Embedding Sustainable Physical Activity into The Everyday Lives of Adults with Intellectual Disability: A Randomised Controlled Trial

Xiangrong Li

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Student Declaration

I, Xiangrong Li, affirm that the contents presented herein represent the product of my independent intellectual endeavours. I declare, to the best of my knowledge, that this submission is devoid of any material previously published or authored by another individual, except where explicit acknowledgment has been provided within the text. Furthermore, I assert that I was the primary researcher responsible for all aspects of the investigations encapsulated within this thesis, including collaborative work involving multiple authors.

I, Xiangrong Li, acknowledge that if I am awarded a higher degree for this thesis, it will be lodged with the University Librarian and made available for immediate public use.

Sign:

Name: Xiangrong Li

Date: 31 March 2025

Supervisor Declaration

This certifies that the thesis titled "Embedding Sustainable Physical Activity into The Everyday Lives of Adults with Intellectual Disability: A Randomised Controlled Trial," authored by Xiangrong Li and submitted in fulfilment of the prerequisites for the degree of Doctor of Philosophy, is in a state suitable for examination.

Professor Glen M. Davis, OAM, PhD, FACSM, Principal Supervisor, Discipline of Exercise and Sport Science, Faculty of Medicine and Health, The University of Sydney.

Sign: Date: 31 March 2025

Professor Roger J. Stancliffe, PhD, Professor Emeritus of Intellectual Disability, Auxiliary Supervisor, Centre for Disability Research and Policy, Faculty of Medicine and Health, The University of Sydney

Sign: Date: 31 March 2025

Dedication

I dedicate this thesis to my wife Jing; my two sons, Yin Kong and Yankun; and my parents, Qing and Ji.

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I acknowledge the use of Grammarly in improving the spelling and grammar of my writing to prepare this thesis. I did not use any generative AI tool to generate written or other content for this thesis.

Abbreviations and Acronyms

6MWT	Six-Minute Walk Test
ACSM	American College of Sports Medicine
BMI	Body Mass Index
CRF	Cardiorespiratory fitness
EPS	Exercise Perceptions Scale
ID	Intellectual disability
IPAQ-ID	International Physical Activity Questionnaire – Intellectual Disability
IPDL	Index of Participation in Domestic Life
LMM	Linear mixed models
LSPA	Lifestyle physical activity
MET	Metabolic equivalent of task
MET-min/week	MET-minutes per week
min/week	Minutes per week
ml/kg/min	Millilitres of oxygen consumption per kilogram of body mass per minute
MVPA	Moderate to vigorous intensity physical activity
Non-RCT	Non-randomised controlled trial
PA	Physical activity
RCT	Randomised controlled trial
SE-AID	Self-efficacy for Activity for Persons with Intellectual Disability Scale
SS-AID	Social Support for Activity for Persons with Intellectual Disability Scale
STEX	Structured exercise
VO_2peak	Predicted peak oxygen consumption

Definition of Terms

Active Support: A person-centred approach for promoting engagement in activities by people with intellectual disability.

Aerobic/cardiorespiratory fitness: Refers to the peak capacity of the circulatory and respiratory systems to furnish oxygen to skeletal musculature.

Exercise: Refers to a subclassification within the spectrum of physical activity characterised by deliberate organisation, repetitive engagement, and a targeted objective of enhancing or sustaining one or multiple facets of physical fitness.

Gains: Refers to obtaining or securing something wanted or desired. In the context of this thesis, gains refer to the acquisition of something through physical activity engagement.

Light physical activity: Refers to physical activities that demand minimal exertion, where individuals may perceive a slight sensation of effort, albeit without a substantial intensity. Participants should experience a moderate level of physical exertion, yet the activity should not impose a significant overall strain.

Low level of physical activity: Or insufficient PA. An insufficient PA level to meet present PA guidelines/recommendations.

Means: Throughout this thesis, "means" refers to either arithmetic means or adjusted-means from the linear mixed models analyses.

Metabolic equivalent of task (MET): Or simply metabolic equivalent. Refers to a physiological measure expressing the intensity of physical activities. One MET is the energy equivalent expended by an individual while seated at rest, usually expressed as ml/kg/min.

MET is the energy equivalent expended by an individual while seated at rest, usually expressed as mLO2/kg/min.

Moderate physical activity: Refers to physical activities that require a moderate degree of physical exertion, inducing a moderate increase in heart rate and respiration. It encapsulates a level of exercise characterised by a perceptible challenge, yet not resulting in complete exhaustion.

Moderate-to-vigorous physical activity (MVPA): On an absolute scale, MVPA refers to the physical activity that is performed at > 3 METs (i.e., > 3 times the intensity of rest). On a scale relative to an individual's personal capacity, MPA is usually a 5 or above on a scale of 0–10.

Muscle strength: Refers to the ability to produce a requisite level of muscular force during the execution of a specific activity. Within this thesis, enhancements in muscle strength are assessed based on the proficiency to generate adequate force for weight movement, with consideration given to ancillary outcomes pertinent to muscle strength, including the dimensions of muscle fibres and the efficacy of neural activation in stimulating muscle fibres.

Nomenclature: "at" and "by" have been used interchangeably to refer to the mean difference or mean change between the stated time point and a previous one.

Physical activity (PA): Refers to any bodily movement produced by skeletal muscles that results in energy expenditure.

Physical activity guidelines: All adults should undertake 150–300 minutes of moderate PA, 75–150 minutes of vigorous PA, or some equivalent combination of moderate and vigorous aerobic PA per week.

Physical fitness: Physical fitness has been defined as "the ability to carry out daily tasks with vigor and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and respond to emergencies. It is a physiologic attribute determining a person's ability to perform muscle-powered work. A fundamental manifestation of this attribute is the ability to move—for example, to walk, run, climb stairs, and lift heavy objects. Its components include cardiorespiratory fitness, musculoskeletal fitness, flexibility, balance, and the ability to move the body quickly.

Sedentary behaviour: Any waking behaviour characterised by an energy expenditure of 1.5 METs or lower while sitting, reclining or lying.

Usual care (Control): Refers to the routine activities in participants' everyday lives without engaging in additional physical activity or exercise programs during the trial.

Vigorous physical activity: Refers to physical activities that demand significant exertion, wherein individuals experience a notable sensation of working vigorously, approaching their maximal effort capacity. Participants typically find themselves capable of sustaining such activities for only brief durations before fatigue sets in, rendering these endeavours exhausting.

Abstract

Sufficient evidence has demonstrated that adults with intellectual disabilities (ID) urgently need to engage in more physical activity (PA) to maintain and enhance their health. Numerous interventions have been attempted to increase this population's PA levels, aiming to meet the recommended 150 minutes per week of moderate-to-vigorous physical activity (MVPA). However, the existing evidence has been inconsistent. Notably, adults with ID often have a limited ability to perform MVPA and experience a lack of support from their caregivers, who also possess insufficient relevant skills. Furthermore, evidence is scarce regarding the long-term sustainability of PA interventions for adults with ID.

This thesis sought to increase the PA levels of adults with ID by integrating exercise specialists and caregiver training into two interventions: lifestyle physical activity [LSPA] and a structured exercise program [STEX]. It evaluated whether the two interventions increased PA participation, improved physical fitness and psychosocial characteristics, and offered long-term sustainability. Furthermore, this work examined whether there were differences in the feasibility and sustainability of the two interventions.

This thesis consisted of two standalone studies. One was a systematic review and meta-analysis that synthesised previous evidence to quantify the effect of PA on improving the aerobic fitness of individuals with ID. The other employed a randomised controlled trial with three groups conducted in community settings in Sydney. In that trial, participants included 96 adults with ID who led physically inactive lifestyles and could attempt to participate in PA and outcome assessments. They were recruited from local disability service organisations and randomly assigned to the LSPA, STEX, or usual care (Control) groups. Each 12-week LSPA and STEX intervention involved 150 minutes of moderate-to-vigorous physical activity (MVPA) per week. The Control group continued with their usual care without engaging in additional PA. The LSPA was customised for each participant individually. Accredited exercise specialists delivered 60 minutes of LSPA while simultaneously training caregivers who independently supported the remaining 90 minutes of activities. The STEX

constituted small group classes with three to six participants. Exercise specialists conducted the 150-minute STEX intervention entirely and provided training for caregivers. Following the conclusion of the interventions, caregivers continued to support the two interventions for an additional 24 weeks. Outcomes were assessed at baseline, three months post-baseline, and nine months post-baseline. Primary outcomes included PA levels and aerobic fitness. PA levels were recorded as accumulated time (minutes) per week across sedentary, light, moderate, and vigorous categories, as well as metabolic equivalent minutes per week (MET-min/week). Aerobic fitness was expressed as peak oxygen consumption (ml/kg/min), which was estimated from submaximal heart rates and power outputs during a multistage cycling test. Secondary outcomes included peak muscle strength, body composition, functional walking capacity, self-efficacy for activity, social support for activity, exercise outcome expectation, and participation in domestic activities.

The significant findings of this thesis, which primarily arose from within-group comparisons of change over time, demonstrated that PA interventions, combined with specialised support and caregiver training, could substantially increase participation in MVPA among adults with ID by over 500 MET-min/week, exceeding the threshold necessary to gain health benefits from physical activity. These interventions enhanced participants' abilities and confidence in engaging in MVPA. Furthermore, the LSPA maintained a satisfactory intervention compliance rate and preserved its incremental effects during the follow-up period, suggesting that it was more suitable and sustainable for adults with ID in the long term than the STEX. Importantly, this thesis quantified the increases in PA levels, enabling clinical practitioners to prescribe PA more accurately. As these findings arose from real-world research, policymakers should consider integrating these interventions into everyday disability services for the daily lives of adults with ID.

