muscle soreness increases significantly or you begin to fall more often while doing the TOP UP exercises, we may need to stop your participation in the study.

9 What will happen to information about me that is collected during the study?

By providing your consent, you are agreeing to allow us to collect personal information about you for the purposes of this research study. Your information will only be used for the purposes outlined in this Participant Information Statement, unless you consent otherwise.

Information about you may be obtained from your aged care health records for the purpose of this research. By signing the consent form, you agree to the study team accessing your health records if they are relevant to your participation in this research project. Any information related to elder abuse will be passed onto your aged care provider.

Your information will be stored securely, and your identity/information will be kept strictly confidential, except as required by the Federal 1988 Privacy Act. Only members of the research team will have access to your surveys, interview audio recording and physical tests. There are no further studies planned for your data, but the research team may decide to run other tests on your data in the future. Any stored data that is used for future research, will first be reviewed, and approved by an appropriately constituted Ethics Committee.

At the completion of the study, we will share the wider study results with you and your aged care service provider but not any of your personal information and results. You can request a confidential report of your progress from the research team on the consent form at the end of this document. You will receive this at the completion of the study.

All information will be stored safely in locked cupboards at The University of Sydney and secure computer systems. This information will be stored for 15 years and then destroyed.

10 Can I have other treatments during this research project?

Whilst you are participating in the TOP UP Study you will be able to take all your regular medications and treatments that you have been taking. Please let the research team know if you have any significant health or treatment changes so we can adapt the program for you and maximise your safety.

11 What if I withdraw from this research project?

If you decide to take part in the study and then change your mind later, you are free to withdraw at any time. You can do this by emailing or calling your care manager or emailing or calling the research team. We will give you a withdrawal form to complete so we know why. You are free to stop the interview or exercises at any time. You may also refuse to answer any questions that you do not wish to answer during the interview.

If you decide to withdraw from the study, we will not collect any more information from you. Any information that we have already collected, however, will be kept in our study records and may be included in the study results. If you do not want this to happen, you must tell the research team before you sign the consent form.

12 Could this research project be stopped unexpectedly?

This research study may be stopped unexpectedly if it appears there is the development of unacceptable side effects such as recurrent falls or pain.

13 What happens when the research project ends?

All participants will return their regular physiotherapy and exercise programs.

14 Complaints and compensation

(aged care facility) has sponsored this study and can be contacted if you are concerned about the way this study is being conducted, the conduct of a researcher or wish to make a complaint to someone independent from the research team, please contact the facility using the details outlined below.

If you suffer any injuries or complications as a result of this research project, you should contact the research team as soon as possible and you will be assisted with arranging appropriate medical treatment. If you are eligible for Medicare, you can receive any medical treatment required to treat the injury or complication, free of charge, as a public patient in any Australian public hospital. The research team will review your injury or complication and ensure your safety is maintained by either modifying your treatment program or withdrawing you from the study.

15 Who is organising and funding the research?

This research project is being conducted and funded by Professor Cathie Sherrington, Director, Institute for Musculoskeletal Health, Sydney School of Public Health, Faculty of Medicine and Health, University of Sydney, Sydney Local Health District. Rik Dawson is supported by NHMRC CRE HDR Scholarship. There is no expectation that any commercialisation of this study will occur. There are no conflicts of interest attached to this study.

16 Who has reviewed the research project?

Research involving humans in Australia is reviewed by an independent group of people called a Human Research Ethics Committee (HREC). The ethical aspects of this study have been approved by the HREC of the Sydney Local Health District (SLHD). As part of this process, we have agreed to carry out the study according to the *National Statement on Ethical Conduct in Human Research (2007).*

The ethics committee can be contacted if you are concerned about the way this study is being conducted, the conduct of a researcher or wish to make a complaint to someone independent from the study, please contact the SLHD HREC using the details outlined below. Please quote the study title (The TOP UP Study).

The Sydney Local Health District HREC contact details are:

Reviewing HREC	Sydney Local Health District Human Research Ethics Committee – Concord Repatriation General Hospital
HREC Exec. Officer	Executive Officer
Telephone	02 9767 5622
Email	SLHD-ConcordEthics@health.nsw.gov.au

17 Further information and who to contact.

If you want any further information concerning this project or if you have any medical problems which may be related to your involvement in the project (for example, any side effects), you can contact the study's principal physiotherapist *Rik Dawson* at any time.

- **Telephone:** +61 2 8627 6265
- **Email:** rik.dawson@sydney.edu.au
- **Fax:** +61 2 8052 4301

Aged Care Principal Investigator:

- **Contact Name:**
- **Phone:**
- **Email:**

Consent Form: Adult providing their own consent

Title	A physiotherapy led telehealth and exercise intervention to improve mobility in older people receiving aged care services: an effectiveness and
Short Title	The TOP UP study
Project Sponsor	*Sydney Local Health District and (aged care partner)*
Coordinating Principal	Professor Catherine Sherrington
Chief Investigator(s)	Mr Rik Dawson, Dr Marina Pinheiro, Professor Vasi Naganathan, Dr Morag Taylor
Location	TBA

Declaration by Participant

I have read the Participant Information Sheet, or someone has read it to me in a language that I understand. I understand the purposes, procedures and risks of the research described in the project.

I give permission for my aged care service provider and other health professionals to release information to the TOP UP research team concerning my medical history and treatment for the purposes of this project. I understand that such information will remain confidential.

I have had an opportunity to ask questions and I am satisfied with the answers I have received.

I understand that I may stop the final interview at any time, and that unless I indicate otherwise any audio recordings and transcriptions will then be erased and the information provided will not be included in the study. I also understand that I may refuse to answer any questions I don't wish to answer.

I understand that personal information about me that is collected over the course of this project will be stored securely and will only be used for purposes that I have agreed to. I understand that this information will only be told to others with my permission, except as required by law.

I understand that the results of this study may be published, and that publications will not contain my name or any identifiable information about me.

I freely agree to participate in this research project as described and understand that I am free to withdraw at any time during the study without affecting my future health care.

I understand that I will be given a signed copy of this document to keep.

I consent to:

Audio-recording and transcription	YES	☐	NO	☐
Videorecording	YES	☐	NO	☐
Photographs	YES	☐	NO	☐
Being contacted about future studies	YES	☐	NO	☐
I consent that any de-identified data collected be used for future studies	YES	☐	NO	☐
I would like to receive feedback about my personal results	YES	☐	NO	☐
I would like to receive feedback about the overall results of this study	YES	☐	NO	☐

If you answered **YES**, please indicate your preferred form of feedback:

Postal: ☐ ____

Email: ☐ ____

Name of Participant (Please print): ________________________________

Signature: ______________________	Date: ________________
Name of Witness (Please print): _______________________________	
Signature: ______________________	Date: ________________

Declaration by Senior Researcher†

I have given a verbal explanation of the research project; its procedures and risks and I believe that the participant has understood that explanation.

Name of Researcher (Please print): __________________________________	
Signature: ______________________________	Date: ___________________

† A senior member of the research team must provide the explanation of, and information concerning, the research project.

Note: All parties signing the consent section must date their own signature.

TOP UP Program

Contents

Contact

We are here to help you so if you have any concerns or questions, please contact your support manager:
Phone -
Email -

Website

https://www.physiotopup.com/

Logging on to telehealth

Physio Zoom number:

Physio Mobile:

Welcome

Physiotherapists are trained to assess and create an exercise program that can improve your strength, balance, reduce falls and improve overall health.

We recommend that you will need to do your exercises at least four times a week for 10 to 30 minutes each time - about 2 hours/week.

We recommend that you walk every second day on top of your balance and strength exercises.

Exercise with confidence

A physiotherapist will start the program with a physiotherapy assessment where they will look at you move and create an exercise program that is easy to follow:

- with exercises in this booklet
- with online exercise programs found in our website, and

Safety

Contact your doctor if, while exercising or walking, you experience:

- Dizziness, Chest pain, Shortness of breath where you are unable to speak
- Have a serious fall

Muscle soreness can occur after new exercises. This soreness should go away after a couple of days. If not, tell your physiotherapist.

Always ‘warm up’ and ‘cool down’ with every exercise session.

Telehealth

It is possible to see a physiotherapist using a device like an iPad and achieve great results.

Diaries

This booklet has an exercise diary where you can record your exercise program. Research has shown that tracking your exercise keeps you motivated.

It is important to you keep your diary up to date so that your physiotherapist can easily track your progress and plan to progress your program.

Safety tips

• Have a clear space to exercise. Remove obstacles (e.g., rugs, cords, furniture) so you don't trip over

• Wear comfortable clothing and well-fitting shoes or sneakers

• Drink water before and after exercise

• Balance exercises must be done with support. Stand so you have a bench, table, or sturdy chair next to you.

• Start any new exercise, slowly and carefully. If there is a video, watch the video before you try the exercise. If the exercise has an 'easy' and a 'hard' option, try the easy option first

• Always keep your phone in reach

Telehealth Tips

• Set your computer or tablet up somewhere stable where you can easily see the screen. Rest it on a few large books on the kitchen bench to make your screen at the right height for standing exercises

• Don't try to keep up with the exercise demonstrator if this is difficult. Exercise at your own pace

Listen to your body

• If any exercise causes you pain, discomfort, or if it makes you feel unsteady or unsafe choose an easier version, hold on for balance or leave it out. Contact Whiddon if you have any questions or concerns about the program

• After a minor illness (e.g., cold) you might start at a lower level, a previous program than usual, and slowly work back up to where you were

• If you have a new major illness, went to a hospital, or are below your usual level of ability, seek advice from Whiddon on how to re-start exercises safely!

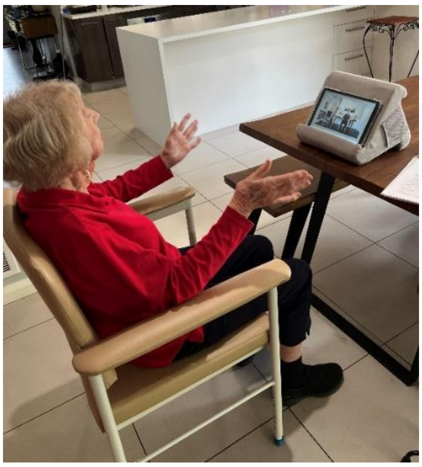
Goals

What do you want to achieve in the program?

1

2

3



4

Why?

Warm up exercises

Always begin with a short warm up to prepare your body for exercise.

Seated March

- Sit up tall in your chair
- Begin marching your legs
- Swing with both arms
- Continue marching for 1 minutes

Head side bend

- Slowly move your ears towards your right shoulder, keep looking forward
- Hold for 3 seconds
- Bring your head back up straight
- Repeat to the left
- Repeat 3 times

Head rotation

- Turn the head slowly to the left, pause in the middle, then slowly to the right
- Ensure that the shoulders stay still
- Repeat 3 times

Trunk Rotation

- Sit up tall with your arms crossed
- Slowly turn the body to the right then slowly to the left
- Keep your hips still
- Repeat 3 times each side

Back of leg stretch

- Sit at the front of the chair
- Straighten one leg placing the heel on the floor
- Place both hands on the side of your chair then sit really tall
- Lean forwards until you feel the stretch in the back of your thigh Hold for 10 seconds
- Repeat 3 times with each leg

Belly breathing

- Sit up tall in your chair
- Place one hand over your belly
- Breathe in through your nose and feel your belly expand
- Breathe out through your mouth as your belly deflates
- Repeat 4 times

TOP UP Program One: Seated

Warm up

Heel and Toe Taps


- Lift your toes up
- Then lift your heel up

Front knee straightening

- Straighten your leg
- Pull your toes back
- Hold for 3 seconds
- Slowly lower your leg down to the floor

Sit to Stand

- Sit tall near the front of the chair
- Place your feet slightly back
- Lean forwards slightly
- Stand up using 2 hands
- Stand tall
- Slowly lower your bottom back into the chair, reaching for the chair as you lower

Repetitions: **Rounds:**

Date	Home Exercise Plan - notes

Exercise Diary EXAMPLE

Monday Date: 3 May 21	Tuesday	Wednesday	Thursday
Group ex via zoom 45 min	**Outdoor walk** 25 min	**Online Ex 1a** 25 min with **COACH**	**Outdoor walk** 20 min
Friday	**Saturday**	**Sunday**	**Notes**
Online Ex 1b 25 min	Busy with family – no exercise	**EX** 15 min **Outdoor walk** 30 min with granddaughter	Any problems with exercises? Right knee was sore after the zoom class on Monday but settled by Tuesday Tired on Sunday after my long walk

Please record the following:

Exercise Program and Minutes: **WALK** indoor or outdoor, **EX** by myself, **GROUP** exercise class, **ONLINE** follow exercise videos, **COACH session**

Pain and other problems associated with your exercise program

Exercise Diary Week 1:

Monday Date:	Tuesday	Wednesday	Thursday
Friday	Saturday	Sunday	Notes
			Any problems with exercises?

Please record the following:

Exercise Program and Minutes: **WALK** indoor or outdoor, **EX** by myself, **GROUP** exercise class, **ONLINE** follow exercise videos, **COACH session**

Pain and other problems associated with your exercise program

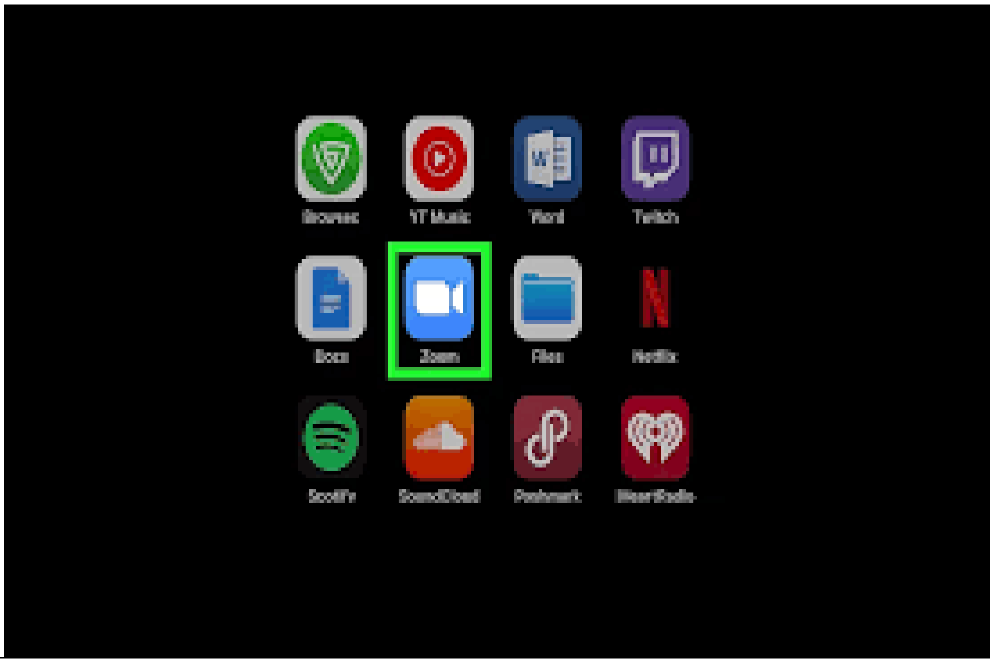
Using Zoom for physio

Quick steps to join a group session

1. Tap ‘Join a session’ on the tablet home screen to launch Zoom
2. Tap the blue ‘Join a Meeting’ button
3. Enter the above Meeting ID then tap Go
4. Select ‘Join with Video’
5. On the bottom left corner of the screen, tap ‘Join Audio’ to start sound

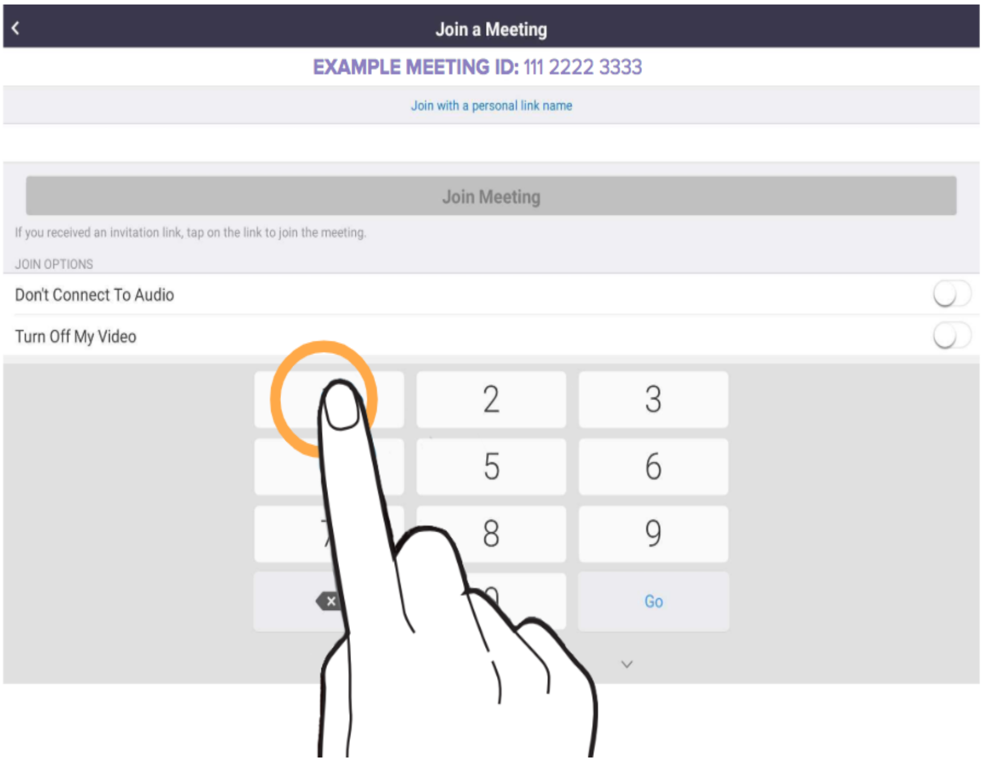
Detailed steps to join a zoom session

1. When it’s time for the Zoom physio session to start, press or tap the zoom app on the bottom of the screen



2. A screen that says ‘Start a Meeting’ at the top will appear.
Press or tap the ***‘Join a Meeting’*** button on the bottom of this screen:

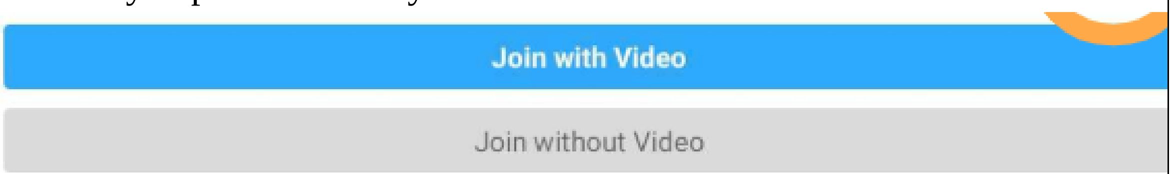
3. Use the number pad to type in the Meeting ID at the top, then press ***'Go'***:



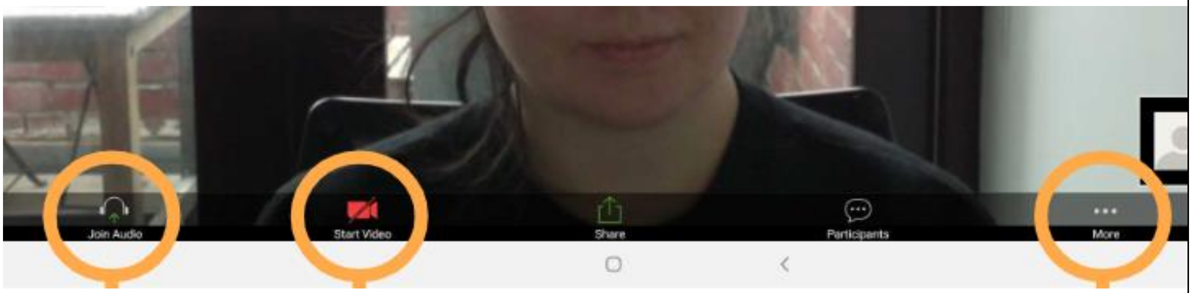
4. Time to join the meeting!

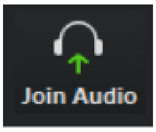
If you want to have your video on select ***'Join with Video'***

If you prefer to have your video off select ***'Join without Video'***

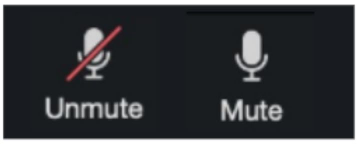


5. When the session starts, tap anywhere on the screen until a black menu bar appears at the bottom:

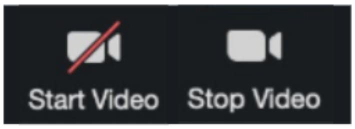




To start sound so that you can hear tap ***'Join Audio'*** on the bottom left corner of your screen.



The symbol will change to a microphone. ***'Mute'*** or '***Unmute'*** yourself depending on whether you would like others to hear you.



To switch your video on and off so that others can see you, tap ***'Start Video'*** or ***'Stop Video'***.

6. To end or leave the video call, tap 'Leave' on the top right hand corner of the screen:

Supplementary File 4: TOP UP Health Service Utilisation and Falls Diary example

Falls and Heath CALENDARS

Thank you for taking part in our research study. As part of this program, we would like to know if you have had any falls or health utilisation contact over the 6-month study period.

A fall is defined as an event, which results in a person coming to rest inadvertently on the floor or another lower level.

At the end of each month, please indicate whether you have had any falls, seen any health care professionals such as a GP visit, a visit from your podiatrist or dietician and your regular help for your community care provider. Please don't record any help from your regular community aged care workers family or friends.

Please do not include any visits or your TOP UP Physiotherapists or other Researchers involved in this study on the calendars.

In this study please place the calendar in the self-reply envelopes provided at the back of this folder and post it into us at the end of the month.

Note: Please post the calendars every month even if no falls or health care service occurred. If we do not receive any correspondence from you in a while, we will ring to follow up.