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CHAPTER ONE

Introduction

1 Introduction

1.1 Overview

Adults with intellectual disability (ID) often lead inactive lifestyles, spending much of their waking hours being sedentary throughout the day (Chow et al., 2018; Oviedo et al., 2017; Temple et al., 2000). They engage in insufficient physical activity (PA) or exercise daily, contributing to various health problems. Current PA guidelines recommend that adults should regularly undertake moderate-to-vigorous intensity physical activity (MVPA) for at least 150 minutes per week (Bull et al., 2020). A PA level below this guideline is defined as insufficient PA (or low PA level). In this thesis, PA refers to MVPA unless otherwise specified (e.g., light PA). According to these guidelines, Dairo et al. (2016) recorded in their systematic review that about 90% of adults with ID can be classified as having a low PA level. In general, many diseases and health burdens are significantly associated with insufficient PA levels and sedentary behaviour (Wilmot et al., 2012; World Health Organization, 2009).

Adults with ID experience significantly lower levels of PA than the general adult population (Sagelv et al., 2019; Stancliffe & Anderson, 2017), despite most individuals with ID possessing adequate physical capabilities (Stancliffe et al., 2019). In Australia, the proportion of adults with ID who engaged in sufficient PA was only about half that of the general community (Armstrong et al., 2000). As a result, adults with ID may face significantly higher levels of adverse health consequences that increased PA could mitigate, leading to health inequity compared to the general community. Extensive research has been conducted to increase PA levels among adults with ID; however, previous systematic reviews have not identified consistent and sustainable interventions for achieving this long-term goal (Hassan et al., 2019; Willems et al., 2018). Given that PA interventions should be tailored for individuals with ID (Physical Activity Guidelines Advisory Committee, 2018), it is crucial to develop and implement PA programs that foster consistent and sustainable long-term lifestyle changes to enhance the PA levels of individuals with ID. Nonetheless, evidence remains insufficient to address these issues in the practice of promoting PA for adults with ID (Willems et al., 2018). Michalsen et al. (2024) noted a lack of relevant skills, knowledge, and interest in PA among adults

with ID *and* their caregivers, contributing to low PA levels. These challenges result in resistance to PA participation and inadequate self-efficacy and social support for exercise (Dixon-Ibarra et al., 2017; Heller et al., 2003). Potential solutions to these barriers include developing feasible and sustainable PA programs for individuals with ID to enhance their PA and fitness levels, as well as training caregivers to acquire necessary knowledge and skills for promoting PA. Although previous studies have explored relevant topics (Heller et al., 2004; Jo et al., 2018; Marks et al., 2013; Pérez-Cruzado & Cuesta-Vargas, 2016) and offered several successful examples of partially addressing relevant issues, the solutions provided have not been maintained over the long term.

In the disability service sector, Active Support is an approach designed to empower individuals with ID to engage in more activities by training caregivers to provide direct support for their participation in daily activities (Stancliffe et al., 2008). An Australian initiative has demonstrated that Active Support effectively involves adults with ID in a greater number of daily activities within group homes (Clement & Bigby, 2008). When creating interventions, specific criteria must be met to implement Active Support in the workplace, such as incorporating the Active Support elements and the core features through on-site training (Stancliffe et al., 2008).

This thesis utilised data from a community-based randomised controlled trial involving two different PA interventions, lifestyle physical activity (LSPA) and structured exercise (STEX), as well as usual care (Control). More information about the two interventions can be found in the published protocol (see Appendix 1-A) (Lante et al., 2014). Tables 1.1 and 1.2 detail the specific requirements for Active Support and describe how the two interventions explored in this thesis fulfilled them. Chapter 7 of this thesis provides a detailed elaboration on Active Support. To the author's knowledge, this approach has not been applied in prior research that aimed at enhancing participation by adults with ID in MVPA.

Table 1.1. The core elements of Active Support in this study

Active Support Elements	LSPA	STEX
1. The focus on assisted participation	Yes	Yes
2. The nature of assistance (verbal requests, step-by-step verbal instructions, gestures, demonstration, physical assistance)	Yes	Yes
3. The focus on engagement	Yes	Yes
4. The use of both classroom-based and onsite staff training	Onsite only	Onsite only
5. Training the entire staff team of the group home simultaneously	No	No
Note. The five items are adapted from Stancliffe et al. (2008). LSPA (lifestyle physical activity) and STEX (structured exercise) are the two interventions in this thesis. As a controlled trial, item 5 is unnecessary to meet because only specific individual staff members, not the entire group home team, participate in the trial. Yes/No indicates whether the element is met or not met.		

Table 1.2. The core features of Active Support on-site training

Core Features	LSPA	STEX
1. Occur in the group home (and sometimes also in nearby community settings)	Yes	Yes
2. Involve one staff member at a time to assist one or more residents in participating in activities	Yes	Yes
3. Use authentic materials and activities that are available in the group home or local community	Yes	Yes
4. Involve interactive coaching and feedback built around these activities to help the staff member learn to more effectively present activities to residents and assist them in taking part	Yes	Yes
Note. The four items are adapted from Stancliffe et al. (2008). LSPA (lifestyle physical activity) and STEX (structured exercise) are the two interventions in this thesis. Yes/No indicates whether the element is met or not met.		

1.2 Rationale

As previously detailed, adults with ID have low PA levels. They are significantly less physically active than the general population, resulting in higher risks for various health problems. To mitigate the preventable health complications related to low PA participation, adults with ID require interventions aimed at increasing their PA levels to match those of the general community. Moreover, society has a responsibility to support this disadvantaged population in reducing health inequalities and fulfilling their needs (Ruger, 2006), ultimately improving their health and well-being which is an essential component of providing disability services. The primary rationale for this thesis was to develop programs that would enable adults with ID to increase their PA engagement in routine daily activities, thereby facilitating regular participation and sustainable implementation.

Another rationale for this thesis was to contribute new knowledge to PA promotion practices for adults with ID. Previous systematic reviews have shown a lack of consistent evidence regarding the effectiveness of PA interventions in improving aerobic fitness (Andriolo et al., 2009; Dodd & Shields, 2005; John et al., 2020; Shin & Park, 2012) and increasing PA levels (Hassan et al., 2019) among people with ID. This thesis aimed to provide new findings in these areas by employing Active Support to increase PA levels, fitness, and PA-related psychosocial outcomes (e.g., exercise self-efficacy, social support for PA, etc.) for adults with ID.

Finally, this thesis created an opportunity for collaboration between researchers and disability service providers in real-world settings. As a pragmatic community-based study, such collaboration fostered an evidence-based approach to training caregivers to support adults with ID in participating in sufficient PA sustainably.

1.3 Aims

The overarching aim of this thesis was to develop sustainable interventions that could be integrated into the daily lives of adults with ID to increase their PA levels, thereby improving physical fitness and well-being in the long term. The objective was also to determine which of the two interventions

(LSPA and STEX) was more effective in increasing PA levels, maintaining the implementation of the intervention, and strengthening psychosocial outcomes related to PA participation.

1.4 Research Methodologies

This thesis employed two study designs: a systematic review and meta-analysis (Chapter 2) and a three-arm randomised controlled trial (Chapters 3 to 6). Other researchers had collected the trial data prior to this thesis. The current author cleaned and analysed the data and reported the findings within this thesis.

Participants were adults with ID. As outlined in the study protocol for the trial (see Appendix 1-A) (Lante et al., 2014), two PA interventions (LSPA and STEX) were implemented using distinct methods. The trial outcomes included PA levels, aerobic fitness, functional capacity, muscle strength, and PA-related psychosocial outcomes. These outcomes were assessed at baseline, three months post-baseline, and nine months post-baseline. Across the three arms of the trial, *between-group* comparisons involved participants who each engaged in one of the two interventions. These participants were compared to one another as well as to those who maintained their usual daily activities (Control) without participating in additional PA programs. The trial also conducted comparisons of outcomes *within groups* over different measurement time points.

During the trial, an individual participant could have a single missing outcome value among the three repeated measurements, resulting in unbalanced datasets where the number of participants in each group varied (see Chapter 4, Figure 4.1). In these circumstances, the initial proposed statistical analyses, involving repeated measures analysis of variance (see Appendix 1-A) (Lante et al., 2014), should not be applied, as this approach necessitates independent variables and excludes participants with missing values across the three measurements (West, 2009). Instead, a linear mixed models statistical approach accommodates incomplete data and was therefore utilised to enable *between-group* and *within-group* comparisons (West, 2009).

1.5 Research Questions

To achieve the aforementioned objectives, this thesis aimed to address the following research questions:

1. What is the relationship between PA and aerobic fitness among individuals with ID? If a significant relationship exists, is it clinically meaningful?
2. What are the current baseline levels of PA, aerobic fitness, functional capacity, muscle strength, body mass index, and body fat in a physically capable sample of Australian adults with ID who have led sedentary lifestyles? Is there a need for them to increase their PA levels?
3. Can the two interventions enhance the PA levels of adults with ID? If so, are the effects clinically meaningful? Are the two interventions feasible and sustainable in the long term? Do the impacts of the two interventions differ?
4. What are the relationships between the two PA interventions and physical fitness (i.e., aerobic fitness, muscle strength, and functional walking capacity) in adults with ID? If there is improvement, are the effects sustainable in the long term?
5. What are the relationships between the two PA interventions and PA-related psychosocial changes (e.g., self-efficacy and social support for PA) in adults with ID? If there is improvement, are the effects sustainable in the long term?

1.6 Structure of The Thesis

This thesis comprises seven chapters. Chapters 2 to 6 are stand-alone works prepared for submission to peer-reviewed journals, while Chapters 3 to 6 stem from a community-based randomised controlled trial. However, some overlap exists in the writing of the reports across these chapters, particularly in the methodological sections concerning participants, interventions, and outcome assessments, making a degree of repetition unavoidable. Cross-references are made between chapters to minimise excessive repetition, even though such cross-referencing is not usual for stand-alone papers when formatted for submission for publication.