If you have any questions, please call **Rik** on 02 86276235

or email rik.dawson@sydney.edu.au

Falls and Health Utilisation Calendar - EXAMPLE

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
31 C					**1**	**2**
3 **C**	**4**	**5** **C**	**6** **PT**	**7** **C** **Other –** dietitian	**8**	**9**
10 **C**	**11**	**12** **C** **GP for medication review**	**13** **PT**	**14** **C**	**15**	**16**
17 **C**	**18**	**19** **C**	**20** **PT**	**21** **C**	**22**	**23**
24 **GP**	**25** **Fall at 2pm at front steps**	**26** **A, AE** **Hosp** **Dehydrated**	**27** **Hosp** **Returned home at 4pm**	**28** **C**	**29** **C**	**30** **C**

Medical events: F is you have had a fall, **H** on days you are admitted to hospital (reason), **A** Ambulance called (for anything), **ED** emergency department visit

Health visits:_PT for Physiotherapist, **OT** for Occupational Therapist, **SP** for Speech Pathologist, **PSY** for Psychologist, **GP** or **Spec** for Specialist (write type), **DIET** for Dietician, **POD** for podiatrists

Falls and Health Utilisation Calendar - August 2022

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Medical events: F is you have had a fall, **H** on days you are admitted to hospital (reason), **A** Ambulance called (for anything), **ED** emergency department visit

Health visits:_PT for Physiotherapist, **OT** for Occupational Therapist, **SP** for Speech Pathologist, **PSY** for Psychologist, **GP** or **Spec** for Specialist (write type), **DIET** for Dietician, **POD** for podiatrists

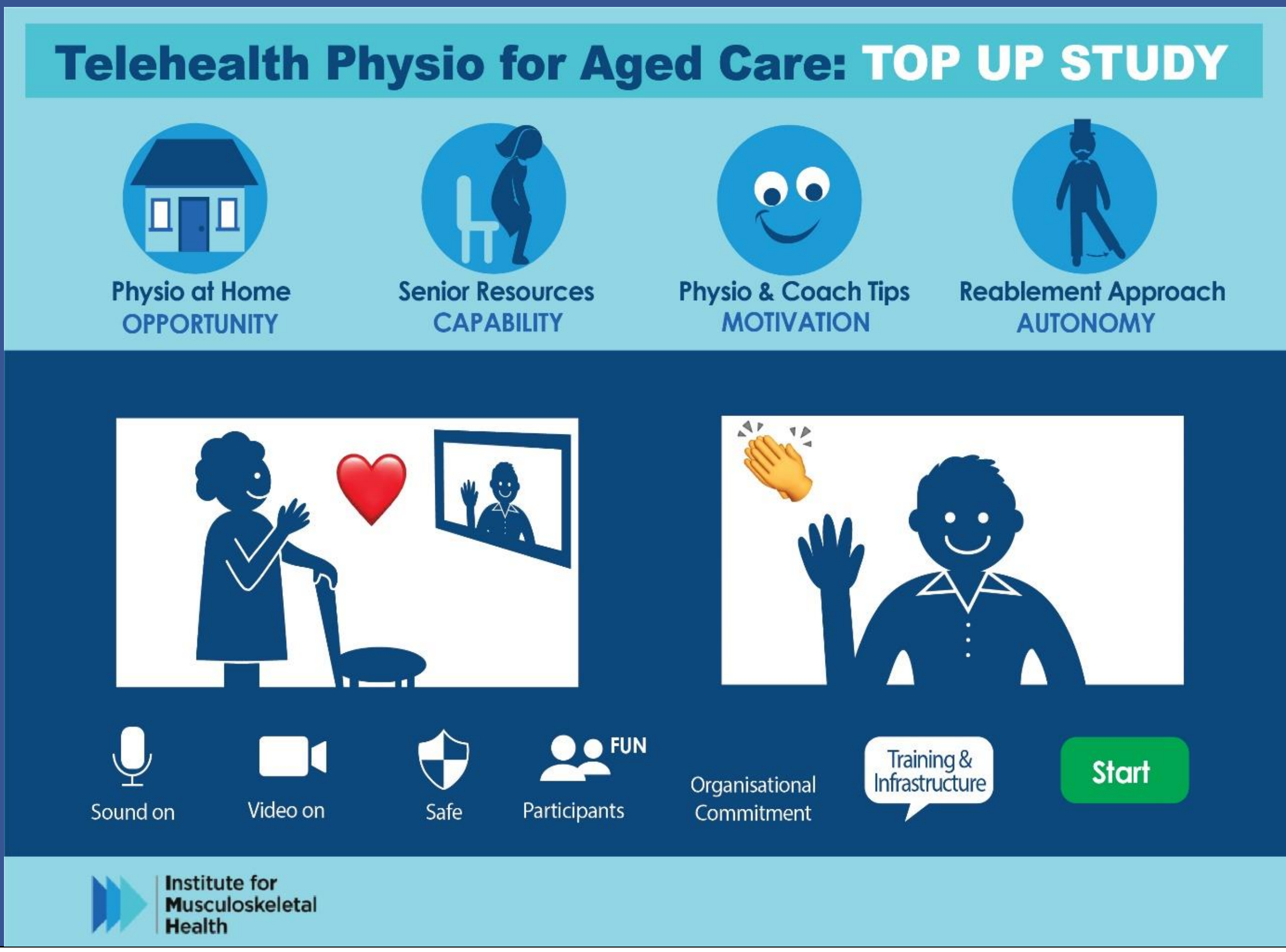
Supplementary File 5: TOP UP trial results summary document

Research invests in telephysiotherapy for aged care

This report outlines the findings from the TOP UP Study. This was a research study between (your aged care provider), Sydney Local Health District and the Institute of Musculoskeletal Health at Sydney University.

The TOP UP trial was run across three years (2021-2023) and examined the feasibility of telehealth physiotherapy. It used a mobile tablet device (like an iPad) to do Zoom physiotherapy assessments, provide exercise videos to encourage older people to follow balance and strength programs supported by weekly visits by a trained support workers.

The study concluded at the end of 2023 and will create some publications that aim to examine the effect of telehealth physiotherapy on older people's walking, falls, quality of life and its cost-effectiveness.



What we did

Results

In 2021 we commenced a 6-month study where we introduced tele-physiotherapy service to 242 aged care service users across Australia.

The program was designed by a team of aged care physiotherapists at the University of Sydney and the study protocol was registered by Sydney Local Health District ethics committee.

120 people were randomised into the exercise group starting September 2021 and 122 people acted as the control group and started their 3-month program in 2022.

Everyone had to keep a health and falls diary and keep a track of their exercises during the trial.

An experienced aged care physiotherapist used the Zoom app to talk the aged care service users 10 times over 6 months and planned an individual exercise program tailored to their health needs.

Every week a support worker would spend 45 minutes with each participant to support them to use the mobile tablet, Zoom with the physio and help them follow their exercise program.

Each participant was given a tablet to use during the study

It works 202 participants exercise group completed the telephysiotherapy exercise program.

Mobility All the participants in the exercise group improved their mobility by either increasing their walking speed or their balance.

Falls There was **…%** less falls in the exercise group.

Acceptable Most participants would recommend telehealth physio to other older people.

Safe There was only one minor fall and no injuries experienced by the exercise group when they were doing the program.

Next Steps Several scientific papers will be published in 2024 exploring what elements of the programs worked, why it worked and how it could be used more widely.

The research team is planning to present at several conferences and work with local media to let people know that tele-physiotherapy is safe, acceptable and feasible.

Thank you for participating!

CHAPTER SEVEN

Qualitative analysis of the TOP UP trial

Chapter Seven is accepted as:

Dawson R, Gilchrist H, Pinheiro M, Nelson K, Bowes N, Sherrington C, Haynes A. "It gives you more independence": experiences of older people, physiotherapists and aged care staff in the TOP UP telephysiotherapy program. *JMIR Ageing*. In press.

5.1 Statement of co-authorship

As co-authors of the manuscript “Physiotherapy-led telehealth and exercise intervention to improve mobility in older people receiving aged care services (TOP UP): protocol for a randomised controlled hybrid type 1 effectiveness-implementation trial”, e confirm that Rik Dawson is the lead corresponding author and has made the primary contribution to this study in each of the following areas:

- Conception and design of the research
- Data Collection
- Data analysis and interpretation of findings
- Writing of the manuscript and critical appraisal of content

Heidi Gilchrist	19 December 2023
Marina Pinheiro	19 December 2023
Karn Nelson	19 December 2023
Nina Bowes	19 December 2023
Cathie Sherrington	19 December 2023
Abby Haynes	19 December 2023

Cathie Sherrington: ____________________ 19 December 2023

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***"It gives you more independence":* experiences of older people, physiotherapists and aged care staff in the TOP UP physiotherapy telehealth program**

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ABSTRACT

Background

Telehealth provides opportunities for older people to access health care. However, limited research exists on the utilisation of telehealth within aged care services, particularly regarding physiotherapy-led fall prevention and mobility programs. Understanding the experiences and interactions of older people, physiotherapists, and aged care service providers is crucial for the scale-up and sustainability of such essential programs. The TOP UP Study, a hybrid type 1 effectiveness-implementation randomised control trial in aged care, employed a supported multidisciplinary telehealth physiotherapy model to motivate older people to engage in exercises to improve mobility and reduce falls.

Objective

This qualitative sub-study aimed to achieve two primary objectives: 1) to describe the experiences and acceptability of the TOP UP intervention for older people, physiotherapists and aged care support workers and managers; and 2) to gain an in-depth understanding of program implementation.

Methods

A purposive recruitment strategy was employed to select 18 older people who participated in the TOP UP intervention, ensuring variation in age, gender, residential status (home or residential aged care), geographical location, and cognitive levels. Additionally, seven physiotherapists, eight aged care support workers, and six managers from seven different aged care provider partners participated in the study. Semi-structured interviews were conducted to explore stakeholders' experiences with the TOP UP program, gather suggestions for improvement, and obtain insight for future implementation of similar telehealth physiotherapy programs. The interview framework and coding processes were informed by behaviour change and implementation frameworks. Data were analysed using an abductive approach, informed by two behavioural change theories (COM-B, Self Determination Theory) and the NASSS framework (Nonadoption, Abandonment and Challenges to the Scale-Up, Spread and Sustainability of Health and Care Technologies).

Results

All participants (n=39) reported high levels of acceptability for the TOP UP program and cited multiple perceived benefits. Thematic analysis generated six main themes: 1) Telehealth physiotherapy expands opportunity, 2) Tailored physiotherapy care with local support enhances motivation, 3) Engaging, senior-friendly educational resources build capability, 4) Flexible reablement approach fosters autonomy, 5) Telehealth physiotherapy is safe, effective and acceptable for many, and 6) Organisational commitment is required to embed telehealth. Motivation to exercise was enhanced by Zoom's convenience, use of tailored online exercise resources, and companionable local support.

Conclusion

This study highlights the inherent value of telehealth physiotherapy in aged care, emphasising the need for investment in staff training, local support and senior-friendly resources in future telehealth physiotherapy iterations. TOP UP represents a convenient and flexible virtual care model that empowers many older people to receive sustainable, high-quality care precisely when and where they need it.

Keywords Physiotherapy, telehealth, exercise, aged care, qualitative methods, behaviour change, technology, virtual care.

INTRODUCTION

Worldwide, the proportion of older people in the population is growing. From 2020 to 2050 older people aged 60 years+ will double to 2.1 billion, representing 22% of the world's population [1]. By 2050 the number of people aged 80 years+ is expected to triple to 426 million [1]. Older people experience poor mobility and higher rates of falls than younger populations leading to significant morbidity, mortality, and poor quality of life [2-4]. Poor mobility and falls are two of the biggest cost drivers in hospital and aged care services [2, 5]. In 2021, 10.7% of people aged 65 and over living in Organisation for Economic Co-operation and Development (OECD) countries received long-term care, either at home or in care facilities costing these governments 1.5% of Gross Domestic Product [6, 7]. Aged care spending has increased over the last 15 years in most OECD countries and population ageing will continue to increase demands on stretched health care systems [7].

Emerging evidence supports the effectiveness and cost-effectiveness of physiotherapy-led exercise programs for enhancing mobility and reducing falls in aged care settings [8]. However, the Australian Royal Commission into Aged Care highlighted significant barriers to accessing mobility promoting and fall prevention interventions delivered by allied health professionals such as physiotherapists [9]. Qualitative evidence suggests that telehealth physiotherapy could be a feasible, acceptable, and effective approach for delivering mobility and fall prevention programs to older people living in the community [10]. Telehealth could be particularly advantageous in increasing access and convenience for people with travel constraints, mobility limitations, or who live in regional and remote areas [11].

Telehealth physiotherapy has been found to have similar effectiveness compared with in-person rehabilitation services for community-dwelling older people following a stroke and it shows no increased risk of adverse events [12]. However, there is no evidence supporting the effectiveness, cost-effectiveness, and implementation feasibility of telehealth physiotherapy for improving mobility, reducing falls, and enhancing quality of life for older people receiving aged care services in their homes or residential aged care.

Telehealth is currently being used in aged care but there is limited guidance on how best to implement it [13]. Hybrid effectiveness and implementation research has been shown to speed up research translation into clinical practice [14]. Implementation research explores the experience of a complex intervention such as telehealth and its relationship to other factors, such as intervention engagement and adherence, perceived effectiveness, acceptability and self-efficacy, which can support implementation translation [15].

The TOP UP trial

TOP UP is designed to provide a scalable solution for delivering physiotherapy exercise interventions via telehealth to improve mobility, reduce falls and enhance quality of life in aged care. The TOP UP program was developed in collaboration with our aged care partners, physiotherapists and aged care service users and their carers. A series of workshops identified potential facilitators to improve older people's engagement with technology and motivation to exercise. The program design was also influenced by behaviour change models such as Self-Determination Theory (SDT) [16] and the Capability, Opportunity, Motivation, Behaviour (COM-B) framework [17].

TOP UP is investigating synchronous and asynchronous modes to optimise both personalised healthcare and self-directed exercise [18] in aged care settings. It involves the delivery of real-time physiotherapy assessments through videoconferencing (synchronous telehealth) using the Zoom application (app) by older people receiving aged care services at home or in residential care. These service users are given access to evidence-based exercise videos on the TOP UP website and the StandingTall app (asynchronous telehealth) to support their exercise program. Each participant has the weekly support of a trained aged care worker to help them access the Zoom app and follow their exercise program. Outcomes being measured include effectiveness (mobility, falls and quality of life), cost effectiveness and implementation measures (acceptability, reach, fidelity, dose-delivered and adoption). The trial is registered with the Australian New Zealand Clinical Trials Registry (ACTRN 1261000734864).

The program is being tested in a hybrid type 1 effectiveness-implementation randomised control trial. Older people are screened by their aged care service providers. Eligibility criteria include the age of older people (65 years and over), possessing sufficient physical, sensory, cognitive, and English skills to participate, and having individual consent or consent from the person responsible. Those with terminal or unstable illness, severe dementia, having participated in a similar physiotherapy program in the last year, or being unable to walk ten metres are excluded from the study. There were 242 participants recruited from a screening pool of 1348 aged care service users (older people). Data analysis is expected to be completed in 2024.

Participants randomised to the intervention group receive 10 videoconference physiotherapy sessions over 6-months using the Zoom app and receive an individualised balance and strength exercise program. These exercise programs are based on the World Health Organization 2020 guidelines on physical activity and sedentary behaviour [19], and the Otago [20] and Sunbeam programs [21] which are often prescribed in aged care. Existing aged care support staff, called ‘coaches’, have been trained to supervise participants to access the technology and provide ‘hands on’ exercise support once per week, with the assistance of exercise videos designed by the research team. The wait-list control group receives a 3-month version of the program once the intervention period at each site is finished.

To inform the successful development of programs such as TOP UP, it is essential to examine not just if, but how and why TOP UP worked (or not) and what strategies could best improve it. Interviews have been used to provide detailed information about how older people, physiotherapists, coaches and aged care managers experienced the intervention and how the delivery of the TOP UP program is mediated by contextual factors, producing transferable learnings about the potential use of future telehealth physiotherapy in aged care [22].

METHODS

Study design and context

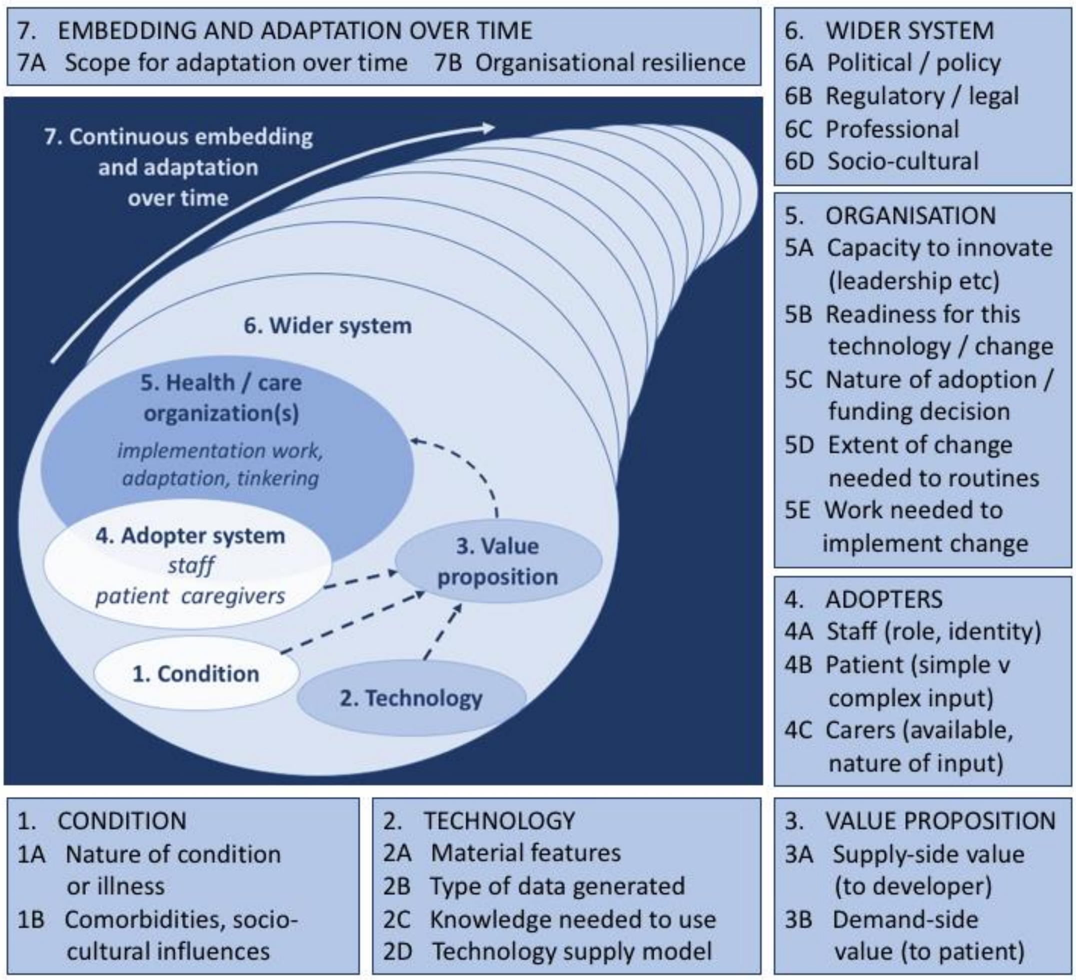
This study used a qualitative description approach through semi-structured one-on-one interviews [23]. Qualitative description is increasingly used in conjunction with effectiveness and implementation trials and aims to present a straightforward description of participants' experiences [24]. The analysis is grounded in participants’ own words, making the results accessible to vulnerable groups, valid, highly translatable and useful for refining interventions [25]. Qualitative description sits within a constructivist paradigm and takes account of multiple meanings and recognises that the research process is never neutral [26]. To strengthen the research rigour we included triangulated data sources (by drawing on perspectives of different stakeholder groups), and reflective discussion of emergent findings amongst the multidisciplinary research team [27].

We used two behavioural change theories, COM-B and SDT, and the NASSS framework (Nonadoption, Abandonment and Challenges to the Scale-Up, Spread and Sustainability of Health and Care Technologies) to provide a conceptual 'lens' to inform data collection and analysis [28]. The COM-B model of behaviour change proposes that to engage in a behaviour such as exercise (B) a person must be physically and psychologically capable (C) and have the opportunity (O) to engage in the behaviour, as well as the motivation to do so (M). The COM-B simplifies complex factors and recognises that to modify behaviour, we need to address at least one of these components [17]. SDT focuses on the motivation underpinning behaviour change, positing that effective programs must support autonomy, competency and relatedness [16]. The NASSS framework is an evidence-based, theory-informed, and pragmatic framework that can help predict and evaluate the success of a technology-supported health program. It consolidates multiple implementation frameworks, targeting key issues relating to the implementation and uptake of telehealth at the micro-level of individual staff and consumers, the meso-level challenges of organisational engagement and adoption, and macro-level policy and regulatory factors (see Figure 1) [28].

Recruitment and data collection

At initial TOP UP recruitment, all aged care service users, coaches, physiotherapists, and aged care managers received an information sheet inviting them to take part in an interview for this qualitative study. After participants read the informational letter and confirmed their interest in participating in an interview, they received an informed consent letter to be signed by themselves or their person responsible before the interview appointment. A list of potential aged care service users, their coaches and physiotherapists was created in consultation with three of our aged care partners (Ashfield Baptist Homes, Whiddon and Uniting AgeWell). A purposive recruitment strategy was employed to select 18 older people who participated in the TOP UP intervention, ensuring variation in age, gender, residential status (home or residential aged care), geographical location, and cognitive levels. All 39 participants contacted agreed verbally and in writing before and on the day of, the Zoom interview. No participant declined to partake in the interviews. The interviews were conducted 3-6 months after interviewees commenced the program. Recruitment was stopped at the point when data adequacy had been reached i.e., when we judged that we had sufficient rich data across our purposive sample with which to answer our research questions [29].

Figure 1. The Nonadoption, Abandonment and Challenges to the Scale-Up, Spread and Sustainability of Health and Care Technologies (NASSS) Framework [28] Conceptual framework



The interview guide was created in consultation with the wider research team and representatives from our aged care partners (Appendix 1). Interview questions targeted concepts from the COM-B model, SDT and the NASSS framework (described above). Specific questions explored the relative value of the different components of TOP UP (e.g., Zoom, exercise videos and the level of support provided). Questions about implementation and effectiveness were included. We also asked interviewees to identify local and potential system-wide barriers and facilitators to the successful adoption of telehealth physiotherapy such as TOP UP and other programs aiming to deliver fall prevention and mobility programs in aged care. We utilised open-ended questions and active listening to confirm our understanding of the interviewees' perspectives. RD and KN conducted the interviews individually on Zoom. RD and KN were involved in the delivery of the program so, to reduce sociability bias, interviewees were encouraged to critique the TOP UP program and its implementation to identify improvements [30].

Aged care participants had a family member or someone familiar to them from their aged care organisation that wasn't their coach to assist them with connection to the Zoom app and support them through the interview. Participants were reminded that they could stop the interview at any time. No repeat interviews were conducted. RD and KN completed memos after interviews and met to discuss the data and emerging thematic content. Interview audio recordings were automatically transcribed using Zoom's free transcription service and transcripts were corrected by RD. Transcripts were not returned to participants.

Data analysis

Transcripts and interview field notes were uploaded to NVivo 12 for data management and coding [31]. Transcripts were coded by one researcher (RD) using an abductive analytical approach. RD drafted an initial thematic framework drawing on emergent themes in the data and informed by domains from the NASSS framework. Two researchers (RD, AH) tested and refined the coding framework on two manuscripts, adding codes and modifying existing codes from inductively identified concepts in the data. RD coded the remainder of the data. RD, CS and AH met regularly to discuss emergent codes and themes.

Recurrent themes were generated from reading across the coded data and reviewed against concepts from SDT [16] and the Capability, Opportunity, Motivation, Behaviour (COM-B) framework [17],[29] to understand how aspects of the TOP UP program influenced exercise engagement. An early overview of findings was discussed with all co-authors and our consumer representative to explore a wider range of possible thematic interpretations and to help ensure we had answered our research questions, including considering the implications of our findings. Disagreements were resolved through discussion. The criteria for reporting qualitative research (COREQ) was used as a reporting checklist (Appendix 2) [32].

Ethical Approvals

Ethical approval for this qualitative sub-study was included in the TOP UP Study approval granted by the Ethics Review Committee at the Sydney Local Health District Research Ethics and Governance Office, Concord, Australia (approval number approval CH62/6/2021-009).

RESULTS

Participants

Thirty nine people participated in semi-structured interviews: 18 aged care service users who completed the TOP UP program (46%), 7 aged care physiotherapists (18%), 8 (21%) coaches and 6 (15%) aged care managers. Interviews took 19 minutes on average (range 8–53 min).

Table 1 Aged care service user interviewee characteristics

ID	Age	Gen-der	Site	Region	Co-Morbid-itites	Cognitive Impair-ment	Falls	Walking aid	iPad	TRI	TH use
1	92	F	RACF	Metro	9	Nil	0	4WW	yes	3.9	no
2	90	M	RACF	Metro	5	Nil	1	4WW	no	2.8	no
3	70	F	RACF	Metro	5	Mild	1	4WW	no	2	no
4	90	F	RACF	Rural	4	Mod	7	4WW	no	1.2	no
5	89	M	HC	Metro	2	Nil	0	Nil	yes	2	no
6	91	F	HC	Metro	8	Nil	0	4WW	no	1.5	no
7	84	F	HC	Rural	4	Mild	1	4WW	yes	1.7	yes
8	88	M	HC	Rural	7	Mild	0	Nil	no	1.6	no
9	74	F	HC	Rural	8	Nil	0	Nil	yes	2.9	yes
10	80	M	HC	Rural	7	Nil	0	Nil	no	1	no
11	73	F	HC	Rural	7	Mild	2	4WW	yes	3.3	yes
12	87	F	HC	Rural	5	Mild	1	4WW	no	2	yes
13	89	F	HC	Metro	10	Nil	1	4WW	no	2.2	no
14	81	M	HC	Metro	6	Nil	0	Nil	yes	2.1	yes
15	93	M	RACF	Rural	6	Nil	0	Nil	yes	2.6	no
16	92	F	RACF	Rural	7	Nil	3	4WW	yes	3	no
17	83	F	HC	Rural	10	Nil	6	4WW	no	1.5	no
18	82	M	HC	Rural	11	Nil	3	Nil	no	1.5	no

Falls = number of reported falls in the past 12 months; HC = Home Aged Care; RACF = Residential Aged Care Facility; 4WW = 4-wheeled walking frame; iPad = owned and use an internet enabled tablet; TRI = Technology Readiness Index [33]; TH = telehealth

The aged care service users' characteristics are displayed in Table 1. These service users were aged from 70 to 93 years at the start of the intervention (median 87.5 years); 11 (61%) were female and 7 (39%) men; 11 (61%) used a 4-wheeled walking frame to walk, 7 (39%) did not need a walking aid to walk; 7 (39%) lived in metropolitan cities in New South Wales (NSW), 11 (61%) in rural/remote areas in NSW and Victoria; 6 (33%) had mild to moderate cognitive impairment, 12 had no cognitive impairment; all had multiple co-morbidities (median 7, range 2-11); 10 (56%) had one or more falls in the last 12 months (median 1, range 0-7). The median Technology Readiness Index (TRI) score was 2/5 (range 1-3.9) which classified the aged care users as technology *avoiders,* people who tend to have a high degree of resistance and low degree of motivation to use technology [33]. Four aged care service users (22%) had used phone-based telehealth before with their general practitioner, but none had used a video-conferencing app like Zoom before the study or used telephysiotherapy.

Four of the seven physiotherapists interviewed were based in metropolitan areas and three were based in rural areas. Four coaches supported aged care services users from residential aged care and four coaches supported aged care services users from home aged care. One aged care manager worked at a remote residential aged care site, one managed a rural residential aged care site and four were home care managers from rural areas.

Main Findings

Our qualitative analysis revealed that all people interviewed found the TOP UP program to be acceptable and would recommend similar telehealth physiotherapy programs to other older people receiving aged care services. Thematic analysis generated six key themes related to experiences of TOP UP. We also compiled evidence of these experiences to identify and manage emergent possibilities, uncertainties and interdependence that could guide the adoption of telehealth physiotherapy in aged care using the NASSS framework. We used quotes to illustrate each theme. We have annotated the quotes for anonymity with aged care service users referred to P1, P2, etc. and other stakeholders are descriptively described.

Theme 1: Telehealth physiotherapy expands opportunity

Theme 1 highlights the expanded opportunities for accessing physiotherapy that TOP UP provided. TOP UP minimised the barriers to physiotherapy access related to travel and associated costs:

Travel in country areas is just too hard and having telehealth in the home makes it so easy to do. I can't do a 70 km round trip – it is too expensive. (P 10)

This was also echoed by service users whose significant disabilities created access barriers:

Because of my health, there's no way I can go out to see a physio. One, I've got to get someone to take me, like a relation, or pay someone to take you, it's not practical. It's hard to park anywhere near the physio, you've got to walk, so by the time you get to the physio you're exhausted. (P 1)

All the physiotherapists and aged care service managers indicated that telehealth could deliver physiotherapy care efficiently, improving opportunities for older people receiving aged care services to get physiotherapy where and when they need it:

Some people need to be able to see a physio quickly and we can provide telehealth services quickly, it is so efficient. (Home care physiotherapist, metro)

TOP UP had the most impact on rural and remote services, especially in areas where telehealth has the potential to address chronic health inequity issues related to workforce shortages:

Our town has a physio that visits once a month. Recently, one of our residents had a fall so I called the clinic and found out that we can't get an appointment to take our resident to see a physio for 6 weeks, if someone has a fall like this, we just can't wait six weeks. Telehealth really helps us. (Residential manager, remote)

Theme 2: Tailored physiotherapy with local support enhances motivation

Regular local support was identified by all interviewees as important for enhancing older people's confidence to try the exercise program and for supporting their motivation to 'stick with' the program, including coping with TOP UP's increasing challenge over time. Many interviewees across the four stakeholder groups explained that it was not just physical and technological support that the coaches offered (e.g., providing stand-by assistance whilst doing balance exercises and managing the Zoom app), but companionship and emotional support:

> *I can't get out much and I began to look forward to the weekly session with my care worker as I really appreciated the support, she gave me to do something positive for my health. My coach understood what was going on in my life and she gave me the confidence to keep doing the exercises. (P 12)*

All the physiotherapists interviewed indicated that the coaches' 'hands-on' support was vital to the success of the program as it helped to build capability and confidence. Importantly, TOP UP was a tailored program where the physiotherapists were able to modify exercises according to the individual needs of each service user, mirroring the person-centred approach typical in-person physiotherapy sessions. This tailored approach was particularly important to aged care service users whose health changes required program adaption:

> *My physio understood that I needed a break when I had some surgery but was ready for me when I got back home and quickly helped me regain the fitness that I had lost in the hospital. (P18)*

The TOP UP program used technology and behaviour change techniques to maximise program adherence. Zoom gave physiotherapists a platform to deliver individualised real time health coaching and goal setting which has been shown in the literature to increase participant adherence [34]. Interview data indicated that these techniques were being used across the program implementation, consistent with behaviour change theory:

> *Physiotherapists start with building external motivation by setting goals, by encouraging them and highlighting their progress we help them develop internal motivation to keep going. If we can motivate them internally, half the job is done, and exercise will become a routine and a lifestyle habit. (Home care physiotherapist, metro)*

Further evidence emerged that these techniques were having the desired effect:

> *Their motivation seemed to improve when they reached their goals and they wanted to keep on trying. Their motivation is the most important thing. (Residential coach, metro)*

But it was the combination of live tailored physiotherapy with enthusiastic and companionable local support that seemed to both develop confidence and underpin motivation:

> *The individual sessions on Zoom were important so I could ask some questions about how I was doing, and having my physio give me some individual feedback was important for my confidence to keep exercising. My coach has made it possible, and her support has been great, she is so lively, and she exercises with me which makes it fun, we had such a laugh, she keeps me motivated, and she takes the monotony out of it. If you are not having fun, it is not worth it. (P 10)*

The previous quote also highlights the vital role of enjoyment in exercise and how this can be enhanced with a trained support worker acting as a coach. This may be especially important for engagement in the TOP UP program given that many of the physiotherapists interviewed suggested that telehealth requires more time to develop therapeutic alliance. Therapeutic alliance refers to how people experience the empathy of clinicians and research shows that a strong therapeutic alliance is connected to positive treatment adherence and results in physical therapy [35]:

> *It's not until you get to the fourth or fifth telehealth session that people start getting to really know you and feel like you can be an advocate for them. I think that telehealth does allow for a personal connection which adds to exercise adherence. (Physiotherapist, home care, rural)*

TOP UP physiotherapists and coaches’ person-centred approach to goal setting, highlighting progress during the program and celebrating any achievements, seemed to enhance the aged care service user’s motivation to exercise:

> *TOP UP helped me care about my future before I just didn't care. I loved the way the physio explained things to me carefully, so I understood. I really appreciate having the support worker exercise with me and reinforce what to do, and how to do the exercises. All of this made me feel like I mattered and now I can walk further, do my shopping, which is a big improvement. (P12)*

Theme 3: Engaging, senior-friendly educational resources build capability

Interviewees expressed enthusiasm for the instructional videos that were designed to support high quality independent exercise throughout the program. The videos incorporated exercises modeled by an older person, slow-paced dialogue in a warm conversational style, natural lighting to maximise visibility, minimal visual distractions and gentle humour which all seemed to increase exercise engagement by older people. In the following quotes two participants describe the importance of 'seeing' another older person in the online videos:

> *It was great to see an older person do the exercises, really motivating to see someone my age doing the program. The videos were at the right pace, and I like how they got harder over time. It was fun. (P 17)*

> *The exercise videos are motivating because I feel like I am doing it with someone – it's interactive and fun. Following a book can be boring. (P 5)*

Many stakeholders commented positively on the video design that incorporated slow demonstration and simple dialogue that aimed to teach aged care service users how to do safe and effective home exercise:

> *The physiotherapist in the videos demonstrated the exercises slowly and explained things easily. I was really surprised how the residents were able to follow everything without any help. (Residential coach, metro)*

> *Having online exercise resources really helps because people aren't familiar with exercise techniques, they can follow their prescribed video and it helps keep their exercise dose up. (Home care physiotherapist, regional)*

Many of the physiotherapists interviewed commented that the TOP UP program was complex and challenged participants to navigate different apps and printed resources, such as exercise diaries while using Zoom. They suggested that simpler telehealth programs (or simpler mechanisms for accessing program components) could be developed to enhance the user experience and minimise program dropout. One physiotherapist commented:

> *I think having an easy to navigate, no fuss system where our clients can look up an exercise, record their exercise program and any problems they may have had, a fall, etc. I think an app where physiotherapists could get access to this information easily during a session and to help prepare for another session would be useful. (Home care physiotherapist, rural)*

Theme 4: Flexible reablement approach fosters autonomy

TOP UP is designed to encourage older people to take a lead in their program planning, flexibility is emphasised, including choice about what resources to use (printed and online) and what skills they wish to develop that would enable them to engage in activities they found most important:

> *I liked how it started easily and I moved my way up the program. There is structure to the program, and you commit to it. I often plan to do a session but if something comes up, I make an appointment with myself to make sure I do it another time. (P 16)*

> *I liked that I could stop and start the videos according to my own needs on the day. (P1)*

This can be described as a reablement approach, and the physiotherapist and coaches were encouraged to build the aged care service users' physical capability and support them to transfer their new skills to access other activities in their community independently:

> *Residents lack enough physical activity here, sometimes we are short staffed, and sometimes the staff don't have time to help. It was great to see our*

residents on the TOP UP program improve their mobility and begin to walk to different activities on their own. (Residential manager, rural)

All stakeholders valued the reablement approach and it was reported that TOP UP seemed to be a catalyst for reablement as many of their clients began to engage in more socialisation with friends and families, and embrace other physical activities as they became stronger and more mobile:

Physios and coaches can work together to ensure that the participant becomes independent and autonomous in their use of telehealth and do more exercise as the program progresses. As they improved, we had discussions with them and their coach about how they could do more outdoor walking. (Home care physiotherapist, rural)

I was surprised about the other quality of life benefits of telehealth, talking to their physio on zoom, seeing their support workers in this new way, learning how to get out and about in the community, all seemed to reduce social isolation which is so important for our customers. (Home care manager, rural)

Theme 5: Telehealth physiotherapy can be safe, effective and acceptable for many

Most interviewees regarded TOP UP as a safe, effective and acceptable program. Interviewees reported positive physical and quality of life improvements:

I think it's fabulous. I wouldn't have imagined that I would be given the opportunity to get physio. Physically, I can walk further. My breathing is better. I'm stronger, it gives you more independence. (P1))

Telehealth has not only helped my customer's strength, mobility and coordination, but it seemed to help their overall quality of life, they seemed happier and more confident to walk. (Residential care manager, rural)

Many interviewees reported that the combination of physiotherapist-led instructional exercise videos and supervision by trained support workers increased the safety of TOP UP:

> *I think having a physio run exercises in the videos gives the intervention more authority, frees up my time to motivate the residents and keep them safe. (Residential coach, remote)*

> *I think having the care worker there with the client to help set up Zoom, hold the iPad, and angling the video so I can see them clearly makes the program safer and more successful. (Home care physiotherapist, rural)*

However, TOP UP was not considered to be suitable for all aged care service users. All stakeholders agreed that telehealth presents challenges for frail clients in residential aged care who often have higher levels of mobility, sensory and cognitive disability. Two cognitive and sensory impaired aged care service users found using Zoom to 'see' their physiotherapist frustrating and as a result, pulled out of the program:

> *First of all, not all dementia residents get used to it, and second, people with hearing and vision problems struggle to follow. (Residential aged care manager, rural)*

Some physiotherapists would hesitate to use telehealth without local support for those aged care service users with high fall risks:

> *For people who are mostly independent I wasn't worried, but if I did have someone who was who was frailer and there was no one there with them I was worried they might fall. (Home care physiotherapist, regional)*

Some aged care service users and managers suggested while telehealth is a good second option, they would still prefer in-person physiotherapy, especially for older people with more complex needs:

> *I prefer a blend of face-to-face physio and telehealth. I need some hands-on physio from time to time to manage the arthritis in my back, but I liked the*

telehealth program because I could follow the physio exercise videos at home, it was so convenient. (P 18)

It appears that a hybrid model that incorporates a blend of face-to-face physiotherapy and on-line exercise resources such as exercise videos was viewed as particularly acceptable for those with significant health challenges:

I don't know if someone with severe dementia or disabilities would be able to access telehealth. I also think a lot of clients would like a hybrid telehealth model starting with a face-to-face assessment. (Home care physiotherapist, rural)

Finally, our screening process uncovered a lot of technology hesitation and potential telehealth data concerns that prevented the recruitment of many potential aged care service users into the TOP UP trial:

There is some hesitancy around technology use due to recent cybersecurity anxiety in the community- for example the Optus and Medibank breaches. (Home care manager, rural)

Theme 6: Organisational commitment is required to embed telehealth

Interviewees explained that considerable organisational commitment is required to embed telehealth programs like TOP UP in aged care. Sufficient investment is required to train staff, more meetings with their physiotherapy service providers to plan for the development of a new service such as telehealth, prioritise TOP UP sessions within busy service schedules, and, where necessary, to direct funds towards supportive technology. Some of the coaches and physiotherapists commented that the use of devices such as large iPads and smart televisions enhanced telehealth engagement by improving the visibility and hearing experience for service users:

Zoom worked well when we connected the iPad to the TV, we were able to turn the volume of the TV up so the resident could hear better. It also gives a bigger picture as well, so they can see the physio better. (Residential care coach, rural)

However, such equipment can be costly and telehealth-specific funding was raised by physiotherapy, aged care managers, and coaches as a key condition for ongoing sustainability for telehealth in aged care:

I think that maybe there needs to be funding support. Telehealth is an important and easy way to increase access and uptake. One physio could service several homes in a full-time caseload. (Residential care physiotherapist, rural)

TOP UP required three people to be available for appointments (the older person, their coach, and the physiotherapist on Zoom), thus scheduling was more challenging than 2-person face-to-face health care interactions:

There are always challenges whenever it comes to scheduling, especially during COVID when we were short of staff. But if you have a good relationship with your physiotherapy provider, who is responsive to time slot suggestions, then our scheduling team could work their magic and get it all booked. (Home care manager, rural)

Training was provided to older people to increase their confidence using an iPad, our website, and relevant apps (Zoom and StandingTall). Coaches were trained to increase their level of comfort navigating the TOP UP website and Zoom. The physiotherapists were trained to deliver effective telehealth assessments using Zoom and given strategies to enhance relationship development with older people and their coaches. All interviewees highlighted this training as an important factor in overcoming ‘telehealth hesitancy’ both for service users and program providers:

There was a lot of telehealth hesitancy at the beginning, but with education they slowly got quite comfortable in doing it. (Home care physiotherapist, metro)

There is a need to have some general training so we [physiotherapists] know how to use it [telehealth technology] effectively: make sure your voice is coming through, how to pace instruction so our clients understand us. The coaches and customers need training to know how to set up a shot, to make sure that they are visible to ensure that the client becomes independent and autonomous in their use of telehealth. (Home care physiotherapist, rural)

The aged care service managers also noted the challenge of training adequate numbers of care workers to facilitate TOP UP and ensure that the coaches are safe and competent:

There is a need to train a large proportion of our support workforce so that we have more trained staff who know how the program works, how to use technology and how to supervise our customers safely. (Home care manager, rural)

Some aged care service managers and physiotherapists indicated that more frequent and more detailed online exercise training programs would be useful to improve the skill level of a wider group of support staff:

It is very important to have lots of staff trained. For example, if the regular coach is sick, another staff member could take over and keep the program going. (Home care manager, rural)

All stakeholders indicated the need for specific investment into better internet connectivity to ensure the sustainability of future telehealth programs:

I've found is there are still a lot of places in rural Australia where older people don't have fast Internet, they don't have smart TVs, or they don't have the technology that metro places have. People are ready to engage with telehealth, but there's no infrastructure in rural areas. (Residential physiotherapist, metro)

Table 2: Overview of TOP UP implementation guidance in relation to the NASSS framework

Domain	Definition of domain	Implementation guidance derived from study findings	Illustrative quotes from interviewees
The condition	The suitability of the participant's attributes and their interaction with the intervention.	TOP UP is suitable for aged care service users with mobility challenges who can walk short distances. It is not suitable for those with significant sensory and cognitive disability	*Someone with severe dementia or severe disabilities wouldn't be able to have that skill to access telehealth. (Residential coach, rural)*
The technology	Technical features related to the usability of telehealth and its support requirements.	TOP UP necessitates internet access through an iPad or similar device. Aged care users, aided by trained care workers, require minimal technological skills to use the iPad, navigate Zoom, and access exercise videos on a website, fostering increased autonomy.	*One of my clients is really good with technology but other clients need my help to turn on the iPad and follow the program. (Residential coach, metro)*
The value proposition	The value proposition of telehealth for upstream end users (aged care service providers) and downstream users (physiotherapists and their clients).	All stakeholders saw telehealth physiotherapy as a valuable addition due to its convenience and perceived effectiveness, especially for those with poor mobility or who are living in rural/remote areas. The value proposition for telehealth to treat musculoskeletal pain is less as stakeholders prefer a more 'hands on' experience. A hybrid model would add value for some.	*Telehealth would save us time and travel and help us to see more people. (Home care physiotherapist, regional)*
The adopter system	The ongoing investment required to support the telehealth intervention and the ongoing acceptability of stakeholders.	TOP UP requires consistent investment in training, human (physio, coaches) and physical infrastructure (devices, fast internet, senior-friendly exercise resources) to create sustainable success. However, we found high levels of system support that are likely to be reinforced as positive returns on investment (such as greater mobility and wellbeing) are seen.	*TOP UP is more than just a fall prevention program, it offers a truly reablement focus where our clients can build their strength and balance and get out into the community again. I think many of our clients could benefit from telehealth. (Home care manager, rural)*
The organisation	An organisation's capacity to embrace the telehealth intervention and the supports required to establish and maintain it as a viable service offering.	Not all aged care services chose to participate in TOP UP due to the perceived burden of working with technology. Providers who joined TOP UP wanted to investigate telehealth's impact on access to fall prevention and mobility programs, in areas where there are physiotherapy shortages. Providers offered considerable support via technology provision, extra administration support for scheduling of telehealth sessions and enough care workers to support the program.	*I was surprised at how easy telehealth was to get started. We gave the clients an iPad and the assistance the care workers gave them was important to help them engage with telehealth. Our scheduling team are fantastic, and they managed to solve the scheduling challenges really well. (Home care manager, rural)*
The wider context	The wider organisational and policy impacts on telehealth uptake and sustainability.	Stakeholders agreed that funders need to provide telehealth specific funding and education for interventions like TOP UP to reduce technology hesitation and improve telehealth systems that enhance its adoption and sustainability.	*I feel that people would be greatly advantaged if there was a separate pocket of funding for allied health so that we could afford to deliver ongoing telehealth" (Home care manager, rural)*

Implementation guidance through the lens of the NASSS framework

TOP UP appears to be well positioned for sustainable adoption and learnings from this study has informed the translation of physiotherapy telehealth services by our aged care partners into practice. We have used the NASSS framework to help explain TOP UP's successes, failures, and explore the facilitators required to embed similar physiotherapy telehealth service delivery in aged care. Refer to Table 2.

DISCUSSION

This study provides valuable insights from a diverse spectrum of participants, including older people, physiotherapists, aged care support workers and aged care managers, who took part in the TOP UP trial. Our thematic analysis identified several key ingredients that contributed to the acceptability of this telehealth physiotherapy program. These included advice from physiotherapists, consistent support from trained care workers, senior-friendly online exercise resources, and a flexible reablement approach. The interview data often supported multiple themes, suggesting that it was the synergistic integration of the various ingredients within TOP UP that might have been responsible for the high levels of acceptability observed during the program. Therefore, it is important to note that while the following discussion explores the impact of single components of the TOP UP trial it is the combination of these different components that contribute to TOP UP's acceptability.

TOP UP Study is acceptable

Findings from this qualitative study highlight the high levels of acceptability of the TOP UP program among aged care service users and their care teams. The concept of acceptability is an important consideration in the design and implementation of complex healthcare interventions such as TOP UP [36]. Our findings align with the increasing body of literature indicating the acceptance of telehealth among older people in community settings despite high levels of technology hesitation [37] [38]. A cohort study of a telehealth program incorporating physiotherapy for rural older people found that telehealth was safe (no adverse events) and feasible (average telehealth attendance 85%) [38]. A 2022 systematic review further affirmed high telehealth acceptability, particularly with videoconferencing rather than via telephone, among community dwelling individuals with Alzheimer's disease, their caregivers and healthcare providers [39].

Barriers and facilitators related to telehealth adoption

TOP UP identified several barriers and facilitators that enabled aged care service user's to overcome high level of technology hesitation and if appropriately addressed could improve the translation of telehealth programs into aged care [40]. TOP UP indicated that barriers related to this population's innate technology hesitation and greater sensory, physical, and cognitive impairments. TOP UP's qualitative findings are reflected in the literature which demonstrates how the provision of local support, internet-connected devices, fast internet, and appropriate telehealth training can mitigate these barriers [39, 41, 42].

Technology barriers could be addressed by the provision of internet-enabled devices and local support. A recent US survey of community-dwelling older people with Parkinson's Disease during the COVID-19 pandemic revealed that a significant proportion (35%) of participants surveyed were technology avoidant and had never used telehealth before [38]. Most participants (82%) required assistance from a family member or paid care worker and 18% were "unable to interact over video" due to cognitive or sensory impairments. This survey found other barriers, health practitioners lacked knowledge of their patients' internet connectivity, and participants faced financial constraints in obtaining internet plans and were unable to pay for internet plans or video-capable devices. Similar findings emerged in TOP UP, where most trial participants had limited access (56%) to video-capable devices, limited telehealth experience (22%), and low telehealth readiness (TRI 2/5). Addressing barriers related to the purchase of telehealth infrastructure and providing local support can facilitate wider acceptance within aged care settings.

Technology training and support are needed for older people to increase telehealth engagement. A recent qualitative exploration of factors influencing acceptability in dementia management revealed that video-conferencing had potential benefits over in-person appointments by improving access to care for those with mobility limitations and reducing stress associated with clinic appointments [43]. A crucial insight from this study emphasised the necessity of technical support and telehealth training involving information on how to access and use different telehealth apps and tips for setting up the video camera for maximum visibility. Similarly, another study examining telehealth's role in enhancing oncology care for older people emphasised that appropriate technology training, integrated into the screening process and program delivery, could enhance telehealth adoption [44]. These studies align with TOP UP's findings that emphasised the delivery of appropriate education at screening and recruitment to reduce technology avoidant behaviours, pre-program technology training to support adoption and training to troubleshoot any emerging technology issues to enhance sustainability.