1.6.1 Chapter 2. Effects of Physical Activity on Aerobic Fitness in Individuals with ID

Chapter 2 addressed research question 1. To enhance the rationale for this thesis, Chapter 2 examined the evidence that PA interventions improve the aerobic fitness of individuals with ID, aiming to provide further insights into whether and how PA can significantly benefit their aerobic fitness. This systematic review and meta-analysis synthesised data from randomised and non-randomised controlled trials that compared participants who engaged in PA interventions with those who maintained their usual activities. The differences in outcomes between the intervention and Control groups were aggregated and analysed in the meta-analysis to determine whether a significant improvement exists.

1.6.2 Chapter 3. Physical Activity, Fitness, and Personal Characteristics for Australian Adults with ID

In response to research question 2, Chapter 3 analysed the baseline data of all trial participants to provide evidence supporting the necessity for interventions aimed at increasing the PA levels of adults with ID and examined the relationships between PA and physical measures (fitness and functional capacity).

1.6.3 Chapter 4. Effects of Exercise Combined with Caregiver Training on Physical Activity Levels among Adults with ID

To address research question 3, Chapter 4 examined whether the LSPA and STEX interventions improved PA participation among adults with ID, whether the effects varied between the two interventions, and whether these interventions were feasible and sustainable as long-term support for adults with ID.

1.6.4 Chapter 5. Effects of Physical Activity on Physical Fitness among Adults with ID

Chapter 5 addressed research question 4 by investigating whether the two interventions significantly benefit the physical fitness of adults with ID and whether the effects varied between the two interventions in the short or long term, potentially indicating the relative feasibility and sustainability of both interventions.

1.6.5 Chapter 6. Impacts of Physical Activity on Psychosocial Factors of Adults with ID

In response to research question 5, the relationships between the two PA interventions and the psychosocial factors were explored in Chapter 6. This chapter covered psychosocial factors such as exercise self-efficacy, social support for PA, participation in domestic activities, and exercise outcome expectations. Both short- and long-term effects were assessed.

1.6.6 Chapter 7. Thesis Discussion and Conclusions

This chapter summarised the findings from previous chapters, discussed the key features of the two interventions examined, and provided information for practice and future research.

1.7 Summary

This intervention- and community-based randomised controlled trial compared the LSPA and STEX interventions to identify a sustainable and practical approach to increasing PA participation, fitness, and PA-related psychosocial outcomes in adults with ID. The findings of this thesis enhanced the disability industry's capacity to support this population in achieving healthy behavioural changes by embedding the Active Support approach PA into everyday disability services.

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CHAPTER TWO

Effects of Physical Activity on Cardiorespiratory Fitness in Individuals with Intellectual Disability: A Systematic Review and Meta-Analysis

Abstract

Background: Peak oxygen consumption (VO_2peak) serves as a primary benchmark for cardiorespiratory fitness. Previous research has shown that individuals with intellectual disability (ID) can improve their VO_2peak by participating in moderate-to-vigorous physical activity (MVPA). This study aimed to evaluate and quantify the effects of MVPA on VO_2peak within this population.

Methods: This systematic review and meta-analysis (PROSPERO registration number: CRD42021248266) was conducted using a literature search across MEDLINE, PubMed, EMBASE, PsycINFO, AMED, CINAHL, SPORTDiscuss, SCOPUS, Web of Science, and Google Scholar. Employing a comprehensive search strategy, studies were included if controlled trials reported mean VO_2peak values for individuals with ID who participated in MVPA interventions and non-intervention controls. This study utilised summary data to estimate the mean difference in VO_2peak between trial groups following the cessation of the MVPA interventions. Furthermore, subgroup, meta-regression, and sensitivity analyses were undertaken.

Results: Among the 1189 studies identified, eight randomised controlled trials (RCTs) and four non-randomised controlled trials (non-RCTs) were included in this meta-analysis involving 360 participants. The overall judgement regarding the risk of bias was low for RCTs and moderate for non-RCTs. The likelihood of publication bias was low. The pooled mean in VO_2peak post-intervention was significantly higher in the PA intervention group by 4.2 ml/kg/min (95% CI [2.2, 6.1], $p < 0.0001$, Cohen's $d = 0.8$) than in the control group, with moderate variability between studies ($I^2 = 63\%$). No significant differences were identified between subgroups.

Conclusion: This study demonstrated that VO_2peak is significantly higher in individuals with ID who participate in MVPA interventions than those who do not. This finding presents a large effect size and is clinically meaningful, indicating a substantial reduction in the adverse sequelae of lifestyle-related and cardiovascular diseases. MVPA promotion should be integrated into regular disability support for individuals with ID in their daily lives.

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2 Effects of Physical Activity on Cardiorespiratory Fitness in Individuals with Intellectual Disability: A Systematic Review and Meta-Analysis

2.1 Introduction

Substantial evidence indicates that cardiorespiratory fitness (CRF) is a crucial clinical indicator for predicting health outcomes across various diseases in the general population, and it can be improved by engaging in regular moderate-to-vigorous physical activity (MVPA) (Ross et al., 2016). As a robust predictor, CRF shows an inverse relationship with the risk of experiencing negative sequelae from adverse health events (Ross et al., 2016). For instance, individuals with lower levels of CRF are more likely to face heightened risks of increased morbidity and mortality associated with cardiovascular diseases. In contrast, a higher level of CRF is significantly associated with considerably lower adverse health events and increased survival rates.

In clinical practice, CRF can be estimated from peak oxygen consumption (VO_2peak) in millilitres per kilogram of body mass per minute (ml/kg/min) during incremental exercise on a treadmill or cycle ergometer, which is widely accepted as a "gold standard" benchmark indicating an individual's CRF (Ross et al., 2016). In the study reviewed by Oppewal et al. (2013), individuals with intellectual disability (ID) were found to have, on average, lower levels of VO_2peak at a young age compared to the general population, and this may decline further as they age. This could lead to increased risks of adverse health consequences in individuals with ID. For instance, the VO_2peak of adults with ID (mean age = 28 years) was found to be 23 ml/kg/min in a previous study (Cowley et al., 2011), suggesting a poor CRF in this population (American College of Sports Medicine & Pescatello, 2014). Furthermore, a CRF level of less than 28 ml/kg/min is associated with an increased risk of adverse cardiovascular events (Ross et al., 2016). Therefore, individuals with ID need to improve their CRF levels to maintain their health status and achieve corresponding health-related benefits.

Researchers have focused on identifying effective physical activity (PA) interventions to improve the CRF levels of individuals with ID. It is essential to note that such interventions must incorporate MVPA components to achieve the expected health benefits (Physical Activity Guidelines Advisory

Committee, 2018; Ross et al., 2016). When comparing the post-intervention effects between MVPA and usual care groups, some studies have shown that individuals with ID can significantly improve their VO_2peak by participating in MVPA interventions (Boer & Moss, 2016; Kim, 2017; Naczk et al., 2021; Oviedo et al., 2014; Rimmer et al., 2004; Seron et al., 2017). However, the *between-group* effects were insignificant in certain studies (Millar et al., 1993; Ordonez et al., 2013) or indicated no effects (Cowley et al., 2011). In this context, a systematic review and meta-analysis are necessary to consolidate the existing evidence and provide clinicians with valuable insights on this topic.

The literature search for the current study identified four systematic reviews (Andriolo et al., 2009; Dodd & Shields, 2005; John et al., 2020; Shin & Park, 2012) that reported on the overall effects of PA interventions on VO_2peak in individuals with ID and/or Down syndrome. However, the findings from these studies were inconsistent. One review (Andriolo et al., 2009) included only two primary studies in their meta-analysis and reported no effects. Another review (John et al., 2020) also found insignificant results. The remaining two reviews presented outcome data as standardised effect sizes, suggesting significant improvements with medium to large effect sizes (Dodd & Shields, 2005; Shin & Park, 2012). However, standardised effect sizes are not considered as clinical indicators, as recommended by Ross et al. (2016) in their scientific statement. Furthermore, the four review studies included a limited number of primary studies with various study designs, which may introduce bias into the analysis.

PA programs are regarded as clinical interventions to address pertinent health issues (Jonas & Phillips, 2009; Ross et al., 2016). Health practitioners should be guided by current and comprehensive clinical information derived from all available research evidence to inform their clinical decision-making. Systematic reviews and meta-analyses exploring the clinical effects of PA interventions on enhancing VO_2peak levels in individuals with ID are critically needed to provide evidence-based strategies for clinical practice and policymaking aimed at supporting this population with special needs. Therefore, an up-to-date systematic review and meta-analysis is necessary to determine how MVPA interventions affect the VO_2peak of individuals with ID.

The present study aimed to examine whether there is a difference in VO_2peak between individuals with ID who engaged in MVPA and the same cohort who received care as usual without engaging in additional MVPA and whether this difference is clinically meaningful.

2.2 Methods

2.2.1 Search Strategy and Selection Criteria

This systematic review and meta-analysis evaluated overall summary estimates pooled from aggregated data of individual studies extracted from randomised controlled trials (RCTs) and non-randomised controlled trials (non-RCTs). As this study aimed to conduct subgroup analyses to investigate the effects of various factors on CRF outcomes, few restrictions were applied to the selection criteria and search strategies. In this study, whether participants had ID was as reported in the original studies. Since Down syndrome has a genetic association with ID (Dierssen, 2012; Lott & Dierssen, 2010), it was considered as such in this study.

Studies were included if they met the following criteria: 1) study participants were reported to have ID and were capable of engaging in the intended MVPA; 2) trial interventions involved any MVPA components aimed at examining effects on VO_2peak; 3) comparators were non-interventional control individuals (e.g., participants in control groups were required to maintain their usual life routines without engaging in additional PA); and, 4) trials provided outcome data for VO_2peak in ml/kg/min following the completion of interventions. Furthermore, if they did not breach inclusion criteria, study participants could be healthy or have another health condition (e.g., obesity). There were no restrictions on the age or sex of participants. Published articles could be in languages other than English. However, the language for the title and abstract was limited to English only. No limitations were applied to study settings or the type, dose, and delivery modes of MVPA. Studies were excluded if they did not satisfy the four inclusion criteria. Furthermore, studies were considered acceptable even if they were not published in peer-reviewed journals or were grey literature.

The search terms employed included medical subject heading terms and truncation relating to study participants, trial interventions and primary outcomes. The foundation of the search strategy

considered of ("intellectual disability", "mental retardation", "learning disability", "developmental disability", "Down syndrome", and Autism) AND ("physical activity", exercise, training, aerobic) AND (cardiovascular, cardiorespiratory, "oxygen consumption", VO_2peak, metabolic). On July 18, 2021, a literature search was conducted across various electronic databases, including MEDLINE (Ovid), PubMed, EMBASE (Ovid), PsycINFO (Ovid), AMED (Ovid), CINAHL Complete (EBSCO), SPORTDiscuss (EBSCO), SCOPUS, and Web of Science. Additionally, a hand search was performed to find further literature on Google Scholar and the reference lists of pertinent articles. The final search took place on September 1, 2021. A comprehensive list of search terms for MEDLINE is available in Appendix 2-A. No attempt was made to seek data or unpublished studies from grey literature sources and trial registries. Study authors were contacted via email for supplementary information when necessary. One investigator (XL) conducted the literature searches. Two reviewers (XL and GMD) independently did the study selection and data extraction. Any disputes between the two authors were addressed through discussion or adjudication by a third investigator (RJS). This study has been registered in the International Prospective Register of Systematic Reviews (PROSPERO) and can be accessed on its website under registration number CRD42021248266.

2.2.2 Data Extraction and Analysis

This systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (Page et al., 2021). Following this, a predefined and piloted data extraction form (see Appendix 2-B) was employed to examine the eligibility of potential studies and collect data items from the selected studies, including publication year, study design, the country from which participants were recruited, sample size, participants' information regarding age, sex, level of intellectual disability, health status, type of developmental disability, living facility, the involvement of exercise professionals in intervention delivery, type and dose of MVPA, the method of assessing VO_2peak, and outcome data measured at baseline and post-intervention. These data were summarised in tables. The data extraction process mirrored that of the study selection. Results might be imputed from available data in the included studies when certain needed data were missing. When multiple publications reported data from the same research or data source, data were sought from all

relevant studies. However, the meta-analysis included only the earliest publication or the one with the required data. In some selected studies, two intervention groups were compared with a single control group. The MVPA components of the two interventions were likely different, so they were not combined into a single comparator group. Instead, the one with possibly a better effect size was included in the meta-analysis to avoid unit-of-analysis error, as it is inappropriate to include the same control group of participants twice. This approach is recommended in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2019). Outcome data represented final mean values and standard deviations measured after the interventions concluded. The primary outcome was VO_2peak, and the secondary outcomes included body mass, body mass index (BMI), and body fat percentage.

The risk of bias in selected individual studies was assessed independently by two reviewers (XL and GMD). Any reviewer disagreement was resolved through discussion or adjudication by a third reviewer (RJS). The RoB-2 assessment tool (Sterne et al., 2019) was used to assess RCTs, and the ROBINS-I assessment tool (Sterne et al., 2016) was used for non-RCTs. Details of the assessed bias domains can be found in Tables 2.3 and 2.4, which present the assessment results. Although the two tools rate the risk of bias slightly differently, the overall risk of bias was described across three levels (low, moderate, and high). Where applicable, a predicted direction of bias for the outcomes was provided.

The data variables extracted for the meta-analysis included the publication year, study design, country, the number of participants, mean age, sex, type and severity of ID, living facility, type and dose of interventions, and outcome data (mean and standard deviation) of both intervention and control groups before and after interventions. In this meta-analysis, participants served as the units of analysis. Outcome data were assessed to identify outliers and extreme values. As such values might influence the study effects, sensitivity analysis was conducted by excluding the relevant study from the meta-analysis to determine whether the overall effects varied significantly.

All reviewers contributed to planning and revising the statistical analyses, while one investigator (XL) carried out the analyses using the R package *meta* (Schwarzer et al., 2015) in R version 4.1.1 (R Core Team, 2021). The intervention effects may vary by participants' age and sex, as well as by intervention implementation across selected studies (Oppewal et al., 2013; Shin & Park, 2012), heterogeneity between studies was anticipated. Therefore, a random-effects model was used to calculate overall estimates in the meta-analysis. Following tradition, the DerSimonian-Laird method was employed to estimate heterogeneity in the meta-analysis (Higgins et al., 2019). To examine and quantify the between-study heterogeneity, the I^2 statistic was utilised, where a value exceeding 75% may indicate substantial heterogeneity. The meta-analysis results were presented as mean differences (MD) along with 95% confidence intervals (CI) between the outcomes of the intervention and control groups, which were visually presented using forest plots. In the statistical testing of this study, a significance level of .05 ($p < .05$) was set, indicating statistically significant effects. The effect size was estimated using Cohen's *d* statistic (Cohen, 1988).

A subgroup analysis was planned to explore whether the effects differed between the study subgroups and the participants based on the abovementioned variables. A meta-regression was conducted to investigate the interaction relationships between the effects and variables. Potential publication bias was assessed for statistical significance using Egger's test and was visualised in funnel plots. The same reviewers evaluated the quality of the findings for this study's primary outcome (VO_2peak) during the data extraction, assessing the strength and confidence in interpretation through the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) approach (Atkins et al., 2004).

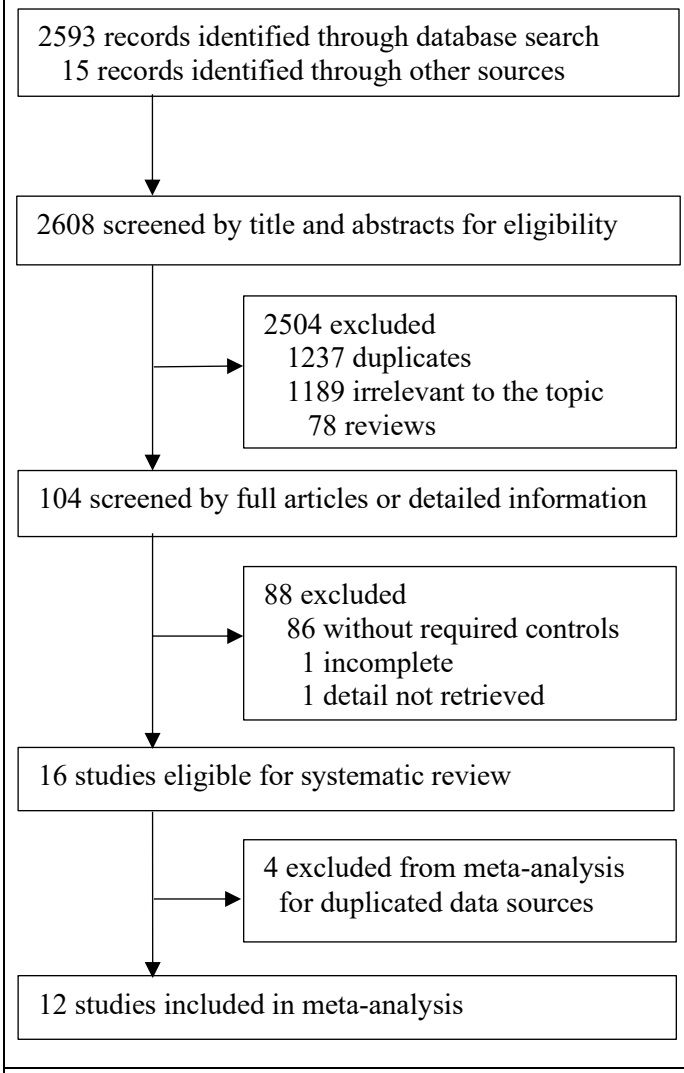

Figure 2.1. Study selection diagram

Table 2.1. Characteristics of included studies

Study	Country	Study design	*n*	Age (year)	ID/ DS	Health status	IQ	Living facility	Trainer	Intervention	VO_2peak assessment
Millar et al. (1993)	United States	RCT	14 (11 boys & 3 girls)	17.8[a] (2.9)	ID/ DS	Healthy	30-70	Family home	NR	I: Brisk walking and jogging (65%-75% MHR) Dose: 30 minutes/session, 3 times a week for 10 weeks	Treadmill
Tsimaras et al. (2003)	NR	Non-RCT	25 men	24.6	ID/ DS	NR	45-60	Group home	Yes	I: Continuous jogging and walking (65%-75% MHR) Dose: 40-45 minutes/session, 3 times a week for 12 weeks	Treadmill
Rimmer et al. (2004)	NR	RCT	52 (23 men & 29 women)	39.4 (6.4)	ID/ DS	NR	Mild to moderate	Group & family home	Yes	I: Stepping, cycling, treadmill, muscle training (50%-70% MHR or 70% 1RM) Dose: 45 minutes/session, 3 times a week for 12 weeks	Cycle
Calders et al. (2011)	Belgium	RCT	45 (27 men & 18 women)	42 (9.2)	ID	NR	45-70	Group home	Yes	I_1: Combination of strength endurance exercises (cycling, stepping, running, muscle training, chest press, bridging, leg extension) (60%-80% 1RM) I_2: cycling, stepping, running (60%-80% 1RM) Dose: 70 minutes/session, twice a week for 20 weeks	Cycle
Cowley et al. (2011)	United States	Non-RCT	30 (19 men & 11 women)	28 (8)	ID/ DS	NR	Mild	NR	NR	I: Extension, presses, pushdown exercise, walking, stepping (70%-80% 1RM) Dose: twice a week for 10 weeks	Treadmill
Ordonez et al. (2013)	NR	RCT	20 women	24.9[a]	ID/ DS	Obese	50-69	Family home	NR	I: Treadmill aerobic exercise (55%-65% MHR) Dose: 30-40 minutes/session, 3 times a week for 10 weeks	Treadmill
Boer et al. (2014)	Belgium	RCT	54 (30 men, 16 women, 8 NR)	17 (3.0)	ID	NR	59 (8.6)	Family home	Yes	I_1: Sprint interval training, cycling (up to 110% ventilatory threshold) I_2: cycling, walking, running, stepping (up to 110% ventilatory threshold) Dose: 40 minutes/session, twice a week for 15 weeks	Cycle
Oviedo et al. (2014)	Spain	Non-RCT	72 (39 men, 27 women, 6 NR)	43.2[a]	ID (14 DS)	NR	Mild to moderate	NR	Yes	I: Brisk walking, jogging, running, dancing, swimming, muscle training (50%-80% VO_2peak or 60%-70% 1RM) Dose: 30-50 minutes/session, 3 times a week for 14 weeks	Treadmill