TOP UP demonstrated that behaviour change training for physiotherapists and coaches in health coaching techniques, motivational interviewing, and collaborative goal setting can increase telehealth adoption. Behaviour change training has been shown to increase therapeutic alliance and enhance exercise programs outcomes in other studies [45]. Strong therapeutic alliance has been identified as a crucial facilitator in previous telehealth interventions [46]. In our study, physiotherapists, coaches, and aged care service users found telehealth suitable for effective behavioural change coaching and suggested that specific training on skills to enhance therapeutic alliance is important to augment telehealth acceptability. Specific examples included targeted training on using Zoom emojis to acknowledge client achievements and building a personal connection through virtual tours of the older person's home and garden. However, they noted that establishing a successful therapeutic alliance through telehealth demands more time compared to in-person sessions, potentially increasing program costs.

Telehealth can provide key ingredients for behaviour change

TOP UP was designed to incorporate the COM-B model to create positive behaviour change related to exercise adherence [17]. Recent data from the Australian Institute for Health and Welfare have showed the critical significance of addressing insufficient physical activity in older individuals, given their 50% contribution to 2.5% of the overall disease burden in Australia [47]. Consequently, increasing motivation and opportunities for exercise in this demographic is crucial in mitigating the adverse health consequences stemming from sedentary behaviour [19] and in supporting the efficiency of the healthcare system [48]. TOP UP's tailored approach and utilisation of senior-friendly resources appeared to increase the capability (C) of older people to exercise. The program provided increased opportunities (O) for exercise by facilitating increased access to physiotherapists. Furthermore, TOP UP heightened motivation (M) through its reablement approach, goal-setting mechanisms, and cultivation of enjoyment via companionable coaching [16].

TOP UP strategically incorporated the principles of SDT to promote increased exercise adherence. According to SDT, intrinsic motivation thrives when individuals perceive a sense of autonomy and control over their activities [49]. Our study findings suggest that the aged care service users valued the opportunity to regain independence through self-directed exercise. The TOP UP program effectively nurtured feeling of competence through its personalised and progressive exercise routines program, fostered a sense of relatedness through local support and the rapport established during the telehealth physiotherapy sessions that actively promoted enjoyment. This observation aligns with Teixeira's systematic review on SDT and exercise adherence, affirming the positive correlation between intrinsic motivation, enjoyment, personal achievement, and heightened program acceptability [50]. We believe that this SDT informed approach likely contributed to the high program adherence observed.

Our study has provided insights into the potential explanatory effects of Bandura's social learning theory and Motivational Theory of Role Modeling in supporting the high acceptability of TOP UP. Bandura's social learning theory underscores the significance of observation and imitation in driving behavioural change [51]. When individuals perceive the modeled behaviour as valuable and the model possesses an admired status while being relatable, the likelihood of behavioural change increases. In this context, physiotherapists, esteemed as exercise professionals in the community [52], played a crucial role in enhancing the perceived value of the TOP UP program. Furthermore, the Motivational Theory of Role Modeling highlights another critical aspect of TOP UP's acceptability [53]. Many interviewees emphasised the importance of including older people as role models in the exercise videos. Both theories suggest that the inclusion of older role models was a pivotal factor inspiring behavioural change, explaining the positive reception of the TOP UP exercise videos.

Scale-up and sustainability of telehealth physiotherapy in aged care

Telehealth has emerged as a prominent method for implementing scalable health care interventions, a trend that intensified during the COVID-19 pandemic [54]. However, the challenge of sustaining these programs is pressing, as evident from reports of high participant attrition rates in telehealth-led exercise programs [55]. Successfully delivering cost-effective exercise programs to frail older people with multi co-morbidities in the aged care environment is challenging and complex, demanding significant resourcing [8]. Insights gained from the NASSS Framework [28] underscore the imperative for careful screening of older people for telehealth participation and the provision of targeted training to all stakeholders to enhance its feasibility. Our analysis indicates that while TOP UP was acceptable, a hybrid model of virtual care which combines in-person initial assessments, synchronous physiotherapy-led telehealth sessions for program progression, and the integration of local support and senior-friendly online exercise resources may further increase telehealth uptake and sustainability in aged care.

While the cost-effectiveness analysis of TOP UP is pending, our qualitative observations indicate that establishing telehealth physiotherapy programs requires substantial investments in both physical and human infrastructure. Telehealth literature discusses the critical role governments have in developing policies and guidelines to foster telehealth adoption [56]. Our interviews revealed a consensus on the need for dedicated funding for telehealth to enhance its adoption and sustainability.

Strengths, limitations and future studies

This qualitative study has several strengths. It triangulates empirical data relating to the uptake and sustainability of telehealth in aged care from four perspectives; older people receiving physiotherapy within aged care services, physiotherapists and trained support workers who deliver the intervention and aged care managers who are charged with case management and overseeing aged care service resource allocation and delivery. Our partnerships with aged care providers and their ongoing input in the research has enabled us to develop a deep understanding of how the TOP UP program was delivered in aged care and, if proven effective, this will speed up its translation into wider practice [14].

Qualitative research serves as a valuable tool for refining program design, deepening insights into the outcomes of quantitative research, and offering valuable guidance for enhancing the implementation of complex interventions such as telehealth services in aged care [26]. In this study we adopted a broad sampling strategy aimed at delivering a rich description of diverse intervention experiences, enlisting the perspectives of 18 older people encompassing a range of sociodemographic characteristics distributed across ten distinct sites. Moreover, the inclusion of independent physiotherapists, separate from both the aged care services partners and the research team, in our study design may have reduced potential social desirability bias, enhancing the credibility of our findings [30].

Several limitations necessitate careful consideration. TOP UP excluded participants from culturally and linguistically diverse (CALD) backgrounds and thus presents a notable gap in our understanding of their experiences. To address this gap, future trials that prioritise the inclusion of CALD communities are required. Additionally, although the interviewee cohort was purposefully selected to encompass maximum variation, it is essential to acknowledge that this pool primarily consisted of individuals who voluntarily participated in the trial, potentially predisposing them to higher levels of exercise engagement and receptiveness to telehealth. Consequently, this may limit the generalisability of these research findings.

Several aged care service users and coaches were interviewed by either the physiotherapist or aged care service provider who delivered the program. This can lead to social desirability biases that may undermine the credibility of the study results [57]. Given this context, aged care service users and staff might have hesitated to openly share negative experiences with their interviewers, despite the research team's assurances that their feedback would have no bearing on their ongoing care or employment status. To mitigate this bias, interviewers made concerted efforts to positioning themselves as eager learners, actively encouraging interviewees to share their 'insider' perspectives for quality improvement and expressing genuine appreciation for any criticisms offered. Future larger scale mixed methods studies should be designed to enhance research quality and further explore the impact of telehealth physiotherapy uptake and sustainability in aged care while carefully addressing social desirability bias.

This study suggests a need for the development of simplified telehealth exercise programs to facilitate greater adoption in aged care. A recent scoping review conducted in 2021, examining the barriers and facilitators to the utilisation of telehealth by older adults, found several impediment associated with current technology, including challenges related to small screens, text size, small icons and insufficient color contrast between text and background, alongside complex functionality [58]. The review also identified ease of use as a key facilitator to telehealth adoption. Some TOP UP stakeholders interviewed indicated a preference for simplified functionality tailored to this demographic. Respondents expressed a desire for telehealth programs that incorporated TOP UP program features like Zoom, exercise diaries and videos into one user-friendly application. These findings advocate for further research aimed at enhancing the user experience.

CONCLUSION

This qualitative study explored the program experiences of aged care service users, physiotherapists, and aged care staff involved in the TOP UP trial – a telehealth-led exercise program designed to improve mobility, reduce falls, and enhance quality of life. All stakeholders indicated high program acceptability, underscored by its safety, and perceived effectiveness. The thematic analysis uncovered key insights: TOP UP's provision of convenient access to physiotherapy services for aged care recipients; the positive impact of tailored physiotherapy, coupled with local support, on exercise motivation; the effectiveness of engaging senior-friendly resources in fostering program adherence; and the facilitation of greater independence through a flexible reablement approach. This study emphasises the importance of sustained organisational commitment for the successful implementation of telehealth programs like TOP UP, highlighting the need for training and external funding to ensure the program's adoption and sustainability.

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Data Availability The data sets generated during this study are not publicly available because of confidentiality promised to the participants as part of the informed consent process. However, data sets are available from the corresponding author upon reasonable request.

Conflict of Interest

None declared.

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Supplementary File 1: Semi structured interview guide

Questions were omitted or modified as appropriate for the type of participant or the participant's background.

Part A. Reasons for participation

1. Have you ever used telehealth before? What were your views about telehealth before you started the program?

2. What made you decide to take part in the TOP UP study?

Part B. Experiences of participation

3. What was your *experience of the TOP UP program overall?*

4. What are the *best aspects* of the TOP UP physiotherapy telehealth program? Specifically:

1) What did you think about *using the iPad*? How much assistance was required to use it?
2) Can you tell me what it was like to receive /give *advice from the physiotherapist*?
3) Did you use the *exercise booklet*? Was it useful?
4) Did you enjoy *the one-to-one exercise session with your TOP UP coach*? How are important is this help?
5) Did you follow the *video programs* from our website? What did you think about them?
6) Did you use *the StandingTall app*? What did you like or dislike about it?

5. What didn't work so well for you in the TOP UP program? What would you change about it?

6. We want to understand how a program like this fits in with people's lives (or, perhaps, doesn't fit in). Is there anything that gets in the way or makes it difficult for you take part?

7. Exercise is important, but it can also feel like hard work. What helped you/your client stick with the exercises and why do you think it helped? Was there any part of the program that that made it easier to keep going or was particularly motivating?

8. How has COVID has affected how we do things? Did it affect your ability to do your exercise?

Part C. Impacts

9. Do you/your client think anything has changed physically or mentally because of taking part in the physiotherapy program so far? Have you noticed any changes in your/their balance, how far you/they can walk, or your/their independence?

10. What are your views about physiotherapy telehealth now? Do you think it has benefits for you/your client?

Part D. What works?

11. We have some ideas about why people would choose to see their physiotherapist using telehealth. Can I share these ideas with you and get your views on them. We think:

a. That using telehealth increase people's *access to physiotherapy*. Has that been your experience?

b. The *tailoring of the physiotherapy program* is important. So, our physiotherapists try to create exercise according to everyone's abilities, taking account of your health needs, using different combinations of exercise handouts and online exercise classes to follow. Do you think we tailored the program to you and was this important?

c. Have you become *independent* doing your exercise program? If yes what helped you? If no, why not?

PART E. Maintenance

12. Thinking about the future now

1) What do you feel will happen with your/their physiotherapy program over the next 12 months? Do you see yourself keeping up with your exercises?
2) Would you/your client like to keep doing the online exercise programs? If not, why? What would help you with that? For example: would you like to own your own iPad?
3) Would you like to see the Coaches and physio regularly? How often? How much would you be prepared to pay for your physio telehealth?

Final thoughts Is there anything else you can tell us that might help us to improve telehealth physiotherapy programs like this and to support older people to be as active as possible and improve their health?

Thank you so much for helping us with our research. It's been really helpful to hear about your experience.

Supplementary File 2: Consolidated criteria for reporting qualitative research (COREQ)

No	Item	Description
Domain 1: research team and reflexivity		
Personal Characteristics		
1	Interviewer	RD and KN conducted the interviews
2	Credentials	RD PhD candidate, KN extensive research experience
3	Occupation	RD Physiotherapist, KN Aged Care Executive Manager
4	Gender	RD male, KN female
5	Experiences	RD completed post graduate qualitative course, KN 10 year+ conducting clinical research into aged care
Relationship with participants		
6	Relationship	RD conducted all the baselines assessment, KN is an executive manager with participants aged care service provider
7	Participant knowledge of the interviewer	Participants were aware of the research aims
8	Interviewer characteristics	All participants were made aware the RD was doing his PhD thesis investigating telehealth physiotherapy in aged care, all relevant participants were aware the KN was investigating the implementation of telehealth physiotherapy for possible business integration
Domain 2: Study Design		
Theoretical framework		
9	Method	Qualitative description
Participant selection		
10	Sampling	Purposive
11	Approach	Phone
12	Sample size	39
13	Non-participation	Nil

Setting		
14	Data collection	Participants home
15	Presence of non-participants	Trained aged care support worker
16	Description of sample	Aged care service users – home and residential aged care
Data Collection		
17	Interview guide	Interview guide attached and piloted in previous study
18	Repeat Interview	No
19	Audio recording	Zoom audio transcription was used
20	Field notes	Field notes were collected after each interview
21	Duration	19 min on average (range 8–53 min)
22	Data saturation	Discussed
23	Transcripts returned?	No
Domain 3: Analysis and findings		
25	Number of data coders	1
25	Description of coding tree	No
26	Derivation of themes	Identified from the data
27	Software	NVivo
28	Participant checking	No
29	Quotation presented	Deidentified quotation were used to illustrate the themes
30	Consistent data findings	Clear link to data and findings
31	Clarity of major themes	Major themes were clearly presented in the results section
32	Clarity of minor themes	Description of diverse cases and discussion of minor themes included

CHAPTER EIGHT

Discussion and Conclusion

8.1 OVERVIEW

Overall, this thesis aims to examine exercise programs and telehealth interventions designed to enhance mobility, reduce falls, and improve the overall quality of life for older people receiving aged care services. The primary focus involved collaboratively developing and testing a novel telehealth model to provide tailored physiotherapy for this specific demographic group.

The research methodology of this thesis incorporated diverse approaches, comprising 1) a quantitative study comparing different methods of fall incident data collection in residential aged care facilities (Chapter 2); 2) an Intervention Component Analysis (ICA) that uses an qualitative approach to explore the essential components of successful fall prevention exercise in Residential Aged Care Facilities (RACFs) (Chapter 3); 3) a systematic review and meta-analysis investigating the effectiveness and implementation of telehealth-based exercises for older adults with mobility issues and cognitive impairments (Chapter 4); 4) a co-design approach to understand the needs of stakeholders to inform the development of the TOP UP trial (Chapter 6); and 5) a qualitative study exploring insights from older individuals, physiotherapists, aged care support workers, and managers regarding the impact, safety, and resource requirements associated with implementing a telephysiotherapy-led exercise program in aged care (Chapter 7). The research process actively involved older adults and healthcare professionals from home and residential aged care settings.

8.2 PRINCIPAL FINDINGS

Addressing the healthcare needs of the ageing global population,[1] especially in regional and remote areas, is crucial due to the high incidence of falls among older people, leading to significant healthcare costs, reduced quality of life, and mortality.[2] Effective fall prevention exercise and mobility programs are essential in aged care for wellbeing and cost reduction.[3] However, limited access to physiotherapy services and transportation challenges for older people combined with the underexplored potential of telehealth in aged care hinder comprehensive support for older people in aged care settigs.[4]

Chapter Two revealed that incident reports are a convenient and reliable method for collecting falls data in residential aged care, contributing significantly to the evaluation of comprehensive fall prevention initiatives. This study demonstrates that incident reports are an efficient measure of falls and serve as a crucial initial step in identifying modifiable fall risk factors to implement fall prevention exercise programs as well as monitoring effects of interventions. The results from the ICA in Chapter Three indicate that effective fall prevention exercise programs involve tailored, supervised strength and balance exercises delivered at a moderate intensity. In Chapter Four, the acceptability of telehealth for delivering exercise programs to older individuals in aged care is demonstrated, contingent upon appropriate technology training and support, though the need for larger studies is emphasised to strengthen the evidence base. Moreover, the co-design process detailed in Chapter Five and Six suggests that a collaborative approach enhances research feasibility in aged care settings. The insights from Chapter Seven suggests that the safety, acceptability, and effectiveness of physiotherapy-led telehealth programs like TOP UP, are contingent upon implementation strategies such as senior-friendly online exercise resources, technology training, and local support to motivate aged care service users in adhering to mobility and fall prevention exercises.

8.2.1 Fall incident reports are a reliable and convenient method for collecting falls data to strengthen fall prevention exercises in aged care

Chapter Two demonstrated a substantial agreement between incident reports and progress notes in residential care facilities, but incident reports are a more efficient method of data collection.

This underscores the significance of fall incident reports in strengthening fall prevention programs within this setting.[5] Incident reports capturing crucial fall details such as time, location, and causative factors, aiding in the identification of trends and risk factors.[6] The structured data collected, including resident information and follow-up actions, provides valuable insights.[7] Moreover, these incident reports, mandated as part of regulatory schemes in many countries, serve as tools for local and national quality improvement initiatives.[8] However, this study identified challenges in accurate data collection due to insufficient staffing, leading to underreporting of falls.[9] Staff may avoid reporting falls due to various reasons, such as fear of consequences or lack of understanding about the importance of accurate reporting.[10]

Incident reports often lack comprehensive information about residents' changing health, medication, and functional impairments, potentially affecting the effectiveness of fall prevention programs.[11] To address these challenges, enhancing staff training could improve the quality of information collected in fall incident reports.[11] Fostering a culture of open communication and transparency can mitigate underreporting issues and enhance data reliability.[11] Additionally, linking fall incident reports to referrals for appropriate interventions, such as tailored exercise programs conducted by physiotherapists, ensures that older adults receive the necessary support to address functional and physical impairments, ultimately contributing to more effective fall prevention efforts.[12]

8.2.2 The right approach for fall prevention exercise programs in residential aged care is important

Chapter Three explores an ICA[13] to synthesise triallists' comments from an updated Cochrane review[14] about what a successful fall prevention exercise could look like. The trialists' commentary supported the development of a theory that explored the right exercise approach involving the delivery of moderate intensity strength and balance exercises tailored to the individual. The trialists suggested that interventions need to be resourced sufficiently to provide structured and supervised exercise at an adequate dose. Due to minimal commentary on the implementation of these programs, our ICA did not provide significant guidance to clinicians and policy makers about how best to support the facilitation of fall prevention exercise programs in residential aged care.

The findings from our ICA informed the development of a Qualitative Comparative Analysis (QCA) presented in Appendix 1.[15] The QCA was conducted with researchers from University College London, the University of Sydney and Flinders University to further test the robustness of our ICA theory. QCA is a data analysis based on set theory that examines the relationship of conditions to outcomes to determine the *necessary conditions* and *sufficient conditions* to create an outcome.[15] We found that exercise programs should provide continuous supervised low to moderate intensity group exercise programs to consistently reduce falls in residential aged care. For programs that mostly include independent ambulatory residents, moderate or low intensity exercise for 1 hour per week, at minimum, should be provided. Considering that many residents currently in residential aged care are frail with significant mobility and cognitive disability,[16] a different dose may be required. Future trials are required to test the effectiveness and cost-effectiveness of group exercise and investigate the implementation of fall prevention exercise programs in residential aged care.

8.2.3 Supporting telehealth interventions to promote exercise in aged care settings

Age-related changes in cognitive, musculoskeletal, and sensory systems contribute to impairments in vision, hearing, mobility, and cognition among older adults, increasing their risk of falls.[12] Falls rates have been rising annually, especially in residential aged care facilities, where nearly all residents have impaired balance and strength, key risk factors for falls and fractures.[17] [18] Exercise interventions, prescribed by physiotherapists and allied health professionals, have been shown to improve physical function in aged care, yet access to these services remains unequal, particularly in rural areas.[19] [20] [21] Telehealth is becoming integral to contemporary physiotherapy care, offering potential solutions to accessibility issues.[22]

The results from the systematic review and meta-analysis in Chapter Four suggest that telehealth can improve mobility, balance and strength in aged care settings. Due to the small number of studies overall certainty of evidence for the effect of telehealth intervention on physical outcomes was rated as very low quality and the pooled results for all outcomes did not reach statistical significance. However, the implementation analysis reveals key findings. The reach of the interventions was moderate, with a median of 55%, while feasibility, indicated by participant inclusion in follow-up data collection, was high with a median score of 87%. Adherence to planned exercise sessions was also high, with a median attendance rate of 86%, and the exercise dose over the study period had a median of 17 hours across eight studies. Overall satisfaction with interventions, measured in eight trials, was high with a median rate of 86% with few safety concerns.

Chapter Four revealed that facilitators for high program adherence included initial participant technology training, ongoing support, the convenience of home-based telehealth programs, and program flexibility. However, barriers were identified, such as technology hesitation impacting recruitment rates and satisfaction, challenges in delivering synchronous classes to multiple sites, and limitations in tailoring exercises in asynchronous programs. It is suggested that any other investigation into telehealth utilisation in aged care settings should address these barriers to improve the feasibility of the trials.

8.2.4 The importance of co-design to enhance implementation of telephysiotherapy exercise interventions in aged care

Chapter Five and Six delve into the co-design methodology employed in the TOP UP trial. The co-design process within TOP UP was a collaborative effort that actively engaged the perspectives of the aged care workforce, healthcare professionals, and older adults. This inclusive approach played a pivotal role in shaping the trajectory of the TOP UP trial. Co-design recognises the unique needs, preferences, and challenges of the ageing population, fostering a more tailored and patient-centric healthcare delivery model.[23] The co-design elements in TOP UP were important because it enabled the TOP UP's intervention, resources and implementation plan to be specifically tailored to the diverse needs and capabilities of aged care service users. Input from all stakeholders helped customise senior-friendly online and printed exercise resources that proved feasible for participants with various physical, sensory and cognitive abilities. Results of the co-design process also reflected the results from Chapter Four's systematic review where an implementation analysis emphasised the importance of support from trained care workers and the necessity of investing in adequate staff training to ensure sustainable adoption.

The integration of older individuals into the co-design process of the TOP UP protocol appears to have heightened participant engagement and fostered a sense of ownership in their telephysiotherapy exercise and contributed to robust implementation outcomes. TOP UP's aged care partners screened a total of 1348 aged care service users spanning 27 sites for eligibility. This screening identified a pool of 512 (38%) eligible participants. Forty-seven percent (n=242) of eligible service users consented to participate representing 18% of the total screened pool. In the context of trial consenting procedures, this can be considered a strong adoption rate which suggests reasonable generalisability of the findings.

Notably, at the six-month primary outcome follow-up assessment, 202 participants remained available, underscoring the high feasibility of TOP UP. The trial recorded a median exercise dose of 29 hours (range 8 to 75) across the six-month trial period as the physiotherapists aligned interventions with the preferences and goals of the end-users. These highlight the significance of involving diverse voices in research initiatives, ensuring the relevance and feasibility of interventions in real-world settings.

The iterative nature of co-design enabled some site-specific adaptions of the TOP UP implementation. Feedback from both participants and healthcare professionals involved in the trial informed implementation adjustments, such a slower exercise videos, ensuring that the programs evolved to meet evolving participant needs at each site.

The use of different implementation frameworks supported the implementation of the trial. The implementation outcomes of acceptability, reach, fidelity, dose-delivered, and adoption are closely related to the NASSS (Non-Adoption, Abandonment, Scale-up, Spread, and Sustainability) framework, as they collectively provide insights into the complexities and challenges of implementing innovations in healthcare settings. The following implementation outcomes relate to the NASSS framework in a number of ways:

1. **Acceptability**: Acceptability refers to the extent to which an intervention is perceived as suitable or agreeable by stakeholders.[24] In the NASSS framework, acceptability is linked to the "Non-Adoption" domain, as interventions that are not deemed acceptable by stakeholders may face resistance or reluctance to adopt them.[25]

2. **Reach**: Reach refers to the proportion of the target population that participates in or is exposed to the intervention. In the NASSS framework, reach is associated with the "Scale-up" and "Spread" domains, as it reflects the extent to which the intervention is implemented across different settings or populations.[25]

3. **Fidelity**: Fidelity refers to the degree to which an intervention is delivered as intended or according to its protocol.[24] Fidelity is closely related to the "Scale-up" and "Spread" domains in the NASSS framework, as maintaining fidelity during the implementation process is crucial for ensuring consistency and replicability across diverse settings.[25]

4. **Dose-Delivered**: Dose-delivered refers to the quantity or intensity of the intervention delivered to participants.[24] In the NASSS framework, dose-delivered intersects with the "Sustainability" domain, as interventions that are delivered inconsistently or inadequately may struggle to be sustained over time.[25]

5. **Adoption**: Adoption refers to the decision by individuals, organizations, or systems to accept and implement the intervention.[24] In the NASSS framework, adoption is central to the "Scale-up" and "Spread" domains, as successful adoption is necessary for the intervention to be implemented widely and effectively.[25]

Overall, the implementation outcomes of acceptability, reach, fidelity, dose-delivered, and adoption provide valuable insights into the multifaceted nature of implementing the TOP UP trial, aligning closely with the domains of the NASSS framework and helping to understand the challenges and facilitators of successful telephysiotherapy implementation in aged care.