Boer and Moss (2016)	South Africa	RCT	46 (25 men, 17 women, 4 NR)	33.8 (8.6)	ID/ DS	NR	NR	Disabled centre	Yes	I_1: Interval sprint training (100% of VO_2peak) I_2: Continuous walking or cycling (70%-80% of VO_2peak) Dose: 20 minutes/session, 3 times a week for 12 weeks	Treadmill
Seron et al. (2017)	Brazil	Non-RCT	41 (25 boys & 16 girls)	15.51 (2.70)	ID/ DS	NR	NR	NR	NR	I_1: Aerobic training on treadmill and stationary bike (50%-70% MHR) I_2: press, extension, pull-up, weightlifting, curls (60% 1RM) Dose: 50 minutes/session, 3 times a week for 12 weeks	Treadmill
Kim (2017)	South Korea	RCT	24 men	19.5[a]	ID	NR	NR	NR	NR	I_1: Aerobic exercise (50%-70% MHR) I_2: half-bath (no physical activity component) Dose: 30 minutes/session, 5 times a week for 12 weeks	Treadmill
Naczk et al. (2021)	NR	RCT	22 (14 boys & 8 girls)	14.7[a]	DS	NR	NR	Family home	Yes	I: Swimming & water exercise Dose: 70-90 minutes/session, 3 times a week for 33 weeks	Treadmill

Note. Data are Mean (*SD*), range or number unless otherwise specified. $N = 445$ participants involved in all selected studies.
DS = Down syndrome. ID = intellectual disability. I = intervention group (I_1 and I_2 refer to two intervention groups, respectively. I_1 is included in the meta-analysis). IQ = intelligent quotient scores or levels. NR = not reported. Non-RCT = non-randomised controlled trial. RCT = randomised controlled trial. Trainer = exercise professionals were involved in the intervention delivery if yes. MHR = maximal heart rate. 1RM = one repetition maximum. VO_2peak was assessed via either a treadmill or cycle ergometer. A percentage of MHR, VO_2peak, 1RM, or ventilatory threshold indicates physical activity intensity.
[a] Data are imputed.

Table 2.2. Outcomes extracted from included studies

Study	*n* (male/female)		VO_2peak (ml/kg/min)				Body mass (kg)				BMI (kg/m^2)				Body fat (%)			
	Intervention	Control	Intervention		Control		Intervention		Control		Intervention		Control		Intervention		Control	
			Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Millar et al. (1993)	10 (8/2) (1 missing)	4 (3/1)	26.95 (7.92)	25.56 (7.82)	26.22 (5.85)	26.24 (5.15)	66.5 (12.5)	67.0 (11.5)	58.4 (25.3)	58.5 (25.3)	26.4[a] (6.8)	NR	24.8[a] (6.2)	NR	NR	NR	NR	NR
Tsimaras et al. (2003)	15 (15/0)	15 (15/0)	29.6 (8.8)	35.7 (10.7)	30.5 (4.3)	30.8 (3.4)	NR	NR	NR	NR	72.3 (10.5)	NR	71.8 (8.7)	NR	NR	NR	NR	NR
Rimmer et al. (2004)	30 (14/16)	22 (9/13)	15.4 (4.0)	17.8 (4.6)	14.7 (4.5)	13.6 (4.5)	80.5 (20.0)	79.5 (19.9)	76.8 (18.1)	78.5 (17.9)	35.2 (8.7)	34.7 (9.2)	33.9 (7.6)	34.4 (7.1)	NR	NR	NR	NR
Calders et al. (2011)	15 (6/9)	15 (6/9)	27.7 (10.03)	30.3 (10.08)	28.5 (8.68)	26.3 (9.72)	66.9 (12.23)	67.7 (13.16)	65.1 (11.50)	65.1 (10.55)	24.0 (3.92)	24.3 (4.19)	22.3 (3.42)	22.9 (3.25)	NR	NR	NR	NR
Cowley et al. (2011)	19 (9/10)	11 (8/3)	23.3 (6.0)	22.9 (5.8)	25.8 (4.2)	28.0 (5.9)	78.3 (12.2)	79.1 (13.3)	73.4 (16.5)	74.1 (15.8)	33.8 (6.1)	NR	30.8 (6.8)	NR	NR	NR	NR	NR
Ordonez et al. (2013)	11 (0/11)	9 (0/9)	20.2 (5.8)	23.7 (6.3)	20.4 (5.5)	20.6 (5.7)	69.8 (5.7)	NR	67.9 (6.1)	NR	30.2 (0.9)	29.8 (0.7)	30.7 (0.8)	30.9 (0.8)	38.9 (4.0)	35.0 (3.8)	37.7 (3.8)	37.8 (3.9)
Boer et al. (2014)	17 (11/6) (1 missing)	14 (9/5) (4 missing)	31.5 (5.2)	31.4 (4.8)	28.7 (5.7)	27.4 (4.6)	76.8 (18.3)	76.0 (19.1)	79.3 (14.7)	80.0 (14.4)	28.4 (4.7)	27.7 (4.7)	26.9 (3.2)	26.9 (2.9)	34.2 (6.9)	30.4 (7.0)	32.0 (7.1)	32.0 (7.0)
Oviedo et al. (2014)	37 (22/15)	29 (17/12) (6 missing)	26.8 (6.8)	29.3 (7.5)	24.1 (5.1)	24.5 (4.9)	70.1 (13.5)	68.1 (13.1)	74.2 (12.5)	74.3 (13.4)	27.4 (5.0)	26.6 (4.8)	28.5 (6.3)	28.6 (7.0)	29.8 (10.5)	28.9 (10.3)	30.4 (9.5)	30.5 (11.5
Boer and Moss (2016)	13 (8/5) (2 missing)	16 (10/6)	31.9 (7.9)	37.3 (7.9)	32.1 (7.1)	30.7 (6.1)	71.7 (8.4)	69.4 (8.3)	74 (8.4)	74.1 (8.4)	29.3 (4.0)	28.5 (4.0)	31.2 (4.6)	30.9 (4.2)	24.7 (10.1)	23.4 (9.6)	27.8 (11.8)	27.1 (11.8)
Seron et al. (2017)	16 (11/5)	10 (4/6)	30.54 (6.26)	30.01 (5.88)	28.05 (3.86)	21.25 (4.3)	61.5 (10.8)	NR	54.7 (11.8)	NR	27.0 (4.4)	NR	27.6 (3.8)	NR	NR	NR	NR	NR
Kim (2017)	8 (8/0)	8 (8/0)	25.12 (1.21)	33.07 (2.37)	27.13 (1.01)	27.05 (1.00)	65.6 (1.5)	61.3 (1.6)	65.5 (1.4)	66.1 (0.5)	24.6[a]	23.0[a]	24.7[a]	24.9[a]	32.3 (1.6)	27.5 (1.1)	32.4 (1.1)	33.1 (1.0)
Naczk et al. (2021)	11 (7/4)	11 (7/4)	27.4 (3.86)	31.7 (4.05)	27.2 (3.13)	25.9 (3.08)	56.8 (7.97)	55.0 (7.11)	57.2 (8.43)	59.7 (8.29)	25.1 (2.37)	24.0 (2.05)	25.4 (2.46)	26.0 (2.72)	26.1 (4.23)	23.7 (4.19)	25.4 (3.32)	26.8 (3.47)

Note. Data are Mean (*SD*). *N* = 360 participants included in the meta-analysis (see Section 2.3 for more explanation).
BMI = body mass index. Before = baseline data. After = outcome post-intervention. NR = not reported.
[a] Data were imputed.

2.3 Results

This systematic review and meta-analysis screened 1189 articles by title and abstract, excluding duplicates and review articles. The study selection process is illustrated in Figure 2.1, detailing the records excluded at each stage. Four of the sixteen eligible studies were derived from the same data sources as other articles and were thus excluded from the meta-analysis. The citations for these four studies are listed in Appendix 2-C. Ultimately, 12 studies involving 445 participants were included in the systematic review. However, only 360 participants were analysed in the meta-analysis. The 85 participants excluded from the meta-analysis were drawn from the five studies that involved two intervention groups (Boer et al., 2014; Boer & Moss, 2016; Calders et al., 2011; Kim, 2017; Seron et al., 2017). Since only one control group from each study was compared, only one intervention group should be included in the meta-analysis to avoid bias (Higgins et al., 2019), which was the intervention I_1 shown in Table 2.1.

Table 2.1 summarises the study and participant characteristics for each study in this meta-analysis, which involved eight RCTs and four non-RCTs. The baseline and post-intervention outcome data were extracted from each study for each trial group (Table 2.2). The study participants were mainly recruited from one to three convenient sources, including special schools (Boer et al., 2014; Millar et al., 1993; Seron et al., 2017; Tsimaras et al., 2003) and community service organisations (Boer & Moss, 2016; Calders et al., 2011; Cowley et al., 2011; Kim, 2017; Ordonez et al., 2013; Oviedo et al., 2014; Rimmer et al., 2004) for individuals with ID. Only one study (Rimmer et al., 2004) provided information on estimating sample size. Study participants were volunteers in two studies (Millar et al., 1993; Ordonez et al., 2013) and were selected by researchers in three studies (Boer et al., 2014; Calders et al., 2011; Oviedo et al., 2014). The remaining studies offered little information on the recruitment and selection of participants. Participants were allocated into trial groups based on their personal choices in two studies (Oviedo et al., 2014; Tsimaras et al., 2003), by convenience in two (Cowley et al., 2011; Seron et al., 2017), by randomisation and matching in four (Boer et al., 2014; Calders et al., 2011; Millar et al., 1993; Ordonez et al., 2013), and by randomisation only in the remaining four studies. At baseline, seven studies (Boer & Moss, 2016; Calders et al., 2011; Millar et

al., 1993; Naczk et al., 2021; Ordonez et al., 2013; Rimmer et al., 2004; Tsimaras et al., 2003) reported no significant difference in outcome measures between groups and the remaining five studies did not provide this information. Only those participants who completed the two outcome measurements before and after the intervention were analysed in the studies with dropouts (Boer et al., 2014; Boer & Moss, 2016; Millar et al., 1993; Oviedo et al., 2014). However, limited information was provided regarding these missing data. The primary outcome, VO_2peak, was assessed via either a treadmill or cycle ergometer during incremental exercise (see Table 2.1).

The mean age of the study participants ranged from 14.7 to 43.2 years. One study (Ordonez et al., 2013) included only women, whereas two studies involved solely men (Kim, 2017; Tsimaras et al., 2003). The remaining studies included both male and female participants. All studies, except one (Naczk et al., 2021), reported participants with ID. According to the classification based on Intelligent Quotient Scores (American Psychiatric Association, 2013), the severity of ID was classified as mild to severe in one study (Millar et al., 1993), mild to moderate in three (Calders et al., 2011; Oviedo et al., 2014; Tsimaras et al., 2003), mild in three (Boer et al., 2014; Cowley et al., 2011; Ordonez et al., 2013), while others did not reported this information. Although the health status of participants was explicitly stated as healthy in only one study (Millar et al., 1993), the participant selection criteria across all studies suggested that individuals with diseases and comorbidities were frequently excluded. Regarding obesity categories (American College of Sports Medicine & Pescatello, 2014), the mean BMI indicated that participants were generally classified as obese (BMI $\geq$ 30 kg/m^2) in four studies (Cowley et al., 2011; Ordonez et al., 2013; Rimmer et al., 2004; Tsimaras et al., 2003), overweight (BMI = 25.0-29.9) in six (Boer et al., 2014; Boer & Moss, 2016; Millar et al., 1993; Naczk et al., 2021; Oviedo et al., 2014; Seron et al., 2017), and within healthy weight ranges (BMI = 18.5-24.9) in only two studies (Calders et al., 2011; Kim, 2017). It is noteworthy that Tsimaras et al. (2003) reported extremely high BMI values in their findings. Study participants resided with their families in four studies (Boer et al., 2014; Millar et al., 1993; Naczk et al., 2021; Ordonez et al., 2013), in supported facilities (e.g., group homes and disability centres) in three (Boer & Moss, 2016; Calders et al., 2011; Tsimaras et al., 2003), or in both settings in one (Rimmer et al., 2004). Consistent

with the sources mentioned earlier, the study participants received education, training, or support services to assist with their daily activities.

In the 12 studies, the primary exercise modalities of the interventions included walking, jogging, stepping, running, cycling, strength training, swimming, or a combination of these (see Table 2.1). In four studies (Calders et al., 2011; Cowley et al., 2011; Oviedo et al., 2014; Rimmer et al., 2004), the interventions combined aerobic exercise and strength training. In the remaining studies, the interventions involved only aerobic exercise. The methods used to quantify exercise intensity varied, including percentages of maximal heart rate, VO_2peak, one-repetition maximum, and ventilation threshold. Concerning the guidelines for classifying exercise intensity into categories (American College of Sports Medicine & Pescatello, 2014), the intervention activities were identified as moderate intensity in two studies (Millar et al., 1993; Tsimaras et al., 2003), vigorous intensity in four (Boer et al., 2014; Boer & Moss, 2016; Cowley et al., 2011; Naczk et al., 2021), light-to-moderate intensity in three (Kim, 2017; Ordonez et al., 2013; Seron et al., 2017), light-to-vigorous intensity in two studies (Oviedo et al., 2014; Rimmer et al., 2004), and moderate-to-vigorous intensity in one (Calders et al., 2011). The duration of each PA session varied between 20 and 90 minutes per session. The interventions typically occurred at a frequency of two or three times per week with an intervention duration of 10 to 33 weeks. Exercise professionals were involved in delivering the interventions in seven of the 12 studies (Boer et al., 2014; Boer & Moss, 2016; Calders et al., 2011; Naczk et al., 2021; Oviedo et al., 2014; Rimmer et al., 2004; Tsimaras et al., 2003). The interventions were commonly implemented in local community settings. No adverse events were reported in any of the studies for the interventions undertaken.

All studies reported their primary outcome data, including baseline and final VO_2peak values. Prior to analysis, the extracted data were examined using boxplots to identify outliers. The baseline outcomes were compared between the intervention and control groups to detect any potential data imbalance at baseline. In the research conducted by Kim (2017), the mean VO_2peak was significantly lower by over 2.0 ml/kg/min (95% CI [-3.1, -0.9], $p < .01$) in the intervention group compared to the control

group. Apart from this, no statistically significant difference were found between trial groups in other individual studies. Overall, all four outcomes did not demonstrate significant differences between trial groups at baseline.

In this random-effects meta-analysis, 12 comparisons between the intervention and control groups contributed to the calculation of the overall VO_2peak outcomes. The Forest Plot (Figure 2.2) summarise the effect estimates, 95% CI for each study, and the pooled results. After excluding the missing values and the second intervention from some studies, 360 participants were analysed. Overall, there was strong statistical evidence that the overall VO_2peak level after the interventions were concluded was, on average, significantly higher in the PA intervention group by 4.2 ml/kg/min (95% CI [2.2, 6.1], $p < .0001$, Cohen's $d = 0.8$) than in the control group. Furthermore, the effect size was large (Funder & Ozer, 2019; Sawilowsky, 2009), and the 95% CI did not include the null effect demarcation and was relatively narrow, suggesting that this finding is precise and clinically meaningful. Across all studies, statistical heterogeneity was observed ($I^2 = 63\%$, $p < .01$) but was not substantial.

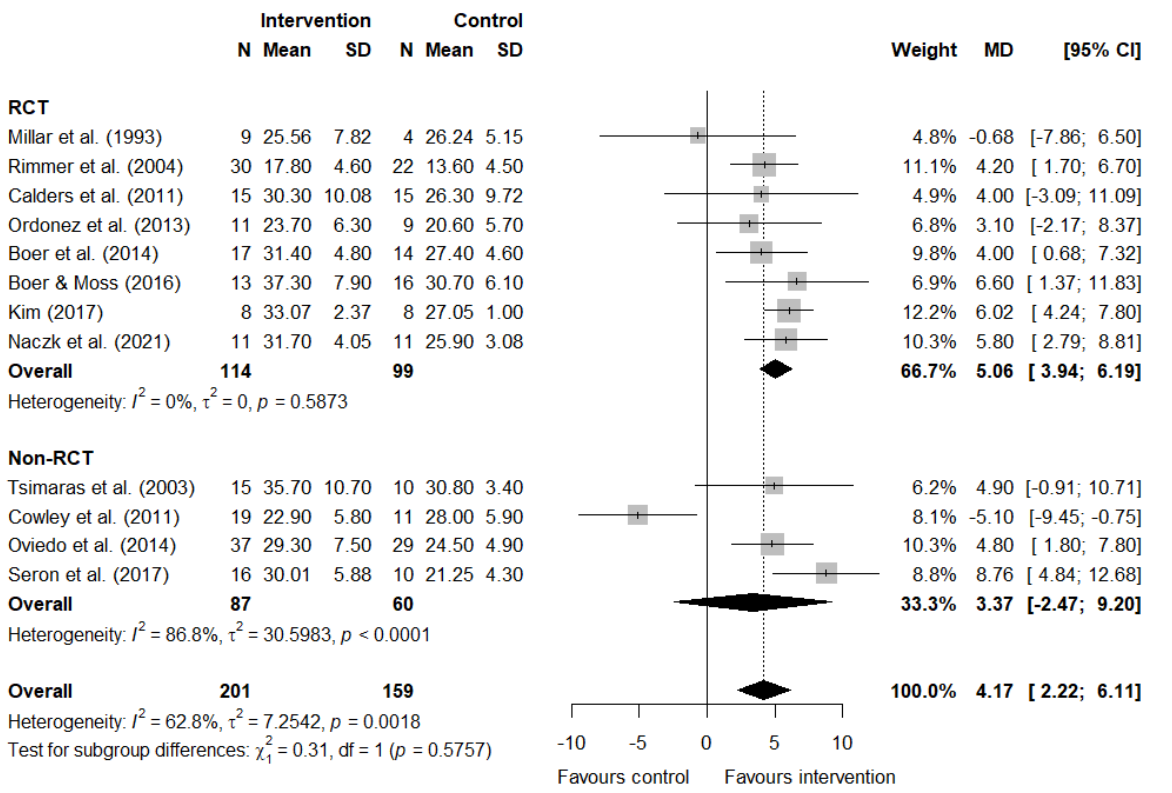

Figure 2.2. Forest plot of overall estimates for peak oxygen consumption by study design
Note. MD = mean difference. CI = confidence interval. Non-RCT = non-randomised controlled trial. RCT = randomised controlled trial.