During our qualitative analysis of the TOP UP trial we did not refence Greenhalgh’s seventh and final domain due to the early stage of this research. The final domain in the NASSS framework is "Sustainability." This domain focuses on the long-term viability and maintenance of the intervention within the healthcare system or organisation. Sustainability encompasses factors such as ongoing funding, integration into routine practice, adaptability to changes in context or policy, and the ability to demonstrate continued effectiveness and benefits over time. This domain would need to be considered in any future analysis of existing telephysiotherapy programs.

8.2.5 TOP UP is safe and acceptable for many older people

Chapter Six briefly explores the safety and acceptability outcomes from the TOP UP trial. One adverse event occurred during the trial when a participant fell while exercising, but no injuries were reported. It appears that the complex comorbidities of the participants were well managed by their treating physiotherapy using telehealth and the support from their trained care workers. At the intervention's end, participants were surveyed about recommending telephysiotherapy. Most participants were willing to recommend telephysiotherapy (TOP UP).

Acceptability is crucial when designing and implementing effective telehealth interventions.[26] TOP UP is a complex intervention comprising multiple interacting components, delivered across different physical settings requiring the support of various different parties and levels within aged care organisations.[27] Telehealth service developers face the challenge of creating effective programs within resources constraints.[28] Successful implementation of telehealth programs like TOP UP depends on both the program delivers (physiotherapists, aged care service providers) and the recipients (older people, their families, care staff,) perceive the intervention as acceptable.[29]

Chapter Seven includes all stakeholder in its qualitative analysis and highlights three key reasons for TOP UP's high levels of acceptability: (1) telehealth's accessibility by eliminating geographical barriers; (2) its convenience, enabling home-based exercises and flexible scheduling; and (3) its motivational aspect, using technology to educate and support older adults, promoting adherence to evidence-based exercise programs. A recent feasibility study corroborates these findings, demonstrating the viability and acceptability of telehealth in hybrid rehabilitation programs for older adults with mobility disabilities.[30]

While telehealth is acceptable for physiotherapy-led fall prevention and mobility exercises, it may not be suitable for hands-on interventions in musculoskeletal physiotherapy, a sentiment echoed by physiotherapists.[30] Despite these reservations, our research aligns with the broader acceptance of telehealth in physiotherapy, emphasising its ongoing clinical role and positive patient experiences.[31] The results of this thesis provides assurances to aged care service and physiotherapy providers that telehealth is acceptable by all stakeholders and gives guidance on how best to implement future iterations of programs such as TOP UP.

The TOP UP program appears to sit well in a reablement model of care and if proven effective could gather support from funders. There is currently an Australian Government focus on 'reablement' and maximising or improving function in people living with dementia in the community.[32] In Australia reablement shares features with rehabilitation, such as maintaining or improving functional ability with a focus on interdisciplinary care.[33] However, reablement has been described as a less structured approach that has potential for enhancing function and independence in people at risk of functional decline who have complex comorbidities including dementia. Reablement distinguishes itself by prioritising home-based care over acute settings such as hospital.[34]

8.3 IMPLICATIONS FOR CLINICAL PRACTICE

Chapter Two highlights the efficiency and accuracy of using incident reports in fall prevention programs and gives aged care service providers the confidence to use them in Australia's new mandatory incident reporting program.[8] Incident reports provide a systematic and standardised means of data collection, enabling clinicians to discern patterns, identify risk factors, understand common causes of falls within aged care settings and evaluate the impact of falls prevention strategies.[12] This information supports evidence-based decision-making, fostering the development and modification of fall prevention strategies in a more efficient way then progress notes. The detailed insights gleaned from incident reports empower healthcare professionals such as physiotherapists to craft targeted intervention strategies tailored to the specific needs and characteristics of individuals at risk.[35] This personalised approach will allow for more effective and nuanced strategies that directly address the root causes identified through incident analysis.[36] The results of this fall agreement analysis highlight the importance of adequate staffing levels to support accurate incident reporting which will facilitate proactive risk assessment, enabling clinicians to identify environmental, patient-specific, or systemic factors contributing to falls. This proactive stance allows for the implementation of preventive measures before further incidents occur, ultimately reducing the likelihood of recurrent falls and associated injuries.[37]

The Intervention Component Analysis (ICA) presented in Chapter Three study holds crucial clinical implications for researchers, clinicians, and policymakers involved in fall prevention programs in aged care. This ICA provides a systematic approach to analysing the components of an intervention, allowing healthcare professionals to identify and understand the specific elements that contribute to its effectiveness.[13] This precision in intervention design enables clinicians to tailor interventions to the unique needs and characteristics of individual patients or specific populations.

The findings presented in Chapter Three emphasise the importance of tailoring exercise interventions to the individual, with balance and strength exercises to be the most likely effective components in reducing falls. Notably, trials that successfully delivered moderate-intensity exercises tailored to residents' needs demonstrated positive outcomes, highlighting the significance of exercise intensity in fall prevention. Implementation strategies, though less explicitly discussed in Chapter Three, are highlighted by the ICA as essential for success. The ICA suggests that sufficient resourcing, including supervision, structure, and adequate dose, could be crucial for effective fall prevention programs. However, the study points out that the median weekly exercise dose across trials was considerably lower than recommended, suggesting a need for more intensive exercise interventions in aged care settings. This ICA gives clinicians emerging evidence that enables them to prioritise and select the most effective components and adapt current interventions to reduce falls in aged care.

Implementing learnings from Chapter Four and Seven support the use of telehealth to deliver physiotherapy-led exercise programs for older people in aged care to improve mobility, reduce falls and improve quality of life. However, the full impact of the rial will not be known until the effectiveness results are analysed. The reach of the trials in the systematic review and the TOP UP trial included a diverse range of participants, encompassing those with multiple health issues and moderate cognitive and mobility impairments. The telehealth interventions enabled tailored exercise guidance, encompassing low to moderate intensity balance and strength exercises, either individually or in group settings. However, limitations to telehealth's reach exist, particularly among individuals with severe cognitive and mobility impairments and significant sensory deficits. Research findings from Chapter Four and Seven highlight the importance of some key implementation facilitators that appeared to enhance the success of telehealth programs in aged care. These facilitators should be considered in future design of telephysiotherapy programs in aged care and include:

- Implementing behaviour change techniques via real-time feedback during synchronous video-conferencing, delivering superior exercise instructions through the use of exercise videos and providing increased prompts to remind older people when and how to exercise with local support.[38 39-42]

- Providing staff and participants with technology training to reduce any technology hesitation and to improve the chances of successful program implementation.[43]
- Ongoing telehealth support to troubleshoot any problems with the technology to enhance exercise participation. [39 41 44-48]

The COVID-19 pandemic highlighted the need for alternatives to in-person consultations without compromising the quality of and access to essential health services such as physiotherapy.[49] Telehealth can be a valuable method for delivering restorative exercise programs to aged care service users, especially when the practice is sensitive to each person's unique needs and their sensory, physical and cognitive limitations.[50 51] The findings of this thesis aligns with the recent implementation guidelines for telehealth that the World Health Organization (WHO) published in 2021. This guidance aimed to provide evidence-based advice about the actions necessary to implement telehealth safely and effectively during COVID-19 and beyond the pandemic.[52] It was aimed at health care system professionals and did not target aged care service users specifically, but parallel findings can be drawn from our research and the WHO's guidance:

- Telehealth should follow a tailored approach with appropriate steps taken to ensure that the accessibility, quality and safety is supported by effective policy and governance.
- Multidisciplinary collaboration between key stakeholders will enhance successful design and implementation.
- User interfaces, functionalities and communication strategies should be co-designed with end-users and adhere to emerging evidence-based practices for usability, accessibility and deliver clear benefits to both end users and the health care system.
- Telehealth support should be consistent to reduce technology anxieties and facilitate wider adoption.

- The adoption of telehealth can widen health care inequity, leaving behind those without digital devices, internet connectivity or relevant skills. It is important to prioritise and carefully assess the adoption and impact of telehealth among people from vulnerable populations such as those from rural communities, culturally and linguistically diverse backgrounds, the aged and those with disability.
- Healthcare providers should assess the readiness stakeholders to use telehealth services based on local, social, regulatory and technological contexts before committing to investing in telehealth program and reduce mismanagement of healthcare funds.

Chapter Five explores how TOP UP aimed to integrate behaviour change theories to influence behavioural patterns and to enhance exercise adherence among older individuals.[53] Chapter Six delves into the integration of key components identified in TOP UP's pre-implementation workshops, crucial for fostering adherence to exercise routines, which later emerge in Chapter Seven as pivotal for enhancing exercise adherence. These include:

1. Goal setting: Telephysiotherapy can facilitate collaborative goal setting between healthcare providers and older adults is a similar way to in-person sessions. Setting specific, measurable, attainable, relevant, and time-bound (SMART) goals creates a sense of purpose and motivation, increasing adherence to exercise programs.[54]
2. Self-Monitoring**:** TOP UP included features for self-monitoring, allowing our participants to record their exercise frequency using written diaries. We expect that including this feature in senior-friendly ways will enhance future telephysiotherapy applications. Zoom appeared to be suitable application for the physiotherapist to communicate the program progress and celebrate the participants achievements. Assisting aged care service users to track their accomplishments can boost self-efficacy and motivation, encouraging continued participation.[55]

3. Feedback and Reinforcement: Telehealth platforms such as Zoom enable real-time feedback from healthcare providers, acknowledging progress and providing positive reinforcement. Regular encouragement and positive reinforcement can enhance motivation and adherence to exercise routines.[56]
4. Social Support: TOP UP has the capacity to integrate social aspects, including virtual group exercise sessions or online exercise communities, thereby cultivating a sense of community and support. Incorporating social interactions and encouragement from peers or healthcare professionals can significantly enhance adherence by fostering motivation and accountability.[57] Crucially, the support provided by TOP UP coaches, as identified in the pre-implementation workshop, played a pivotal role in enabling participant engagement with telephysiotherapy and facilitating the accomplishment of complex balance assessments and the delivery of moderate-intensity balance and strength exercises. This supportive mechanism emerged as a crucial factor contributing to the feasibility of TOP UP.
5. Cognitive Reappraisal: TOP Up offered repeated educational components that aimed to give the participant the tools to adhere to exercise program safely (exercise videos, weekly local support and education via Zoom with the physiotherapists). We believe that this helped the participants reframe their negative thoughts or concerns about exercise. Addressing misconceptions and fears can alleviate anxiety and boost confidence, leading to increased adherence.[56]
6. Problem-Solving: In Chapter Seven the physiotherapist interviewed indicated that Zoom platform can offer opportunities that help older adults identify barriers to exercise adherence and develop problem-solving skills. Learning coping strategies and finding solutions to challenges can empower individuals to overcome obstacles and maintain their exercise routines.[58]

7. Routine: The TOP UP program supported participants in establishing a regular exercise routine through weekly visits from their coaches and consistent physiotherapy sessions. The creation of a structured and predictable exercise schedule contributes to the formation of a habit, increasing the likelihood of adherence to the exercise regimen among older adults.[59] We propose that future initiatives explore the augmentation of this aspect by developing applications capable of sending text reminders and additional motivational support, aiming to further enhance the effectiveness of subsequent telephysiotherapy programs.
8. Modeling: The TOP UP program integrated Bandura's theory of modeling, and this emerged as a significant facilitator in our qualitative analysis.[55] By featuring older individuals in the TOP UP exercise videos, the program leveraged visual learning to enhance confidence, ensure proper technique, and bolster motivation.

Telephysiotherapy, as explored in the TOP UP trial, holds promise in providing timely, patient-centred care, especially for frail aged care service users. The incorporation of behaviour change strategies into TOP UP appears to have contributed to adequate exercise adherence among participants. If the results from the TOP UP trial demonstrate the effectiveness and cost-effectiveness of telehealth interventions in improving mobility, reducing falls, and enhancing quality of life, it will reinforce the crucial role telehealth can play in delivering evidence-based exercise, bridging health access gaps, and improving health outcomes for older people in aged care settings.

8.4 IMPLICATIONS FOR FUTURE RESEARCH

8.4.1. Future research is required for culturally and linguistically diverse (CALD) populations

Conducting research in culturally and linguistically diverse (CALD) populations in Australia is essential for promoting health equity, addressing health disparities, and informing policy development. As a result of migration trends, older CALD populations increasing sharply.[60] In 2014-15, 27% of home care recipients and 19% of residential aged care were from CALD background. In 2018, one-third of people with dementia were from CALD populations.[61] It has been shown that the burden of dementia may have been disproportionately greater among particular CALD groups, potentially due to social determinants of health (e.g., socioeconomic conditions).[12] The prevalence of dementia in Australia was highest among Italian, Greek, and Chinese born populations.[61] In the TOP UP study, less than 10% of participants were from CALD backgrounds and there was little evidence of CALD participants in Chapter Four's systematic review of telehealth. There is a lack of research on telehealth interventions designed to improve physical outcomes of older people from CALD backgrounds. Hybrid implementation and effectiveness research that used mixed methods can help identify barriers and facilitators unique to CALD committees is required.

8.4.2 Future co-design research is required to investigate the usability of telehealth applications

TOP UP tested two telehealth applications, Zoom and a co-designed website, to deliver tailored and progressive strength and balance exercises. We have identified the need for the development of a comprehensive application (TOP UP app) to enhance program usability and outcomes. Funding has been secured to develop the TOP UP app through a co-design process with aged care service users in 2024. Additionally, grants have been submitted for a large-scale trial involving 720 participants, incorporating the TOP UP app. This proposed trial plans to utilise synchronous videoconferencing and asynchronous exercise videos, supported by local staff, to deliver tailored balance and strength exercise. The study's objective is to evaluate the influence of the TOP UP app on falls. It will be a hybrid type 1 effectiveness-implementation trial, intending to examine how the simplified user interface, exercise adherence tracking, and embedded motivational texts impact exercise motivation and adherence among older adults in residential aged care.

This thesis discusses the challenges and opportunities associated with implementing effective telehealth exercise programs for aged care services users. Understanding the usability of telehealth applications is crucial for ensuring widespread and effective adoption of remote healthcare solutions.[62] Research in this area is needed to assess how easily users, including older people and those with varying technological proficiency, can navigate and engage with telehealth platforms. Identifying usability challenges and streamlining user interfaces can enhance accessibility, user satisfaction, and overall effectiveness of telehealth applications in delivering remote healthcare services.[63]

8.4.3 Future trials that include all aged care service users

It is important to highlight that the findings of this thesis related to the eligibility parameters outline in the TOP UP protocol, which excluded aged care service users with severe cognitive, physical and sensory impairments from participating in the trial. Older people with dementia, severe sensory impairments, and mobility impairments are at a higher risk of falling compared to those without these conditions.[12]

Dementia can affect cognitive function, leading to impaired judgment, reduced spatial awareness, and an increased risk of falls. Severe sensory impairments, such as vision or hearing loss, can further hinder an individual's ability to detect environmental hazards and maintain balance, contributing to the risk of falls. Mobility impairments, including muscle weakness, gait disturbances, and difficulties with balance and coordination, also significantly increase the likelihood of falls among older adults.[12,16,18] The combination of these conditions creates additional challenges in navigating the environment safely, making fall prevention strategies essential for older adults with dementia and severe sensory and mobility impairments.[20]

Future trials that include people with severe cognitive, physical, and sensory impairments are important for several reasons:

1. Inclusivity: To ensure that the interventions developed to be generalisable to real-world settings and populations of older adults, including those with diverse impairments and functional limitations. By including individuals with severe impairments, researchers can assess the effectiveness and feasibility of telephysiotherapy strategies across a wide range of abilities and needs.
2. Ethical considerations: Excluding individuals with severe impairments from fall prevention trials may perpetuate disparities in healthcare access and neglect the needs of vulnerable populations. It is ethically important to ensure equitable access to interventions aimed at improving the health and safety of all older adults, regardless of their impairments.
3. Comprehensive understanding: Including people with severe impairments provides a more comprehensive understanding of the barriers and challenges they face in engaging with telephysiotherapy. It allows researchers to identify specific needs, preferences, and

barriers to participation in virtual exercise programs, informing the development of more tailored and effective interventions.

8.5 IMPLICATIONS FOR POLICY AND PRACTICE

TOP UP holds substantial potential to influence policy by showcasing the acceptability, safety, and effectiveness of telephysiotherapy. If the trial is found to be effective and cost-effective this evidence combined with the implementation outcomes may drive policymakers to integrate telephysiotherapy into comprehensive healthcare policies, potentially involving direct funding to enhance physiotherapy access for aged care service users in thin markets. The research outcomes could inform the creation of specialised frameworks and implementation guidelines for aged care, fostering collaboration, training initiatives, and regulatory adaptations. Furthermore, these findings may contribute to public awareness, encouraging policymakers to implement educational campaigns for the widespread integration of telehealth practices in aged care physiotherapy.

Chapter Seven sheds light on telehealth's transformative potential in enhancing aged care service delivery by improving access, reinforcing preventive care, and facilitating older individuals' access to exercise at their convenience. The qualitative analysis results have inspired TOP UP's aged care service partners to develop their telephysiotherapy models, connecting aged care clients to physiotherapy services. These services commenced operations in 2023, and the forthcoming effectiveness and cost-effectiveness results may provide additional value if they prove positive. Overall, TOP UP has the capacity to instigate significant policy and practice changes in support of telehealth initiatives in aged care physiotherapy.

8.6 CONCLUSION

The ageing global population demands healthcare systems prepare for this demographic shift. Prescription of evidence-based exercise targeting the mobility improvement, fall prevention, and enhanced quality of life among older people should play a pivotal role in ensuring efficient healthcare service delivery.[64] Telehealth's pivotal role in delivering continuous care during the COVID-19 pandemic underscores its potential to reduce morbidity and mortality. Despite this, there's limited evidence guiding sustained telehealth implementation in aged care. This thesis contributes significantly to the evolving evidence on the acceptability and implementation of telephysiotherapy programs in aged care settings, offering valuable insights for clinicians, caregivers, and service providers. The translational impact of the implementation findings will be fully realised if the trial is found to be effective.

The findings presented in this thesis provides evidence for the importance of integrating fall incident data collection methods into effective fall prevention exercise programs, emphasising their accuracy and efficiency. The Intervention Component Analysis (ICA) highlights that successful exercise programs should feature balance and strength exercises at a moderate intensity, tailored to individual needs. Additionally, insights from our systematic review on telehealth's impact on older people demonstrate that with support and training telehealth can align with the needs of aged care service users. Qualitative findings from the TOP UP trial collectively indicate that telephysiotherapy is a suitable, safe, acceptable, and feasible medium for delivering evidence-based exercise in aged care, aligning with the principles outlined in the ICA approach.

The work presented in this thesis emphasises the need to educate aged care users about telehealth's convenience and safety and the need to address this population's technology hesitancy. Tailored marketing strategies, comprehensive planning, co-design efforts, and collaboration between stakeholders are essential for successful telephysiotherapy adoption. While COVID-19 accelerated telehealth, challenges persist in reducing healthcare inequities, necessitating collaborative efforts for the sustainable and widespread accessibility to deliver effective exercise in aged care. Future research is needed to investigate the effectiveness of the delivery of exercise program through telehealth among CALD older participants and to explore the usability of telehealth applications in aged care. Large scale randomised controlled trials focusing on the effectiveness and scalability of telephysiotherapy applications are also warranted.

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APPENDIX A

Qualitative Comparative Analysis of Exercise Interventions for Fall Prevention in Residential Aged Care Facilities

Qualitative Comparative Analysis of Exercise Interventions for Fall Prevention in Residential Aged Care Facilities

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Abstract

Background: Exercise interventions are highly effective at preventing falls in older people living in the community. In residential aged care facilities (RACFs), however, the evidence for effectiveness is highly variable, warranting exploration of drivers of successful trials. This study aims to identify the features of randomised controlled trials (RCTs) that are associated with reducing falls in RACFs.

Methods: Included RCTs testing exercise interventions in RACFs compared to usual care, reporting rate or risk of falls from the systematic Cochrane Collaboration Review and a search update to December 2022. Two authors independently extracted and coded trial features and effectiveness. Trial features were coded as either absent, present or by degree of presence according to a theory developed from prior Intervention Component Analysis. Trial effectiveness was coded as effective or ineffective based on point estimates for rate ratio or risk ratio, or $p<0.05$ where ratios were not available. Qualitative Comparative Analysis (QCA), utilising Boolean minimisation theory, was conducted to determine the key trial features associated with successful trial outcomes.

Results: 18 trials undertaken in 10 countries with 2,279 residents were included. Participants were predominately ambulant females aged 70 to 80 with cognitive impairment. Interventions tested were mostly fully supervised, or initially supervised, exercise programs. QCA identified two configurations of features associated with successful falls prevention programs: (i) moderate or low intensity group exercise, or (ii) for independent ambulatory residents, moderate or low intensity exercise for more than 1 hour per week (coverage, a measure of the trials explained by each pathway, was 0.67 and 0.75 respectively). The combination of the two scenarios had high consistency (indicating strongly sufficient relationships) and total coverage scores of 1 indicating that the combined pathways explained all trials.

Conclusion: To consistently reduce falls in RACFs, exercise programs should provide continuous supervised moderate-intensity group exercise. For programs that mostly include independent ambulatory residents, moderate or low intensity exercise for more than 1 hour per week, should be provided. As many current residents are frail, tailored exercise is likely necessary and an individualised dose may be required. Future trials should test exercise interventions for less mobile residents.

Keywords: fall prevention, exercise intensity, care home, nursing home, exercise program

Introduction

Exercise interventions can facilitate safe mobility by enhancing muscle strength and balance and the ability to avoid falls. Thus, exercise is a featured and recognised intervention approach in falls prevention guidelines [1, 2]. In the community, there is high certainty evidence that balance and functional exercise interventions for falls prevention can lead to a 24% reduction in the rate of falls amongst older adults [3]. However, in residential aged care facilities (RACFs), the evidence is highly variable (rate ratio of 0.93, 95% CI 0.72 to 1.20, 2002 participants from 10 studies, I^2= 76%), leading to a conclusion that the effect of exercise was not certain in most recent 2018 Cochrane Collaboration review [4]. RACFs are a complex environment to provide exercise interventions in. Exercise professionals are required to integrate with the organisation through varied funding schemes and work with a high turnover of nursing staff and vulnerable residents with additional falls risks due to cognitive impairment, frailty, and malnutrition [5, 6].

Despite the environmental complexities, a recent reanalysis of exercise interventions in RACFs comparing end of intervention data to end of follow up data demonstrated a beneficial effect on falls prevention [7]. Trials of exercise interventions reduced falls at the end of exercise intervention in comparison to usual care (rate ratio 0.68, 95% CI 0.49-0.95, I^2 =85%; risk ratio 0.84, 95%CI 0.72–0.98, I^2 = 18%) [7]. No effect was observed beyond the intervention period (rate ratio 1.01, 95% CI 0.80 – 1.28, I^2 =58%, risk ratio 1.05, 95% CI 0.92-1.20, I^2 =10%), where no exercise intervention was provided, suggesting that continuing exercise programs in RACFs is required to maintain a reduction in falls amongst residents [7]. However, the considerable heterogeneity observed between trials (I^2 =85%) where some trials clearly reduced falls and others increased falls, warrants further exploration to understand the differences between successful and unsuccessful exercise interventions for falls prevention [8].