Additional forest plots (Appendix 2-D) present the results for body composition variables. Nine studies contributed to the meta-analysis of body mass. The mean body mass in the intervention group was significantly lower by 4.3 kg (95% CI [2.9, 5.8], $p < .0001$, $d = 0.3$) compared to the control group. Seven studies provided BMI data. The mean BMI in the intervention group was significantly lower by 1.0 kg/m^2 (95% CI [0.5, 1.6], $p = .001$, $d = 0.3$) than in the control group. The mean body fat percentage, derived from six studies, was significantly lower in the intervention group by 3.8% (95% CI [1.9%, 5.6%], $p < .0001$, $d = 1.0$) compared to the control group. In these analyses, the *between-study* heterogeneities for these outcomes were not statistically significant (I^2 = 0.9-35.1%, $p > .05$). However, some additional information should be noted. Kim's (2017) study, which only involved male participants, contributed 77% to the overall summary of body mass (see Appendix 2-D, Figure 2-D.1). Ordonez et al.'s (2013) study, which only involved obese female participants, contributed 74% to the overall summary of BMI (see Appendix 2-D, Figure 2-D.2). After excluding these studies

from the meta-analysis, the overall effects did not demonstrate a statistically significant difference. Therefore, these results should be interpreted with caution.

Subgroup analyses for post-intervention VO_2peak were conducted based on study design (RCT versus non-RCT), mean age (teenager versus adult participant), exercise professional involvement (reported or not), and assessment of VO_2peak (treadmill versus cycle ergometer). The overall results for VO_2peak across these subgroups did not differ significantly. However, some findings may be informative. As illustrated in Figure 2.2, the RCTs presented consistent evidence of minimal variation between studies ($I^2 = 0$). The overall result of RCTs (*MD* = 5.1 ml/kg/min, 95% CI [3.9, 6.2], $p < .0001$, $d = 0.9$) was statistically significant, aligning with the general effect observed across all studies. In contrast, statistical heterogeneities among the non-RCTs were substantial ($I^2 = 87\%$, $p < .01$). The 95% CI for their overall effect [-2.3, 9.03] was broad and included the null effect demarcation. This may be attributed to one study (Seron et al., 2017) reporting the most significant effect in favour of the intervention, whereas another (Cowley et al., 2011) reported a remarkable result supporting the control group. Interestingly, these were the only two studies where participants were allocated to trial groups based on the researchers' judgment. Furthermore, as shown in Appendix 2-D (Figure 2-D.4), the effects were remarkably consistent in studies involving exercise professionals in the PA interventions ($I^2 = 0$), whilst the heterogeneity among the studies that did not report this information was substantial ($I^2 = 86\%$, $p < .01$). Insufficient data were available for a meaningful subgroup analysis for other variables.

Meta-regression analyses revealed no statistically significant associations between the pooled VO_2peak and the factors investigated. Sensitivity analyses were conducted by excluding certain studies from the meta-analysis, such as those with extreme values, high risk of bias, imbalanced baseline data, and missing participant data. These analyses did not identify significant changes in the pooled VO_2peak. Consequently, this meta-analysis included all studies.

The judgment of risk-of-bias assessments for each included study is presented in Table 2.3 for the eight RCTs and Table 2.4 for the four non-RCTs. The overall risk of bias was considered low for all

RCTs and moderate for all non-RCTs. The study by Kim (2017) was rated as high risk of bias due to its likely underestimation of the intervention's effect on improving VO_2peak. The primary concern for the eight RCTs was related to missing data, while the main source of bias for the four non-RCTs was the selection of participants. However, the sensitivity analyses indicated that these factors did not significantly alter the overall result of the meta-analysis. Therefore, the overall risk of bias for this systematic review was moderate.

Table 2.3. Judgement of risk of bias assessment for randomised controlled trials

Study	D1	D2	D3	D4	D5	Overall
Millar et al. (1993)	Low	Low	Some concerns	Low	Low	Some concerns
Rimmer et al. (2004)	Low	Low	Low	Low	Low	Low
Calders et al. (2011)	Low	Low	Low	Low	Low	Low
Ordonez et al. (2013)	Low	Low	Low	Low	Low	Low
Boer et al. (2014)	Low	Low	Some concerns	Low	Low	Some concerns
Boer and Moss (2016)	Low	Low	Some concerns	Low	Low	Some concerns
Kim (2017)	High	Low	Low	Low	Low	High
Naczk et al. (2021)	Low	Low	Low	Low	Low	Low

Note. Adapted from Page et al. (2021).
D = domain of bias. D1 = bias arising from the randomisation process. D2 = bias due to deviations from intended interventions. D3 = bias due to missing data. D4 = bias in measurement of outcomes. D5 = bias in selection of the reported result.

Table 2.4. Judgement of risk of bias assessment for non-randomised controlled trials

Study	D1	D2	D3	D4	D5	D6	D7	Overall
Tsimaras et al. (2003)	Low	Moderate	Low	Low	Low	Low	Low	Moderate
Cowley et al. (2011)	Moderate	Moderate	Low	Low	Low	Low	Low	Moderate
Oviedo et al. (2014)	Low	Moderate	Low	Low	Serious	Low	Low	Serious
Seron et al. (2017)	Moderate	Moderate	Low	Low	Low	Low	Low	Moderate

Note. Adapted from Page et al. (2021).
D = domain of bias. D1 = bias due to confounding. D2 = bias in selection of participants into the study. D3 = bias in classification of interventions. D4 = bias due to deviations from intended interventions. D5 = bias due to missing data. D6 = bias in measurement of outcomes. D7 = bias in selection of the reported result.

The Egger's analysis indicated no statistically significant evidence (p = .25) of publication bias in this meta-analysis. Furthermore, the symmetrical funnel plot (Appendix 2-E) also suggested a low risk of publication bias.

Under the GRADE approach (Atkins et al., 2004), the overall level of certainty of our findings for the primary outcome was rated as high because: (i) the pooled effect was calculated from the direct comparisons between intervention and control groups in the target populations; (ii) the effect magnitude was relatively large and precise; (iii) there was no obvious evidence suggesting plausible effect-confounding and -modifying factors; (iv) the risk of bias was not high; and, (v) the probability of publication bias was low.

2.4 Discussion

This systematic review and meta-analysis synthesised data from 12 studies that contrasted CRF outcomes between PA interventions and non-intervention comparators, examining the overall effects of PA on CRF among individuals with ID. Robust evidence supported the finding that VO_2peak levels were significantly higher by 4.2 ml/kg/min (95% CI 2.2 to 6.1) in individuals with ID who participated in PA than those who did not. No evidence supported significant differences in subgroup effects for VO_2peak based on age, study design, type of PA, or modalities used to measure VO_2peak. However, insufficient evidence was available to examine whether the overall effects varied by sex or PA dose. Although the secondary outcomes of interest were not reported in all studies, strong evidence indicated that participants in the intervention group significantly reduced their weight, BMI, and body fat compared to those in the control group (see Appendix 2-D). The overall improvement in VO_2peak was greater than 3.5 ml/kg/min, indicating a large effect magnitude (d = 0.8) that signals clinically significant importance (Ross et al., 2016).

Other than the evidence from the primary research outcome (VO_2peak) included in this systematic review, the findings of this study can be supported by comparing them with existing evidence for similar health outcomes in general populations or those with chronic health conditions, including individuals with ID. As detailed in Table 2.1, the major components of PA interventions comprised

aerobic activities, such as walking, running, jogging, and cycling, or a combination of aerobic and muscle-strengthening exercises. These are recommended for achieving CRF health benefits and are effective for maintaining overall health (American College of Sports Medicine & Pescatello, 2014; Ross et al., 2016). According to the ACSM's classification of PA intensity (American College of Sports Medicine & Pescatello, 2014), the intensity of these PA interventions would be considered moderate or vigorous. Particularly, those interventions that involved jogging, running, or swimming should be classified as vigorous intensity, thus meeting the dose-potency requirements in prescribing exercise for health efficacy and potentially yielding greater health benefits than those at a lower intensity for the population with ID (Physical Activity Guidelines Advisory Committee, 2018).

A key strength of this review is the relatively broad range of literature search strategies employed with minimal restrictions. Consequently, more studies were identified in this review than in previous systematic reviews on similar topics. This enabled undertaking subgroup and meta-regression analyses to gain deeper insights into the research question regarding the effects of PA on CRF. In particular, the sensitivity analyses indicated that some studies with extreme values or a high risk of bias had a negligible impact on the overall effect. Another strength is the minimal between-study heterogeneity ($I^2 = 0$) after excluding one study with extreme values (Cowley et al., 2011). With a very low risk of publication bias, the findings of this review were considered consistent and of high quality.

The magnitude of the effect for VO_2peak has significant clinical implications for disability service providers and policy development. In general, strong evidence suggests that an increase of 3.5 ml/kg/min (1 MET) is associated with a reduction of up to 30% in adverse events related to cardiovascular diseases and a 25% lower risk of all-cause mortality (Ross et al., 2016). Given the beneficial relationships between VO_2peak and these health outcomes, the findings of this review suggest that engaging in MVPA can lead to considerable health benefits. This can potentially alleviate the burden on the healthcare system and improve the health and quality of life for individuals with ID.