A recent intervention component analysis (ICA) identified a key theory for drivers of successful falls prevention exercise interventions from the perspective of trialists [9, 10]. The theory stated that provision of the 'right' exercise with sufficient resourcing could be required for a falls prevention exercise intervention to effectively reduce falls in RACF. 'Right' exercise was described as consisting of a targeted balance and strength program providing individualised exercise prescription of moderate intensity, focusing on a realistic approach to exercise for older adults. Sufficient resourcing referred to supporting structured supervised group exercise for 30 hours or more and education for staff and residents on falls prevention [9]. This theory provides a starting point for qualitative comparative analysis (QCA) where it can be tested and refined to identify the combinations of conditions that best explain the success and failure of all trials [11].

QCA is increasingly applied in systematic reviews because of its suitability for examining intervention complexity [12-14]. Based on an assumption that complex interventions differ in multifarious ways and that outcomes result from the interplay of an intervention with its implementation and context, QCA combines processes and principles of qualitative inquiry with quantitative analytical methods to identify critical features related to the intervention and / or contextual elements [11]. The underlying logic of QCA derives from set theory and involves exploring how sets of trials with similar characteristics overlap with sets of trials defined as having a successful or unsuccessful outcome. As a result, this method can identify features associated with successful trials in complex interventions where it is unclear why some trials are successful while others or not.

This study aimed to use QCA to test the consistency and inclusion of components identified from ICA as an initial theory and refine the theory as required to identify combinations of exercise trial features that are associated with reducing falls RACFs.

Methods

Study Selection

Randomised control trials (RCTs) that tested exercise interventions compared to usual care in RACFs and reporting data for rate or risk of falls at the end of intervention, suitable for meta-analysis, or had falls data with a p-value when effect estimates and confidence intervals were not available, were included. Trials included in the Cochrane Collaboration review [3] and records from an additional search update of CENTRAL, MEDLINE, Embase and CINAHL Plus databases from 2017 to December 2022 were screened to identify eligible trials [4]. Trial records and conference abstracts were not systematically searched or included in this review. Records retrieved from the updated search were first imported into Endnote x9 (Clarivate Analytics, PA, USA) for duplicate removal. Remaining records were imported into Covidence (Veritas Health Innovation, Melbourne Australia) for independent screening and data extraction by two authors. Any discrepancies were discussed with a third author as necessary.

Data extraction and Risk of Bias

Study characteristics and end of intervention falls outcomes data from new trials identified from the search update were independently extracted by two authors using a proforma or in Covidence [4]. Risk of bias determined by two authors using the Physiotherapy Evidence Database (PEDro) scale was extracted [8]. A study characteristics table and data table were generated from extracted data.

Qualitative Comparative Analysis

Data Table

A Data Table was constructed based on the methods of Sutcliffe and colleagues [11]. All RCTs providing exercise in RACFs with end of intervention falls data were tabulated against intervention features identified from the ICA theories and trial effectiveness to form a data table. To code intervention features, evidence from all published records detailing information on each feature was used to allocate a code of intervention feature absent (0), present (1), or by degree of presence (numbers from 0 to 1 excluding 0.5), independently by two physiotherapist researchers. Trial effectiveness outcomes used were from the end of intervention random effects timepoint meta-analysis by Dyer and colleagues [7] and Cochrane Collaboration Review [4]. Data for rate of falls (i.e., the total number of falls per unit of person time that falls were monitored during the intervention) was used in preference to risk of fallers (i.e., the number of fallers during the intervention) to code trial effectiveness, when present, as this outcome appears more sensitive to change [3, 4]. Trial effectiveness was coded as 1 for statistically or clinically significantly reducing falls (point estimate ≤0.8 or $p<0.05$ where point estimates were not available); or 0 for no effect (point estimate >0.8 to <1.2) or increased falls (point estimate ≥1.2). Any discrepancies between data extraction and coding of conditions were resolved by discussion between two authors, involving a third author as necessary.

Analysis

QCA was conducted in R Project (version 4.3.1, 2023-06-16, 64bit) using the graphical user interface (GUI) [15]. The data table of coded intervention conditions (analogous to factors or variables) and effectiveness was imported into the GUI. The intervention components of the theory from ICA were included in a Truth Table to determine the degree of inclusion of each component in impacting trial effectiveness. In a truth table, each row represents a single or multiple studies with the same configuration of characteristics [15]. The results of the first Truth Table determined if a modified theory should be tested in a refined Truth Table or if the initial theory can progress to the next step of QCA.

As the ICA theorised that (a) “right exercise” by targeting balance and strength, tailored to the individual and delivered simply at a moderate intensity and (b) “sufficient resourcing” to deliver structured and supervised exercise at an adequate dose were both important in driving trial success from the perspective of trialist. These two features were first tested in a truth table accordingly [9]. Subsequent ‘theories’ were developed for exploration that represented adaptations to the original theory.

For each theory, in line with QCA guidance [14-16], the following QCA steps were conducted:
1) Truth Table analysis to test if configurations of the features in the theory have consistency scores demonstrating that the theory explains the allocation of studies into successful and unsuccessful sets for falls prevention accurately. A consistency score, also known as a (sufficiency) inclusion score, indicates the degree to which configuration of studies are a subset of effective studies, and the extent that the combination of intervention components can be viewed as sufficient in triggering an effective intervention. Scores of zero indicate that studies sharing a given configuration of conditions are not members of the successful outcome set, and scores between zero and 1 indicate various degrees of partial membership with a score of 0.5 representing maximum ambiguity as to the strength of a sufficient relationship. If the combination of conditions in the Truth Table tested were not able to explain the success or failure of most or all included trials, the inclusion and consistency scores were used to identify which conditions explain most trials to retain for further Truth Table analyses, as well as which trials were not explained, to identify additional conditions from the data table to be examined in further Truth Table analyses.

2) If the configurations had inclusion and consistency scores which were able to explain the success or failure of most or all included trials, Boolean minimisation was conducted to identify the simplest combination of trial features providing a solution. Coverage scores indicated the percentage of cases associated with the configuration.

3) To help to simplify the minimised solution, logical remainders (configurations which are not represented in the existing trials) were then incorporated into the solution (analogous to imputation in statistical analysis). First, the parsimonious solution was tested in which logical remainders were incorporated in the minimisation of the solution; this solution prioritised the simplicity of the expression over theoretical knowledge, with the software identifying the expected outcomes regardless of whether these were supported by theory. Next, an intermediate solution was developed which incorporated logical remainders but where the reviewers, incorporated assumptions about the likely outcomes of conditions and configurations and their plausibility based on theory and knowledge. The intermediate solution then tested the logical assumption along with contradictory simplifying assumptions to determine if this assumption was not contradictory and could offer a simpler solution following the practice of Dusa [15].

4) If the theory withstood any logical remainder and contradictory simplifying assumptions tests, the inverse theory was then analysed by the negated outcome to check if the opposite theory was a better theory (with higher inclusion and consistency scores).

Subgroup meta-analysis

Combinations of critical features identified by QCA were tested in subgroup meta-analyses, to see if these drivers of effectiveness explained the considerable heterogeneity observed in the meta-analysis of exercise trials in aged care. This method of using QCA to develop a theoretically driven subgroup analysis has been previously applied by Harris and colleagues [12]. Subgroup meta-analyses were conducted using the generic inverse variance method using RevMan Web as described in the Cochrane Collaboration 2018 review [4]. Analyses were conducted for both rate of falls and risk of falls. Rate of falls was reported as a RaR and 95% confidence interval (CI). Risk of falls was reported as RR and 95% CI.

Results

Eighteen trials met the inclusion criteria for the QCA (Figure 1). Examples of key studies excluded at full text review are given in Appendix 1. Rate ratio outcomes data was used for fifteen trials and risk ratio was used for three trials to code effectiveness (Table 1). The findings represent trials conducted in 10 countries enrolling 2,279 participants living in RACFs (Table 1). Participants were predominately ambulant females in their 70s or 80s with a degree of cognitive impairment who were mostly provided fully or initially supervised exercise programs (Table 1; Appendix 2 Table S1).

The included trials varied in terms of their characteristics, including level of cognitive impairment of participants, degree of participant mobility, type and duration of exercise programs and study quality (Appendix 2, Table S1 and S2). This variation provides trial characteristic data suited to analysis with QCA [17, 18]. Specifically, five trials included only residents with no cognitive impairment while three trials included only residents with cognitive impairment; the remainder included a mix (Appendix 2, Table S1). The abilities of participants to mobile also varied with 11 trials mainly recruiting completely independent residents, 3 trials with majority of resident requiring walking aids to mobilise and 4 trials where the majority of residents required significant assistance to mobilise (Appendix 2, Table S1). Exercise interventions were provided for 3, 4, 6, 12 or 15 months in comparison to other non-exercise activities or usual care, amongst predominately groups of less than 50 participants in the control and intervention arms (Table 1). Two trials provided resident education on falls prevention in addition to exercise (Appendix 2, Table S1).

Figure 1: PRISMA Flow Diagram of Systematic Study Selection [19]

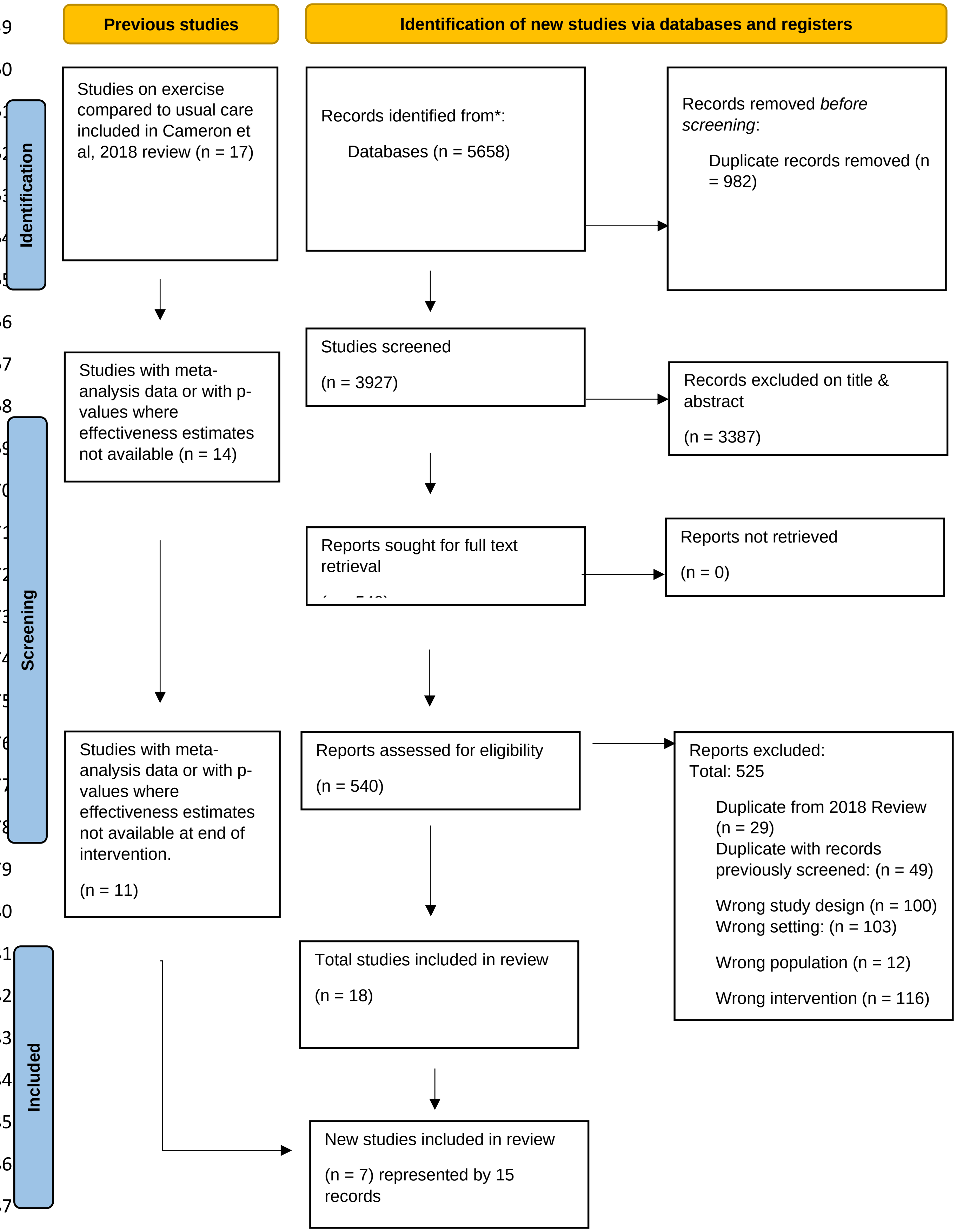


Table 1: Study Characteristics

Author, year	Study Design	Country	N randomised	Age, mean (SD)	Female (%)	Intervention	Control	Falls Outcome Used
Arrieta, 2019 [20]	RCT	Spain	112 I: 57 C: 55	84.9 (6.9) I: 85.1 (7.6) C: 84.7 (6.1)	70.5	Exercise professional supervised group training of individualised progressive multicomponent strength and balance exercises at moderate intensity. 1 hour session twice a week for 6 months. Individually tailored walking recommendations based on baseline 6-min walking test performance and goal of completing 140 minutes per week for 6 months.	Routine low intensity activities usual offered such as memory workshops, reading, singing, soft gymnastics etc.	Rate of falls (Rate ratio, 95%CI): 0.45 (0.29, 0.69)
Brett, 2021 [21]	RCT	Australia	60 I A: 20 I B: 20 C: 20	85 (NR) I A: 86 (NR) I B: 84 (NR) C: 86 (NR)	66	Group exercises (a range of seated and standing exercises which targeted strength, balance, endurance, and flexibility) supervised by physiotherapist. Intervention A: 45 minutes of group exercise per week once a week for 3 months Intervention B: 15 minutes 3 times a week for 3 months	Usual low intensity group activities such as seated bingo, concerts, movies, quizzes, and gentle range of movement exercises were encouraged. These activities were available for 30-60mins, once or twice a week.	Rate of falls (Rate ratio, 95%CI): 0.23 (0.14,0.37)
Buckinx, 2014 [22]	RCT	Belgium	62 I: 31 C: 31	83.2 (7.9) I: 82.2 (9.0) C: 84.2 (6.8)	76	Physiotherapist or researcher supervised whole body vibration program (75 seconds or 1.25 minutes), three times a week with a minimum of 1 day between sessions for 6 months.	Usual: no change to lifestyle of involvement in any new type of physical activity.	Rate of falls (Rate ratio, 95%CI): 1.34 (0.73, 2.45)
Cadore, 2014 [23]	RCT	Finland	32 I: 16 C: 16	91.9 (4.1)	70	Supervised multicomponent exercises (i.e., warm up exercise, muscle power training, balance and gait retraining, and cool down exercise) for 40 minutes, twice weekly with 2 consecutive days between sessions for 3 months.	Routine mobility exercises for 40 minutes at least 4 days a week, routinely encouraged in most Spanish nursing home.	Rate of falls: no falls in intervention vs. 0.8 falls per patient per month (p<0.001)
Choi, 2005 [24]	Quasi RCT	Korea	68 (recruited) I: 29 C: 30	77.9 (7.3)[a] I: 77.0 (7.7) C: 78.7 (6.9)	75	35 minutes supervised Tai Chi group sessions, 3 times per week for 3 months.	Usual routine activities.	Number of fallers (Risk ratio, 95%CI): 0.60 (0.19, 1.87)

Dhargave, 2020 [25]	RCT	India	163 I: 82 C: 81	74.6 (8.5) I: 75.3 (8.7) C: 73.9 (8.3)	53.3	Program consisted of bilateral range of motive exercises and stretching as well as progressed bilateral strengthening and balance exercises. 30-minute sessions once a day. Supervised by therapist for first week then visited once every 15 days for 3 months. Advised to also walk for 30 minutes in a day outside of the home.	Falls prevention education program at the beginning of the study about identifying risk factors for falls, identifying, and avoiding environmental hazards, maintaining habit of at least 15mins of walking daily.	Rate of falls (Rate ratio, 95%CI): 0.72 (0.44, 1.17)
Hewitt, 2018 [26]	Cluster RCT	Australia	221 I: 113 C: 108	86 (7.0)[a] I: 86 (7) C: 87 (7)	65	Physiotherapist individually prescribed progressive resistance training plus balance exercises performed in a group setting for a total of 50 hours over 25 weeks. Followed by a 6-month maintenance program twice weekly for 30 minutes by trained facility staff or volunteers.	Continued with usual regular activity schedule without the intervention program.	Rate of falls (Rate ratio, 95%CI): 0.45 (0.33, 0.61)
Irez, 2011 [27]	RCT	Turkey	60 I: 30 C: 30	75.4 (6.7)[a] I: 72.8 (6.7) C: 78.0 (5.7)	75.4	60-minute supervised Pilates sessions, 3 days per week for 3 months. For 1st 4 weeks mat exercises. After 4 weeks, additional Thera-Band elastic resistance exercises followed by Pilates ball exercises for beginners.	Usual exercise. Told to refrain from new exercise programs or changing current level of exercise.	Rate of falls (Rate ratio, 95%CI): 0.28 (0.15, 0.54)
Jahanpeyma, 2020 [28]	RCT	Turkey	72 I: 36 C: 36	75.2 (5.2)[a] I: 74.6 (5.9) C: 75.8 (4.5)	73.6 [a]	Researcher supervised small group (9 participants) Otago exercises for 45min sessions 3 days a week for 1 month. Followed by performing exercise individually for 2 months where research visited weekly.	Walking on level ground at normal pace for 30 minutes 3 days a week for 3 months. Demonstration once and given training and follow up booklet where researcher conducted weekly follow up and consultation in first month.	Rate of falls (Rate ratio, 95%CI): 0.39 (0.23, 0.66)
Kovacs, 2013 [29]	RCT	Hungary	86 I: 43 C: 43	77.8 (11.3)[a] I: 76.4 (9.6) C: 79.2 (12.7)	81	Physiotherapist supervised multimodal small group (2-4 participants) exercise program (based on Otago and included progressive resistance, strength, and balance) twice a week for 12 months. Supervised walking to practice gait elements once a week.	No exercise program but participation in social activities.	Rate of falls (Rate ratio, 95%CI): 0.77 (0.37, 1.62)
Mulrow, 1994 [30]	RCT	USA	194 I:97 C:97	Total: 80.6 (8.2)[a] I: 79.7 (8.5) C: 81.4 (7.9)	71	Physical therapist tailored one-to-one exercises (gait, balance, coordination, strength/resistance, and flexibility) for 30 to 45minutes, 3 times a week for 4 months.	Friendly visit	Rate of falls (Rate ratio, 95%CI): 1.32 (0.95, 1.85)

Rosendahl, 2008 [31]	Cluster RCT	Sweden	191 I: 91 C: 100	84.7 (6.5) I: 85.3 (6.1) C: 84.2 (6.8)	73	Five 45-minute sessions held every two weeks for 3 months. Functional exercise (e.g., weight-bearing challenging leg strength, postural stability, and gait ability) every fortnight, selected for each resident by physiotherapist. High intensity and increased load were encouraged.	5 sessions of 45minutes seated programme by occupational therapist including watching films, reading, and singing, every fortnight.	Number of fallers (Risk ratio, 95%CI): 0.98 (0.69 to 1.39)
Sakamoto, 2006 [32]	RCT	Japan	553[b]	81.6 (9.0) I: 81.2 (NR) C: 82.3 (NR)	74	Standing unipedal balance exercise for both legs, for 1 minute on each leg, 3 times a day for 6 months, led by physiotherapist	Usual care without exercise	Rate of falls (Rate ratio, 95%CI): 0.82 (0.65, 1.04)
Schoenfelder, 2000 [33]	RCT	USA	16 I: 9 C: 7	82.8 (NR)	75	20 minutes exercise, 3 times a week for 3 months, delivered by a research member. Supervised ankle strengthening exercises and up to 10 minutes of walking.	Usual care	Rate of falls (Rate ratio, 95%CI): 2.86 (1.16, 7.04)
Shimada, 2004 [34]	RCT	Japan	32 I: 18 C: 14	Total: 82.4 (6.1)[a] I: 81.8 (5.9) C: 83.1 (6.4)	78	Perturbed gait exercise on a treadmill (i.e., gait, balance, coordination, and endurance) supervised and individually tailored by physical therapists in additional to usual exercises. Total of 600 minutes of exercise over 6 months, 1 to 3 times per week.	Usual exercise program including stretching, resistance training, group training and outdoor gait training.	Rate of falls (33.3% in intervention vs. 54.6% in control, p=0.426)
Toots, 2019 [35]	RCT	Sweden	186 I: 93 C: 93	85.1 (7.1) I: 84.4 (6.2) C: 85.9 (7.8)	76	Physiotherapist led group exercise consisting of 39 functional exercises at high intensity and in weight bearing positions similar to daily activities. 5 sessions per fortnight for 4 months.	Attention control consisting of structured activities developed by occupational therapist (OT) or OT assistants such as seated group conversations, singing, listening to music, reading, or looking at pictures and objects.	Rate of falls (Rate ratio, 95%CI): 1.30 (0.81, 2.08)
Varela, 2018 [36]	RCT	Spain	74 (39 completed) C:22 I: 17)	Total: 81.1 (8.2)[a] I: 77.9 (8.8) C: 83.6 (7.1)	38[a]	Cycling at self-selected intensity for at least 15 minutes per day for 15 months.	Recreational activities for 15 months.	Rate of falls (Rate ratio, 95%CI): 0.67 (0.37, 1.21)

Yokoi, 2015 [37]	Cluster RCT	Japan	105 I: 51 C: 54	79.3 (6.7)[a] I: 80.2 (7.9) C: 78.5 (5.2)	60	Six group-based supervised, seated short stick activities with rolled newspaper as the stick including a warm-up. 25 minutes per session, twice a week for 6 months.	Usual activities including daily housekeeping, hobbies, work and 10-minute group stretching exercises.	Number of fallers (Risk ratio, 95%CI): 0.21 (0.03, 1.55)

[a] reviewer calculated. [b] Number of participants for intervention and control group not reported.

Abbreviations: C: control; I: intervention; NR: not reported

Qualitative Comparative Analysis

Investigation of original theory from ICA

Providing the "right exercise" plus "sufficient resourcing" explained effectiveness in 12 of 18 included trials (inclusion and consistency scores: 0.859) (Table 2). This theory was not consistent with all trial outcomes as one trial which had both right exercise and sufficient resourcing was not effective [35]; two trials with right exercise alone were effective [23, 34] and three trials with neither right exercise nor resourcing were effective [24, 36, 37] (Table 2). As the presence or absence of right exercise alone was consistent with the outcomes in 15 of 18 of the included studies, the components of right exercise were further explored.

Table 2: Truth Table of Right Exercise & Sufficient Resourcing

Configuration	**Right exercise**	**Sufficient Resourcing**	**Outcome (Reduced Falls)**	**No. trials**	**Sufficiency**		**Cases**	**Supports theory**
					Inclusion Score (incl)	Consistency Score (PRI)		
1	Yes[b]	Yes[b]	Yes	8	0.859	0.859	**Arrieta [20], Brett [21], Dhargave [25], Hewitt [26], Irez [27], Jahanpeyma [28], Kovacs [29],** Toots [35]	Unclear
2	Yes[b]	No[a]	Yes	2	0.660	0.660	**Cadore [23], Shimada [34]**	No
3	No[a]	No[a]	No	8	0.375	0.375	**Choi [24],** Buckinx [22], Sakamoto [32], Mulrow[30], Rosendahl [31], Schoenfelder [33], **Yokoi [37], Varela [36]**	Unclear

In QCA as [a] 0, [b] 1,

Inclusion cut-off = 0.80 for fuzzy scoring

Right exercise was calculated by the addition of codes for Progressive standing strength and dynamic balance, Tailored exercise and Moderate intensity divided by 3

Supporting engagement was calculated by the addition of codes of 'funding strength and balance', 'group exercise and 'fall education, divided by 3.

Effective case, non-effective case.

Adaption 1 – Exploration of conditions of right exercise

The components of the "right exercise" theory for reducing falls amongst residents in RACFs were: (i) progressive standing strength and dynamic balance exercise, which is (ii) tailored to the individual resident and (iii) conducted at moderate intensity. The truth table examining these three features against trial effectiveness was constructed (Appendix 3, Table S1). The presence of all three features explained falls reduction at the end of intervention period in 7 of 18 included trials (configuration 1) and the absence of all 3 components lead to ineffectiveness in 6 trials (configurations 3, 5and 6) but did not explain the remaining 5 effective trials [24, 27, 34, 36, 37] in configurations 2, 3 and 4 (Appendix 3, Table S1). Also, as progressive standing strength and dynamic balance exercise were present in both configurations that supported and did not support the theory, this feature did not appear to be a critical factor for trial effectiveness.

Minimisation suggested that the combination of tailored exercise at moderate intensity was associated with falls reduction in 15 of 18 trials, with inclusion score of 1.000, proportional reduction inconsistency score 1.000 and coverage score of 0.750 (Appendix 3, Table S2).

There were two logical remainders (configurations not represented by the existing trials), which were moderate intensity exercise that is not tailored progressive standing strength and dynamic balance, and moderate intensity strength and balance exercise that is not tailored. As moderate intensity was consistently present in 9 of 12 of the effective studies and explained effectiveness in 15 of 18 studies, the assumption was that the logical remainder of moderate intensity alone could explain trial effectiveness, but three trials were unexplained by the theory [24, 36, 37] (Appendix 3, Table S2).

Therefore, the Data Table (Appendix 2, Table S1) was revisited to identify similar conditions amongst these three trials that did not provide moderate intensity exercise. The presence of enrolling only independent ambulatory participants, conducting exercise in a group or conducting exercise at low intensity were features that appeared relevant for further investigation.

Adaption 2: Exploration of independent ambulatory, tailored, moderate or low intensity and group exercise.

A truth table of independent ambulatory, tailored, moderate or low intensity group exercise suggested that it was unclear whether a trial could be successful when moderate or low intensity exercise is provided to independent ambulatory residents without group or tailored exercise (Appendix 3, Table S3, configuration 5). Minimisation demonstrated that the provision of (i) moderate or low intensity group exercise, or (ii) moderate or low intensity tailored exercise for independent ambulatory participants had high inclusion and proportional reduction inconsistency scores and coverage of the configurations tested (i.e., 1.000), explaining 17 of 18 studies (Appendix 3, Table S4). One trial was not consistent with the theory [36] (Appendix 3, Table S4). Testing an intermediate solution that moderate intensity alone could trigger effectiveness did not pose a better solution (Appendix 3, Table S5). Similarly, through the advanced intermediate solution where the educated assumption that moderate intensity alone, along with the exclusion of the associated contradictory assumptions present in both configurations (i.e., Sakamoto), supported this theory and did not pose a better solution which could also explain the final trial [36] (Appendix 3, Table S6). Similarly, the negated solution (Appendix 3, Table S7) also did not pose a better solution.

Adaption 3: Components of Sufficient resourcing

As Sufficient Resourcing was part of the initial ICA-derived theory, components of Sufficient Resourcing were examined through a Truth Table and Minimisation to explore whether it could explain the final trial by Varela and colleagues [36] (Appendix 4, Table S1 and S2). It appeared that Structured Supported Exercise was generally present in effective cases and could be tested with moderate or low intensity group exercise (i.e., conditions that are consistently present in most effective cases). Truth Table and Minimisation demonstrated that, the presence of (i) moderate or low intensity and structured supported exercise or (ii) moderate or low intensity group exercise explained 16 out of 18 trials (coverage score 0.833, Appendix 4, Table S3 and S4). Two remaining trial by Cadore and colleagues [23] and Shimada and colleagues [34] were not explained by this theory, however both trials had only recruited residents without cognitive impairment.

A Truth Table and Minimisation of structured supportive exercise with moderate or low intensity group exercise for participants with no cognitive impairment explained all 12 effective trials (Appendix 4, Table S5 and 6). Whilst the intermediate solution supported this theory, there were two cases (i.e., one effective and one ineffective) which contradicted the theory and 3 effective cases which overlapped between configurations (Appendix 4, Table S7). The negated solution explained all ineffective cases but did not explain effective cases.

From Appendix 4, Table S7, the addition of Structured Supportive Exercise appeared to be most promising solution without any contradictions (Appendix 4, Table 8). From further examining this feature of the ICA theory, the dose of 30 hours was derived from a trial testing 30 hours over 25 weeks. Therefore, a weekly dose of 1.2 hours per week (rounded to more than 1 hour per week) was tested in QCA in lieu of 30 hours [26].

Final theory

A Truth Table of independent ambulatory participants, moderate or low intensity exercise, tailored exercise, group exercise and an exercise dose of more than 1 hour per week demonstrated that these features were able to discriminate between effective and ineffective trials (Table 3). Minimisation demonstrated three scenarios that explained the success and failure of all 18 of falls prevention exercise interventions in RACFs included in this sample, with the highest QCA inclusion and coverage scores of 1.0 (Table 4). The intermediate solution (Appendix 4,Table S6) considering the exclusion of one contradictory case (i.e., Mulrow et al [30]) that is an ineffective trial was explained by both configurations and testing the logical remainders assuming that moderate or low intensity exercise alone can drive effectiveness and analysis of the negated outcome both supported these theories (Appendix 5, Table S1). Therefore, the solution posed as the final refined theory from the QCA, is: Moderate or low intensity group exercise OR moderate or low intensity exercise for independent ambulatory resident for more than 1 hour per week are the critical features of successful exercise programs for falls prevention in RACFs.

Table 3: Truth Table of moderate or low intensity exercise, tailored, group, independent ambulatory and >1 hour per week.

Configuration	Independent ambulatory	Tailored	Moderate or low intensity	More than 1 hour per week	Group	Outcome (Reduced Falls)	No. trials	Sufficiency		Cases
								Inclusion Score (incl)	Consistency Score (PRI)	
1	Yes	Yes[b]	Yes	Yes	Yes	Yes	4	1.000	1.000	**Arrieta [20], Irez [27], Jahanpeyma [28], Kovacs [29]**
2	Yes[b]	Yes	Yes	Yes	No	Yes	3	1.000	1.000	**Cadore [23], Dhargave [25], Shimada [34]**
5	Yes	No	Yes	No	Yes	Yes	1	1.000	1.000	**Yokoi [37]**
6	Yes	No	Yes	Yes	No	Yes	1	1.000	1.000	**Varela [36]**
7	Yes	No	Yes	Yes	Yes	Yes	1	1.000	1.000	**Choi [24],**
8	Yes	No	Yes	No	No	No	3	0.000	0.000	Buckinx [22], Sakamoto [32], Schoenfelder [33]
11	Yes	Yes	No	Yes	Yes	No	1	0.000	0.000	Rosendahl [31]
3	No	Yes	Yes	No	Yes	Yes	1	1.000	1.000	**Brett [21]**
4	No	Yes	Yes	Yes	Yes	Yes	1	1.000	1.000	**Hewitt [26]**
9	No	Yes	No	Yes	Yes	No	1	0.000	0.000	Toots [35]
10	No	Yes	Yes	Yes	No	No	1	0.000	0.000	Mulrow[30]

Inclusion set to 0.9.
Light grey fill = not present in effective cases, dark grey fill = not present in ineffective cases.

Effective case, non-effective case.

Table 4: QCA Minimisation of moderate or low intensity exercise, tailored, group, independent ambulatory and >1 hour per week.

Configuration	**Conditions**				**Outcome (Reduced Falls)**	**No. of effective studies**	**Sufficiency**				**Cases explained**
							Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique Coverage (covU)	
1	Moderate/ Low Intensity	Independent ambulatory participants [a]	More than1 hour per week		Yes	9	1.000	1.000	0.750	0.667	**Varela [36], Choi [24], Cadore [23], Dhargave [25], Shimada [34]**, **Arrieta [20], Jahanpeyma [28], Irez [27], Kovacs [29],** Mulrow [30], Schoenfelder [33], Buckinx [22], Rosendahl [31], Sakamoto [32], Toots [35]
2	Moderate/ Low Intensity	Independent ambulatory participants [a]	Group	Not Tailored	Yes	2	1.000	1.000	0.167	0.083	**Choi [24], Yokoi [37]**
3	Moderate/ Low Intensity	Independent ambulatory participants	Group	Tailored	Yes	2	1.000	1.000	0.667	0.250	**Brett [21], Hewitt [26]**
Overall							**1.0000**	**1.000**	**1.000**		18

[a] Independent ambulatory participants (independent with or without walking aid)

Effective case, non-effective case.

Table 5: QCA Minimisation of Table 4 considering logical remainders and contradictory assumptions.

Configuration	**Conditions**			**Outcome (Reduced Falls)**	**No. of effective studies**	**Sufficiency**				**Cases explained**
						Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique Coverage (covU)	
1	Moderate/ Low Intensity	Group		Yes	8	1.000	1.000	0.667	0.250	**Choi[24], Yokoi [37], Arrieta [20], Jahanpeyma [28], Kovacs [29] Brett [21], Hewitt [26], Irez [27],** Buckinx[22], Rosendahl [31], Sakamoto [32], Toots [35], Mulrow [30], Schoenfelder [33]
2	Moderate/ Low Intensity	Independent ambulatory participants [a]	More than1 hour per week	Yes	9	1.000	1.000	0.750	0.333	**Varela [36], Choi [24], Cadore [23], Dhargave [25], Shimada [34]**, **Arrieta [20], Jahanpeyma [28], Irez [27], Kovacs [29],** Mulrow [30], Schoenfelder [33], Buckinx [22], Rosendahl [31], Sakamoto [32], Toots [35]
Overall						**1.0000**	**1.000**	**1.000**	-	18

[a] Independent ambulatory participants (independent with or without walking aid)

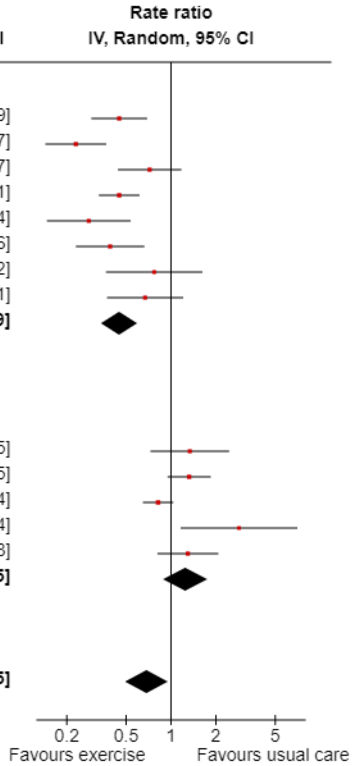
Effective case, non-effective case.

Sub-group meta-analyses

Sub-group meta-analyses confirmed greater fall prevention effects in trials that included the components of the final QCA theory (p for subgroup differences <0.01). The final theory saw a 55% reduction in rate of falls with a reduction of the heterogeneity to moderate (Figure 2, rate ratio 0.45, 95%CI 0.34 to 0.59, I^2= 60%) while the sub-group of trials without these features did not prevent falls. The final theory was also associated with a 34% reduction in the risk of falling one or more times (Figure 3, risk ratio 0.66, 95%CI 0.53 to 0.82), I^2= 0%, p for sub-group differences <0.05) while the sub-group of trials without these features did not prevent falls.

Figure 2: Meta-analysis of exercise in residential aged care grouped by the presence or absence of the final QCA theory [a]: rate of falls

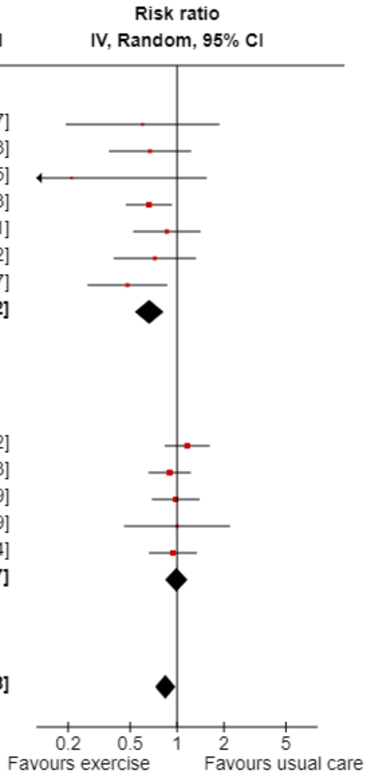
Study or Subgroup	log[Rate ratio]	SE	Exercise Total	Usual care Total	Weight	Rate ratio IV, Random, 95% CI
51.1.1 Presence of Final QCA Theory						
Arrieta 2019	-0.8	0.22	43	39	8.2%	0.45 [0.29 , 0.69]
Brett 2021	-1.47	0.24	36	19	8.0%	0.23 [0.14 , 0.37]
Dhargave 2020	-0.33	0.25	75	77	7.9%	0.72 [0.44 , 1.17]
Hewitt 2018	-0.8	0.16	97	92	8.8%	0.45 [0.33 , 0.61]
Irez 2011	-1.27	0.33	30	30	7.0%	0.28 [0.15 , 0.54]
Jahanpeyma 2021	-0.94	0.27	35	36	7.7%	0.39 [0.23 , 0.66]
Kovacs 2013	-0.26	0.38	32	30	6.4%	0.77 [0.37 , 1.62]
Varela 2018	-0.4	0.3	17	22	7.3%	0.67 [0.37 , 1.21]
Subtotal (95% CI)			**365**	**345**	**61.4%**	**0.45 [0.34 , 0.59]**
Heterogeneity: Tau² = 0.09; Chi² = 17.39, df = 7 (P = 0.02); I² = 60%						
Test for overall effect: Z = 5.64 (P < 0.00001)						
51.1.2 Absence of Final QCA Theory						
Buckinx 2014	0.29	0.31	31	31	7.2%	1.34 [0.73 , 2.45]
Mulrow 1994	0.28	0.17	97	97	8.7%	1.32 [0.95 , 1.85]
Sakamoto 2006	-0.2	0.12	315	212	9.1%	0.82 [0.65 , 1.04]
Schoenfelder 2000	1.05	0.46	9	7	5.6%	2.86 [1.16 , 7.04]
Toots 2019	0.26	0.24	93	93	8.0%	1.30 [0.81 , 2.08]
Subtotal (95% CI)			**545**	**440**	**38.6%**	**1.24 [0.88 , 1.75]**
Heterogeneity: Tau² = 0.09; Chi² = 12.25, df = 4 (P = 0.02); I² = 67%						
Test for overall effect: Z = 1.25 (P = 0.21)						
Total (95% CI)			**910**	**785**	**100.0%**	**0.68 [0.49 , 0.95]**
Heterogeneity: Tau² = 0.30; Chi² = 81.64, df = 12 (P < 0.00001); I² = 85%						
Test for overall effect: Z = 2.26 (P = 0.02)						
Test for subgroup differences: Chi² = 20.55, df = 1 (P < 0.00001), I² = 95.1%						



[a] Moderate/low intensity group exercise OR moderate/low intensity exercise for independent ambulatory resident for >1 hour per week

Figure 3: Meta-analysis of exercise in residential aged care grouped by the presence or absence of the final QCA theory [a]: risk of falling

Study or Subgroup	log[RR]	SE	Exercise Total	Usual care Total	Weight	Risk ratio IV, Random, 95% CI
51.2.1 Presence of Final QCA Theory						
Choi 2005	-0.51	0.58	29	30	1.7%	0.60 [0.19 , 1.87]
Kovacs 2013	-0.4	0.31	32	30	5.4%	0.67 [0.37 , 1.23]
Yokoi 2015	-1.56	1.02	51	54	0.6%	0.21 [0.03 , 1.55]
Hewitt 2018	-0.416	0.174	113	108	13.9%	0.66 [0.47 , 0.93]
Arrieta 2019	-0.151	0.254	43	39	7.7%	0.86 [0.52 , 1.41]
Dhargave 2020	-0.329	0.311	75	77	5.4%	0.72 [0.39 , 1.32]
Brett 2021	-0.734	0.301	36	19	5.7%	0.48 [0.27 , 0.87]
Subtotal (95% CI)			**379**	**357**	**40.4%**	**0.66 [0.53 , 0.82]**
Heterogeneity: Tau² = 0.00; Chi² = 3.57, df = 6 (P = 0.73); I² = 0%						
Test for overall effect: Z = 3.79 (P = 0.0002)						
51.2.2 Absence of Final QCA Theory						
Mulrow 1994	0.15	0.17	97	97	14.3%	1.16 [0.83 , 1.62]
Sakamoto 2006	-0.11	0.16	315	212	15.6%	0.90 [0.65 , 1.23]
Rosendahl 2008	-0.02	0.18	87	96	13.2%	0.98 [0.69 , 1.39]
Buckinx 2014	0	0.4	31	31	3.4%	1.00 [0.46 , 2.19]
Toots 2019	-0.062	0.181	93	93	13.1%	0.94 [0.66 , 1.34]
Subtotal (95% CI)			**623**	**529**	**59.6%**	**0.99 [0.84 , 1.17]**
Heterogeneity: Tau² = 0.00; Chi² = 1.36, df = 4 (P = 0.85); I² = 0%						
Test for overall effect: Z = 0.14 (P = 0.89)						
Total (95% CI)			**1002**	**886**	**100.0%**	**0.84 [0.72 , 0.98]**
Heterogeneity: Tau² = 0.01; Chi² = 13.43, df = 11 (P = 0.27); I² = 18%						
Test for overall effect: Z = 2.27 (P = 0.02)						
Test for subgroup differences: Chi² = 8.49, df = 1 (P = 0.004), I² = 88.2%						



[a] Moderate/low intensity group exercise OR moderate/low intensity exercise for independent ambulatory resident for ≥1 hour per week

Discussion

This QCA of trials in RACFs suggests that exercise interventions that provided moderate or low intensity group exercise for participating residents are more consistently associated with a reduction in falls. Trials that enrolled mostly independent ambulatory residents (who can independently mobilise with or without a walking aid), providing moderate or low intensity, structured exercise of more than 1 hour per week, consistently reduced falls. Moderate or low intensity exercise is the condition common to these two pathways, suggesting that it's a critical factor in exercise programs for residents and that high intensity exercise is not suitable for falls prevention in this setting [31, 35]. Most of the included effective trials tested a moderate intensity intervention (Table 1). Only three effective trials that mostly enrolled independent ambulatory residents conducted exercise at low intensity [24, 30, 36]. Thus, moderate intensity exercise is considered the most suitable approach for the broader range of exercise participants in RACFs and is consistent with the recommendation for “moderate challenge” in community falls prevention guidelines [2, 38-40].

Recently, a timepoint meta-analysis demonstrated that the effectiveness of exercise for falls prevention in this setting is not sustained beyond the intervention period [7]. The current study adds the detail that a dose of more than 1 hour per week of structured exercise for independent ambulatory residents is needed.-While a dose of more than 1 hour is lower than that recommended by the Australian physical activity guidelines for all older adults generally [41], it may reflect the feasibility of balancing delivery challenges and effectiveness of falls prevention amongst this most frail group of older adults.

Although moderate or low intensity exercise delivered in a group for all residents, or more than 1 hour for ambulant residents, were the critical features that differentiated successful studies from unsuccessful studies, it is important to consider that this is driven by the context of the existing trials in this analysis. Within the included studies, the majority of structured interventions were supervised for the whole trial duration [20-24, 26-35, 37] or in the first week then bi-monthly [25]. Only one trial did not provide any supervised exercise, and this was conducted for residents who were able to walk independently without aids [36]. This suggests that any exercise program in this setting should be supervised, as a necessary part of safe exercise provision [42].

While tailored exercise was present in the penultimate theory (Table 4) which explained 15 of 18 trials, it was not a feature of the final QCA solution (Table 5). This was due to tailoring being absent in the one trial which only included residents who were able to safely walk independently without aids and thus participate in a self-paced cycling intervention. Therefore, tailored exercise is also considered likely to be important amongst independent ambulatory residents who use walking aids [36]. Trials including participants with more restricted mobility required the support of exercise professionals to tailor their exercise program (Table 1). This aligns with the intention of physiotherapy services [43].

With the worldwide ageing population, governments and organisations need to consider the abilities of older adults when applying these findings. The evidence from available trials is more representative of residents who can independently mobilise with or without a walking aid because this was the restrictive inclusion criteria that was applied in most trials (Table 1). Admission to RACFs has been associated with decline in ambulatory ability due to the loss of intrinsic capacity associated with ageing [44]. This decline is further evidenced by the trend of residents admitted to RACFs with increasing disability and complexity of health conditions over the last two decades [45]. Consequently, the majority of residents currently living in care home are likely to be frailer than the residents studied in many of the included trials [46].

While a variety of exercise programs were tested in the included trials, the specific type of exercise program provided was not a clear factor driving effectiveness. Most exercise programs provided one or both elements of progressive strength and balance exercises. Although progressive strength and balance exercises is recommended in the community setting [3], the findings from this analysis could not clearly identify if this, or another type of exercise was important for effectiveness, because these features were not distinguishing features present amongst effective trials in contrast to ineffective trials in this set of studies. In other studies that did not measure falls, both tailored multicomponent exercise and resistance exercise has demonstrated improvement in gait speed and sit to stand performance in RACFs [47, 48]. When future trials implement the critical features identified here and measure falls, further QCA may identify the type of exercise important for falls prevention in this setting.

Future studies should report in detail the degree of mobility of participating residents, the degree of tailoring and support provided in the exercise program and rates of adherence to the exercise program. These details were not consistently reported in the included trials but would assist in understanding the transferability of the trial programs into practice and in conducting additional QCA which may help to further understand the residual heterogeneity observed.

Conclusion

Exercise interventions for falls prevention in RACFs should focus on providing moderate or low intensity group exercise. For falls prevention interventions that mostly include residents who can mobilise independently with or without a walking aid, moderate or low intensity exercise for more than 1 hour per week should be provided. Considering the level of frailty and limited mobility of many residents currently in RACFs, supervision and exercise tailoring are likely to be also necessary and an individualised dose may be required. Future trials should focus on examining exercise interventions for less mobile resident. When further data allows, future analyses should consider if there is a specific type of exercise that more successfully prevents falls in this population.

References

Appendices

Appendix 1: Key studies excluded at full text review.

Key studies excluded	Exclusion reason	Study citation	Reason for exclusion descriptor
From included exercise vs. usual care studies in Cameron 2018	Wrong outcome	Buettner, 2002 [49]	No suitable falls data as effect estimates and confidence interval or numerical falls data with p-values not provided
	Wrong outcome	Da Silva Borges, 2014 [50]	No effect estimates and confidence interval for falls data. While p-value is provided, data to indicate number of falls was not reported.
	Wrong outcome	Toulotte, 2003 [51]	No effect estimates and confidence interval for falls data
	Wrong outcome	Sihvonon 2004 [52, 53]	Falls data only at a follow up time point. No falls data at end of intervention.
	Wrong outcome	Kerse 2008 [54]	Falls data only at a follow up time point. No falls data at end of intervention.
	Wrong outcome	Faber 2006 [55]	Falls data only at a follow up time point. No falls data at end of intervention.
From search update	Ongoing study	Grede, 2021[56]	Walking programme for older adults living in the community or nursing homes. Protocol only.
	Wrong outcome	Buhring 2019 [57]	Pilot study of semi-recumbent vibration exercise where falls were measured as adverse events.
	Wrong outcome	Birimoglu Okuyan, 2021[58]	No effect estimates and confidence intervals for falls data
	Wrong outcome	Taani, 2022 [59]	Pilot study of semi-recumbent vibration exercise where no falls data was measured.
	Wrong study design	Zou, 2022[60]	Group based Otago exercise program in nursing homes, but participants self-selected allocation and therefore study design was not randomised.

Appendix 2: Features in Data Tables

Table S1: Original Data Table of Included Trials

	Study, year	Participant Characteristics					Design Characteristics		Intervention Characteristics				Implementation Characteristics				Falls Outcomes
									Components of Right Exercise			ICA part 1	Components of Supporting exercise engagement			ICA part 2	
		All have CI[a]	All do not have CI[a]	Degree of CI [a,b]	Degree of Mobility [c]	Independent ambulatory only [d]	Study Quality [e]	Small Study Size [f]	PSSDB[g]	Tailored [a]	Moderate Intensity [a]	Right Exercise [h]	Funding strength & balance >30hrs [a]	Group exercise [a]	Falls education [a]	Sufficient resourcing [i]	Effective
1	Arrieta, 2019 [20]	0	0	1	1	1	0.6	0	1	1	1	1	1	1	0	0.7	1
2	Brett, 2021 [21]	1	0	0	0.3	0	0.6	1	1	1	1	1	1	1	0	0.7	1
3	Buckinx 2014 [22]	0	0	1	0.7	0	0.6	0	0.3	0	0	0.1	0	0	0	0	0
4	Cadore 2014 [23]	0	1	0	1	1	0.4	1	1	1	1	1	0	0	0	0	1
5	Choi, 2005 [24]	0	0	1	1	1	0.6	1	0.7	0	0	0	0	1	0	0.3	1
6	Dhargave 2020 [25]	0	0	1	1	1	0.6	0	1	1	1	1	1	0	1	0.7	1
7	Hewitt 2018 [26]	0	0	1	0.3	0	0.8	0	1	1	1	1	1	1	1	1	1
8	Irez, 2011[27]	0	0	1	1	1	0.6	0	0.6	1	1	0.9	1	1	0	0.7	1
9	Jahanpeyma 2020 [28]	0	1	0	1	1	0.6	0	1	1	1	1	1	1	1	1	1
10	Kovacs 2013 [29]	1	0	0	1	1	0.8	0	1	1	1	1	1	1	0	0.7	1
11	Mulrow 1994 [30]	0	0	1	0.3	0	0.6	0	0.3	1	0	0.4	0	0	0	0	0
12	Rosendahl 2008 [31]	0	0	1	0.7	1	0.7	0	1	1	0	0.3	0	1	0	0.3	0
13	Sakamoto 2006 [32]	0	0	1	0.7	1	0.4	0	0	0	0	0	0	0	0	0	0
14	Schoenfelder 2000 [33]	0	0	1	1	1	0.4	1	0.3	0	0	0.1	0	0	0	0	0
15	Shimada 2004 [34]	0	1	0	1	1	0.4	1	0.3	1	1	0.8	0	0	0	0	1
16	Toots 2019 [35]	1	0	0	0.3	0	0.8	0	1	1	0	0.7	1	1	0	0.7	0
17	Varela 2018 [36]	0	1	0	1	1	0.6	1	0	0	0	0	1	0	0	0.3	1
18	Yokoi 2015 [37]	0	1	0	1	1	0.7	1	0	0	0	0	0	1	0	0	1

Abbreviations: CI, cognitive impairment; PSSDB, Progressive standing strength and dynamic balance.

[a] 1= yes, 0 = no

[b] As all resident included in inclusion criteria

[c] 1 = majority (over 50%) completely independent, no walking aids, 0.7 = majority (over 50%) ambulant with walking aids, 0.6= majority (over 50%) needing 1 assist to mobile, 0.3= majority needing significant assistance to mobilise

[d] 1 = inclusion criteria only includes independent ambulatory residents
as all residents included

[e] Study quality based on Physiotherapy Evidence Database (Pedro) Risk of Bias Tool score out of 10; divided by 10

[f] Definition of small study sample was less than 30 participants in each trial arm.

[g] 1= yes, 0 = no, 0.6 = mostly fulfills the component, 0.3 =partially fulfils the exercise component or involvement in the exercise or progression varies

[h] Calculated by the addition of codes for Progressive standing strength and dynamic balance, Tailored and Moderate intensity; divided by 3.

[i] Calculated by the addition of codes for 'Funding strength and balance more than 25hours', 'Group exercise' and 'falls education'; divided by 3.

Table S2: Additional features added to Data Table to refine the theory in QCA

Study, year		**Intervention Characteristics**									
		Components of progressive standing strength and balance			Additional features related to "Right exercise"			Additional features related to "Sufficient Resourcing"			
		Progressive Strength Training [a]	Progressive dynamic balance training [a]	Progressive Standing Exercise [a]	Low intensity [b]	High intensity [b]	Moderate or low intensity [b]	Supervised exercise [c]	Dose of 30 hours [b]	Dose > 1 hour per week [b]	Funded [b]
1	Arrieta, 2019 [20]	1	1	1	0	0	1	1	1	1	1
2	Brett, 2021 [21]	1	1	1	0	0	1	1	0	0	1
3	Buckinx 2014 [22]	0	0	1	1	0	1	1	0	0	0
4	Cadore 2014 [23]	1	1	1	0	0	1	1	0	1	1
5	Choi, 2005 [24]	0	1	1	1	0	1	1	0	1	0
6	Dhargave 2020 [25]	1	1	1	0	0	1	0.4	1	1	1
7	Hewitt 2018 [26]	1	1	1	0	0	1	1	1	1	1
8	Irez, 2011[27]	1	0.3	0.3	0	0	1	1	1	1	1
9	Jahanpeyma 2020 [28]	1	1	1	0	0	1	0.6	0	1	1
10	Kovacs 2013 [29]	1	1	1	0	0	1	1	1	1	1
11	Mulrow 1994 [30]	0.3	0.3	0.3	1	0	1	1	0	1	0
12	Rosendahl 2008 [31]	1	1	1	0	1	0	1	0	1	0
13	Sakamoto 2006 [32]	0	0	1	1	0	1	1	0	0	0
14	Schoenfelder 2000 [33]	0	0	1	1	0	1	1	0	0	0
15	Shimada 2004 [34]	0	0	1	0	0	1	1	0	1	0
16	Toots 2019 [35]	1	1	1	0	1	0	1	1	1	1
17	Varela 2018 [36]	0	0	0	1	0	1	0	0	1	1
18	Yokoi 2015 [37]	0	0	0	1	0	1	1	0	0	0

[a] 1= yes, 0 = no, 0.6 = mostly fulfills the component, 0.3 =partially fulfils the exercise component or involvement in the exercise or progression varies [b] 1= yes, 0 = no [c]1= yes, 0.6 = mostly supervised, 0.4 = partially supervised, 0 = no.

Appendix 3: QCA

Table S1: Truth Table of Conditions of Right Exercise

Configuration	**Progressive standing strength & dynamic balance**	**Tailored**	**Moderate Intensity**	**Outcome (Reduced Falls)**	**No. studies**	**Sufficiency**		**Cases**	**Supports theory**
						Inclusion Score (incl)	Consistency Score (PRI)		
1	Yes[b]	Yes[b]	Yes[b]	Yes	7	1.000	1.000	**Arrieta [20], Brett [21], Cadore [23], Dhargave [25], Hewitt [26], Jahanpeyma [28], Kovacs [29]**	Yes
2	No[a]	Yes[b]	Yes[b]	Yes	2	1.000	1.000	**Irez [27], Shimada [34]**	No
3	No[a]	No[a]	No[a]	No	5	0.523	0.523	Buckinx [22], Sakamoto [32], Schoenfelder [33], **Varela [36], Yokoi [37]**	Unclear
4	Yes[b]	No[a]	No[a]	No	1	0.438	0.438	**Choi [24]**	No
5	No[a]	Yes[b]	No[a]	No	1	0.000	0.000	Mulrow [30]	Yes
6	Yes[b]	Yes[b]	No[a]	No	2	0.000	0.000	Rosendahl [31], Toots [35]	Yes

Coded in QCA as [a] 0, [b] 1,

Inclusion cut-off = 0.9

Effective case, non-effective case.

Table S2: Minimisation of components of Right Exercise

Configuration	Conditions		Outcome (Reduced Falls)	No. of effective studies	Sufficiency			Cases explained	Cases unexplained
					Inclusion Score (InclS)	Consistency Score (PRI)	Coverage Score (covS)		
1	Tailored exercise	Moderate intensity	Yes	9	1.000	1.000	0.750	**Arrieta [20], Brett [21], Cadore [23], Dhargave [25], Hewitt [26], Irez [27], Jahanpeyma [28], Kovacs [29], Shimada [34]** Buckinx [22], Mulrow [30], Rosendahl [31], Sakamoto[32], Schoenfelder[33], Toots [35]	**Choi [24], Varela [36], Yokoi [37]**
Overall					**1.0000**	**1.000**	**0.750**	**15**	**3**

Inclusion cut-off = 0.9.

Effective case, non-effective case.

Table S3: Truth Table of Adaption 2

Configuration	Independent ambulatory participants [a]	Tailored	Moderate or low intensity	Group	Outcome (Reduced Falls)	No. studies	Sufficiency		Cases	Supports theory
							Inclusion Score (incl)	Consistency Score (PRI)		
1	Yes	Yes	Yes	Yes	Yes	4	1.000	1.000	**Arrieta[20], Irez [27], Jahanpeyma [28], Kovacs [29]**	Yes
2	Yes	Yes	Yes	No	Yes	3	1.000	1.000	**Cadore[23], Dhargave [25], Shimada [34]**	Yes
3	Yes	No	Yes	Yes	Yes	2	1.000	1.000	**Choi [24], Yokoi [37]**	Yes
4	Yes	Yes	No	Yes	No	1	0.000	0.000	Rosendahl [31]	Yes
5	Yes	No	Yes	No	No	4	0.250	0.250	Buckinx [22], Sakamoto[32], Schoenfelder[33], **Varela [36]**	Unclear
6	No	Yes	Yes	Yes	Yes	2	1.000	1.000	**Brett [21], Hewitt[26]**	Yes
7	No	Yes	Yes	No	No	1	0.000	0.000	Mulrow [30]	Yes
8	No	Yes	No	Yes	No	1	0.000	0.000	Toots [35]	Yes

[a] Independent ambulatory participants (independent with or without walking aid)

Effective case, non-effective case.

Table S4: QCA Minimisation of Only Ambulant, Tailored, Non-High Intensity and Group Exercise

Configuration (Possible Pathway)	Conditions			Outcome (Reduced Falls)	No. effective studies	Sufficiency				Cases explained	Cases not explained
						Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique Coverage (covU)		
1	Moderate/Low Intensity	Group		Yes	8	1.000	1.000	0.667	0.333	**Choi [24], Yokoi [37], Arrieta [20], Jahanpeyma[28], Kovacs [29] Brett [21], Hewitt [26], Irez [27],** Buckinx [22], Rosendahl [31], Sakamoto [32], Toots [35], Mulrow [30]	**Varela [36]**
2	Moderate/Low Intensity	Tailored	Independent ambulatory participants [a]	Yes	6	1.000	1.000	0.583	0.250	**Cadore [23], Dhargave[25], Shimada [34]**, Schoenfelder [33] **Arrieta [20], Jahanpeyma [28], Kovacs [29],** Mulrow[30] **Irez [27]**	
Overall						**1.0000**	**1.000**	**0.917**		**17**	**1**

[a] Independent ambulatory participants (independent with or without walking aid)

Effective case, non-effective case.

Table S5: QCA Intermediate solution*

Configuration (Possible Pathway)	Conditions			Outcome (Reduced Falls)	No. effective studies	Sufficiency				Cases explained	Cases not explained
						Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique Coverage (covU)		
1	Moderate/Low Intensity	Group		Yes	8	1.000	1.000	0.667	0.333	**Choi [24], Yokoi [37], Arrieta [20], Jahanpeyma [28], Kovacs[29] Brett [21], Hewitt [26], Irez [27],** Buckinx [22], Rosendahl [31], Sakamoto[32], Toots [35], Mulrow [30]	**Varela [36]**
2	Moderate/Low Intensity	Tailored	Independent ambulatory participants [a]	Yes	6	1.000	1.000	0.583	0.250	**Cadore [23], Dhargave [25], Shimada [34]**, Schoenfelder [33] **Arrieta [20], Jahanpeyma[28], Kovacs [29],** Mulrow[30] **Irez [27]**	
Overall						**1.0000**	**1.000**	**0.917**		**17**	**1**

*Tests whether the assumption applied to the logical remainder that the presence of tailored, not high intensity & group exercise leads to effectiveness regardless of the ambulatory status of participates included in the exercise trial, simplifies the solution

Table S6: QCA Advanced intermediate solution*

Configuration	**Conditions**			**Outcome (Reduced Falls)**	**No. effective studies**	**Sufficiency**				**Cases explained**	**Cases not explained**
						Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique Coverage (covU)		
1	Moderate/Low Intensity	Group		Yes	8	1.000	1.000	0.667	0.333	**Choi [24], Yokoi [37], Arrieta [20], Jahanpeyma [28], Kovacs [29], Brett[21], Hewitt [26], Irez[27],** Buckinx [22], Rosendahl [31], Sakamoto [32], Toots [35], Mulrow [19]	**Varela [36]**
2	Moderate/Low Intensity	Tailored	Independent ambulatory participants [a]	Yes	6	1.000	1.000	0.583	0.250	**Cadore[23], Dhargave[25], Shimada [34]**, Schoenfelder [33], **Arrieta[20], Jahanpeyma[28], Kovacs[29],** Mulrow [30], **Irez [27],** Sakamoto [32]	
Overall						**1.0000**	**1.000**	**0.917**		17	1

***** Tests whether the logical remainder assumption from the intermediate solution excluding contradictory assumptions provides a simpler solution

[a] Independent ambulatory participants (independent with or without walking aid)

Effective case, non-effective case.

Table S7: Negated Solution*

Configuration	Conditions				Outcome (Reduced Falls)	No. ineffective studies	Sufficiency				Ineffective cases explained	Ineffective cases not explained
							Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique Coverage (covU)		
1	High Intensity	Tailored	Group		Yes	2	1.000	1.000	0.333	0.333	Rosendahl [31], Toots [35]	Sakamoto [32], Buckinx [22], Schoenfelder [33]
2	Moderate/Low Intensity	Tailored	Individual	Not independent ambulatory participants [a]	Yes	1	1.000	1.000	0.167	0.167	Mulrow [30]	
Overall							**1.0000**	**1.000**	**0.500**		**3**	**3**

*Tests whether the inverse theory offers a better solution.

[a] Independent ambulatory participants (independent with or without walking aid)

Effective case, non-effective case.

Appendix 4: Adaption 3 exploration of Sufficient resourcing

Table S1: Truth table of components of Sufficient resourcing

Configuration	**Structured Supported Exercise**	**Group**	**Falls Education**	**Outcome (Reduced Falls)**	**No. studies**	**Sufficiency**		**Cases**	**Supports theory**
						Inclusion Score (incl)	Consistency Score (PRI)		
1	Yes[b]	Yes[b]	Yes[b]	Yes	2	1.000	1.000	**Hewitt [26], Jahanpeyma [28]**	Yes
2	Yes[b]	No	Yes[b]	Yes	1	1.000	1.000	**Dhargave [25]**	Yes
3	Yes[b]	No[a]	No[a]	Yes	1	1.000	1.000	**Varela [36]**	Yes
4	Yes[b]	Yes[b]	No[a]	No	5	0.800	0.800	**Arrieta [20], Brett [21], Irez [27], Kovacs [29],** Toots [35]	Unclear
5	No[a]	Yes[b]	No[a]	No	3	0.667	0.667	**Choi [24],** Rosendahl [31], **Yokoi [37]**	Unclear
6	No[a]	No[a]	No[a]	No	2	0.000	0.000	Buckinx [22], **Cadore [23],** Mulrow [30], Sakamoto [32], Schoenfelder [33], **Shimada [34]**	Unclear

Effective case, non-effective case.

Table S2: Minimisation of components of Sufficient resourcing

Configuration	**Conditions**		**Outcome (Reduced Falls)**	**No. of effective studies**	**Sufficiency**			**Effective cases explained**	**Effective cases unexplained**
					Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)		
1	Structured supported exercise	Falls education	Yes	3	1.000	1.000	0.250	**Dhargave [25], Hewitt [26], Jahanpeyma [28]**	**Choi [24], Yokoi [37], Arrieta[20], Brett [21], Cadore [23], Irez [27], Kovacs [29], Shimada [34]**
2	Structured supported exercise	Group	Yes	2	1.000	1.000	0.167	**Varela [36], Dhargave [25]**	
Overall					**1.0000**	**1.000**	**0.333**	4	8

Table S3: Truth Table of structured supportive exercise with moderate or low intensity group exercise

Configuration	**Structured Supported Exercise**	**Moderate or low intensity**	**Group**	**Outcome (Reduced Falls)**	**No. studies**	**Sufficiency**		**Cases**	**Supports theory**
						Inclusion Score (incl)	Consistency Score (PRI)		
1	Yes[b]	Yes[b]	Yes[b]	Yes	6	1.000	1.000	**Arrieta [20], Brett [21], Hewitt [26], Irez [27], Jahanpeyma [28], Kovacs [29]**	Yes
2	Yes[b]	Yes[b]	No	Yes	2	1.000	1.000	**Dhargave [25], Varela [36]**	Yes
3	Yes[b]	No[a]	Yes[b]	Yes	1	1.000	1.000	**Choi [24], Yokoi [37]**	Yes
4	No[a]	Yes[b]	No[a]	No	5	0.333	0.333	Buckinx [22], **Cadore [23],** Mulrow [30], Sakamoto [32], Schoenfelder [33], **Shimada [34]**	Unclear
5	No[a]	Yes[b]	Yes[b]	No	3	0.000	0.000	Toots [35]	Yes
6	No[a]	No[a]	Yes[b]	No	2	0.000	0.000	Rosendahl [31]	Yes

Effective case, non-effective case.

Table S4: Minimisation of structured supportive exercise with moderate or low intensity group exercise

Configuration	**Conditions**		**Outcome (Reduced Falls)**	**No. of effective studies**	**Sufficiency**				**Effective cases explained**	**Effective cases unexplained**
					Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique coverage (covU)		
1	Moderate or low intensity	Structured supported exercise	Yes	3	1.000	1.000	0.667	0.167	**Varela[36], Dhargave [25]** **Arrieta [20], Brett [21], Irez [27], Hewitt [26], Jahanpeyma[28]**	**Cadore [23] Shimada [34]**
2	Moderate or low intensity	Group	Yes	2	1.000	1.000	0.667	0.167	**Choi [24], Yokoi [37], Kovacs [29]** **Arrieta [20], Brett [21], Irez [27], Hewitt [26], Jahanpeyma[28]**	
Overall					**1.0000**	**1.000**	**0.833**		10 out of 12	2 out of 12

Table S5: Truth table of structured supportive exercise with moderate or low intensity group exercise for participants with no cognitive impairment

Configuration	**No cognitive impairment**	**Moderate or low intensity**	**Structured Supported Exercise**	**Group**	**Outcome (Reduced Falls)**	**No. studies**	**Sufficiency**		**Cases**
							Inclusion Score (incl)	Consistency Score (PRI)	
1	Yes	Yes	Yes	Yes	Yes	1	1.000	1.000	**Jahanpeyma [28]**
2	Yes	Yes	Yes	No	Yes	3	1.000	1.000	**Varela [36]**
3	Yes	Yes[b]	No	Yes	Yes	2	1.000	1.000	**Yokoi [37]**
4	Yes	Yes	No	No	Yes	1	1.000	1.000	**Cadore [23], Shimada [34]**
5	No	Yes	Yes	Yes	Yes	4	1.000	1.000	**Arrieta [20], Brett [21], Hewitt [26], Irez [27], Kovacs [29]**
6	No	Yes[b]	No	Yes	Yes	1	1.000	1.000	**Choi [24]**
7	No	Yes[b]	Yes	No	Yes	1	1.000	1.000	**Dhargave [25]**
8	No	No	No[a]	Yes	No	1	0.000	0.000	Rosendahl [31]
9	No	No	Yes	Yes	No	1	0.000	0.000	Toots [35]
10	No	Yes	No	No	No	4	0.000	0.000	Mulrow [30], Buckinx [22], Sakamoto [32], Schoenfelder [33]

Effective case, non-effective case.

Table S6: Minimisation of structured supportive exercise with moderate or low intensity group exercise for participants with no cognitive impairment

Configuration	Conditions		Outcome (Reduced Falls)	No. of effective studies	Sufficiency				Effective cases explained
					Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique coverage (covU)	
1	Moderate or low intensity	Structured supported exercise	Yes	8	1.000	1.000	0.667	0.083	**Dhargave [25]** **Arrieta [20], Brett [21], Irez [27], Hewitt [26], Jahanpeyma [28], Varela[36], Kovacs [29]**
2	Moderate or low intensity	Group	Yes	8	1.000	1.000	0.667	0.083	**Choi [24]** **Arrieta [20], Brett [21], Irez [27], Hewitt [26], Jahanpeyma [28], Yokoi [37], Kovacs [29]**
3	Moderate or low intensity	No cognitive impairment	Yes	5	1.000	1.000	0.417	0.167	**Cadore [23], Shimada [34]** **Yokoi [37], Varela [36], Hewitt [26]**
Overall					**1.0000**	**1.000**	**1.000**		**12 out of 12**

Table S7: Intermediate solution of structured supportive exercise with moderate or low intensity group exercise for participants with no cognitive impairment

Configuration	**Conditions**		**Outcome (Reduced Falls)**	**No. of effective studies**	**Sufficiency**				**Effective cases explained**	**Contradictory assumptions**
					Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique coverage (covU)		
1	Moderate or low intensity	Structured supported exercise	Yes	8	1.000	1.000	0.667	0.083	**Dhargave [25]** **Arrieta [20], Brett [21] , Irez [27], Hewitt [26], Jahanpeyma [28], Varela [36], Kovacs [29]**	None
2	Moderate or low intensity	Group	Yes	8	1.000	1.000	0.667	0.083	**Choi [24]** **Arrieta [20], Brett [21], Irez [27], Hewitt [26], Jahanpeyma [28], Yokoi [37], Kovacs [29]**	
3	Moderate or low intensity	No cognitive impairment	Yes	5	1.000	1.000	0.417	0.167	**Cadore[23], Shimada [34]** **Yokoi [37], Varela [36], Hewitt [26]**	Buckinx,[22] **Kovacs [29]**
Overall					**1.0000**	**1.000**	**1.000**		**12 out of 12**	

Table S8: Negated solution for structured supportive exercise with moderate or low intensity group exercise for participants with no cognitive impairment

Configuration	**Conditions**			**Outcome (Reduced Falls)**	**No. of not effective studies**	**Sufficiency**				**Ineffective cases explained**	**In effective cases unexplained**
						Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique coverage (covU)		
1	High intensity			No	8	1.000	1.000	0.333	0.333	Rosendahl [31], Toots [35]	
2	No cognitive impairment	Not structured supported exercise	No group	No	8	1.000	1.000	0.667	0.667	Buckinx [22], Mulrow[30], Sakamoto [32], Schoenfelder [33]	
Overall						**1.0000**	**1.000**	**1.000**		6	0

Appendix 5

Table S1: Negated solution of moderate or low intensity exercise, tailored, group, independent ambulatory and >1 hour per week.

Configuration	**Conditions**				**Outcome (Reduced Falls)**	**No. of effective studies**	**Sufficiency**				**Cases explained**
							Inclusion Score (InclS)	Consistency Score (PRI)	Coverage (covS)	Unique Coverage (covU)	
1		High intensity exercise	More than1 hour per week	Group	No	2	1.000	1.000	0.333	0.333	Toots [35], Rosendahl [31]
2	Not independent ambulatory participants [a]	Moderate/ Low Intensity	More than1 hour per week	Not group	No	1	1.000	1.000	0.167	0.167	Mulrow [30]
3	Independent ambulatory participants [a]	Moderate/ Low Intensity	Less than 1 hours per week	Not group	No	3	1.000	1.000	0.500	0.500	Buckinx [22], Sakamoto [32], Schoenfelder [33]
Overall							**1.0000**	**1.000**	**1.000**		**6 out of 6**