In practice and policy development, individuals with ID tend to have a lower VO_2peak than those without ID (Oppewal et al., 2013), making it an urgent health imperative to enhance their CRF to a higher level. On the other hand, individuals with ID likely engage in insufficient MVPA in their daily lives to achieve relevant health benefits (Dairo et al., 2016; Stancliffe & Anderson, 2017). Therefore, as recommended for the general population (Ross et al., 2016), monitoring and improving CRF in individuals with ID should be a standard part of disability and healthcare services. Healthcare professionals should prescribe PA to individuals with ID by referring to the interventions included in this review. Policymakers should strive to incorporate PA into disability services. To achieve these, monitoring VO_2peak (or a proxy) should be a regular service for individuals with ID.

As shown in the forest plot (Figure 2-D.4 in Appendix 2-D), the effects were highly consistent across studies that employed exercise professionals to deliver PA interventions. In contrast, the effects varied widely among the studies that did not report this information. Individuals with ID likely require support in their daily activities (Stancliffe & Anderson, 2017), let alone participating in MVPA. Understandably, exercise professionals can deliver PA programs as intended much more reliably than caregivers who may lack relevant knowledge and skills (Dixon-Ibarra et al., 2017; Heller et al., 2003). Therefore, it is genuinely necessary to promote this approach when developing a disability service policy, such as employing accredited exercise specialists and providing caregiver training. These can be essential requirements for disability service organisations and should be a focus of future research.

Further research should also investigate whether caregivers can be trained to develop the relevant skills for delivering PA programs as intended, given that they already provide everyday support to their clients with ID. Such services may prove to be more sustainable in the long term. This is important because the increase in CRF among individuals with ID gradually diminished over time after PA interventions ceased (Boer, 2018; Rosety-Rodriguez et al., 2014). As the subset data was insufficient to establish any findings related to age, sex, or PA dosage in this systematic review, future research should focus on these potential effect-modifying factors by including adequate subgroup data. Concerning closely related evidence (Physical Activity Guidelines Advisory Committee, 2018),

a dose-response relationship likely exists between PA dosage and changes in VO_2peak levels in individuals with ID, and thus should be explored in future studies.

This study had several limitations that constrained the findings. First, analysing the study design of the included articles was a significant source of limitations, as more information was required regarding the methods used to define the target sampling populations and sample sizes in nearly all studies reviewed. Second, the duration of the interventions in all studies was time-limited, ranging from 10 to 33 weeks. Long-term maintenance of improved CRF requires ongoing adherence to continued PA participation (Physical Activity Guidelines Advisory Committee, 2018). The studies reviewed do not address the feasibility and acceptability of such participation, which constitutes an important topic for future research and policy. Third, the sources from which participants were recruited included several schools and disability service organisations that could be reasonably considered small sampling frames, suggesting limited representativeness for the entire population with ID. Furthermore, the mean age of the study participants ranged from 14 to 44 years. In other words, the study participants mainly consisted of teenagers and young to middle-aged adults. These factors limited the representativeness of the study participants and reduced the generalisability of the findings.

The author expresses a caveat concerning the interpretation of the findings for clinical or community practice involving a broader population with ID. In a subsequent examination of the PA doses, another limitation identified was the lack of sufficient evidence to quantify the dose potency for the PA in the study interventions. The components of exercise prescription, such as weekly frequency, duration of each PA session, and PA intensity, were reported within a range that does not allow for precise quantification of potential dose-response benefits on CRF. The final limitation may be the absence of subset data, which could provide deeper insight into subgroups by sex and PA dose that likely influence VO_2peak changes differently. However, overall, the results of further analyses indicate that these limitations do not undermine the confidence in the findings from the quality assessment.

In conclusion, this systematic review provided compelling evidence that CRF levels are significantly higher in individuals with ID who engage in MVPA compared to those who do not. Furthermore, the overall effect size was substantial, suggesting clinically meaningful health benefits. Therefore, participation in MVPA should be a fundamental component of disability support services in clinical practice.

Declaration of interests

The authors declare that there are no conflicts of interest regarding this study.

Data Sharing

As a systematic review and meta-analysis, no primary data is shared.

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CHAPTER THREE

Physical Activity, Fitness, and Personal Characteristics of Australian Adults with Intellectual Disability

Abstract

Objectives: Personal factors of adults with intellectual disability (ID) are crucial for tailoring this population's physical activity (PA) interventions. This study sought to assess PA, physical fitness, and functional capacity levels in a cohort of Australian adults with ID to determine whether they experienced problems with low PA and fitness levels and their abilities to engage in moderate-to-vigorous intensity physical activity (MVPA). It also examined the relationships between MVPA and physical capacity measures, including physical fitness and functional walking capacity.

Methods: This study analysed the baseline data from an intervention- and community-based randomised controlled trial. Participants were adults with ID who led sedentary lifestyles and resided in group homes or other supported living facilities in Sydney. Outcomes included weekly time of being sedentary and/or performing PA (light, moderate, and vigorous intensity) assessed by accelerometry, maximal oxygen consumption (VO_2peak) on a cycle ergometer, muscle strength by isometric tests, and functional capacity via the 6-Minute Walk Test (6MWT). Multiple regression analysis was used to examine whether participants' MVPA level was associated with physical fitness and functional capacity.

Results: Of the 96 participants recruited, the mean age was 38.4 years (*SD* = 9.3), 55 (57%) were men, and 37 (39%) had Down syndrome. The mean body mass index (BMI) was 32 kg/m^2 (*SD* = 7.5), and 77 (82%) participants had a BMI ≥ 25 kg/m^2. Based on the average weekly time, participants spent 2718 minutes (*SD* = 1264) being sedentary, 1667 (792) on light PA, and 126 (122) on MVPA. Among all participants, 59 (77%) did not engage in vigorous PA, and 53 (69%) participated in MVPA less than 150 minutes weekly. The mean VO_2peak was 26.2 ml/kg/min (*SD* = 7.9). In the 6MWT, the mean distance was 541 metres (*SD* = 112). Means (*SD*) for other outcomes were 31.5% (10.4%) for body fat, 34.5 kg (15.9) for knee extension strength, 28.4 kg (9.6) for triceps extension strength, 35.5 kg (13.0) for biceps flexion strength, and 26.6 kg (14.0) for hand grip strength. Multiple regression identified that the time on MVPA significantly increased by 2.1 min/week (95% CI [0.3, 4.0], *p*

= .025) for every 1-kg increase in knee extension strength. Men had higher muscle strength than women, and women had higher body fat than men.

Conclusions: Australian adults with ID exhibited low levels of MVPA. They also face poor aerobic fitness and muscle strength. The majority were either overweight or obese. Although they had functional walking capacities similar to those of healthy adults, most did not engage in vigorous PA and spent most of their time inactive daily. This study demonstrated that most adults with ID could perform MVPA and complete physical assessments satisfactorily.

Funding: The Australian National Health and Medical Research Council (Partnership Project Grant: APP1012692) and two Australian disability service organisations (the Lorna Hodgkinson Sunshine Home and the House with No Steps) funded the project.

Registration: The International Standard Randomised Controlled Trial Number Registry (ISRC TN77889248).

3 Physical Activity, Fitness, and Personal Characteristics of Australian Adults with Intellectual Disability

3.1 Introduction

According to general theories for health promotion practice (U.S. Department of Health and Human Services, 2018), increasing participation in physical activity (PA) requires a long-term behaviour change, which is significantly influenced by personal factors. To this end, gathering personal data from a target population is crucial for promoting PA. This becomes particularly important for adults with intellectual disability (ID) who require support for their daily living activities (Stancliffe & Anderson, 2017). To assist adults with ID in engaging in more activities, Active Support (see Chapter 1 for further information) is a pragmatic approach (Flynn et al., 2018; Stancliffe et al., 2008). In promoting PA for individuals with ID, programs need to be tailored specifically to them (American College of Sports Medicine & Pescatello, 2014; Physical Activity Guidelines Advisory Committee, 2018). Since Active Support is a person-centred approach (Jones & Lowe, 2008), it likely provides high-quality support in customising PA for individuals with ID. However, a person-centred approach necessitates a detailed understanding of personal factors.

PA levels differ across various populations with ID. In their systematic review, Dairo et al. (2016) examined the PA levels of adults with ID. They uncovered a significant variation (ranging from 0% to 46%) among study participants who engaged in sufficient (≥ 150 min/week) moderate-to-vigorous intensity physical activity (MVPA). Likewise, Oppewal et al. (2013) reviewed 31 articles reporting the aerobic fitness of individuals with ID and also noted that the results of these studies varied widely in relative peak oxygen consumption, ranging from 22.7 to 49.5 ml/kg/min. Furthermore, the muscle strength and functional walking capacity of individuals with ID, which directly affect their ability to engage in PA, showed marked differences between studies, such as walking ability and handgrip strength (Boer & Moss, 2016; Calders et al., 2011). Notably, intervention-based evidence has been inconsistent regarding its effectiveness in increasing the PA levels of individuals with ID (Hassan et al., 2019). A potential reason for this may be that interventions were not sufficiently tailored to meet the specific needs of this population (Willems et al., 2018). If this is the case, the findings from

previous studies may not apply to a specific cohort of adults with ID, such as Australian adults with ID, when designing customised interventions for PA promotion. Consequently, gathering personal data from the target population with ID is vital for tailoring PA interventions prior to their development.

Factors influencing the PA participation of adults with ID may encompass various aspects, including environmental, social, and personal factors (Dixon-Ibarra et al., 2017; Stancliffe & Anderson, 2017; Westrop et al., 2024). This study focused on the personal factors related to PA capability in Australian adults with ID, such as PA levels, physical fitness, and functional walking capacity, which are crucial for performing the MVPA necessary to obtain health benefits (Physical Activity Guidelines Advisory Committee, 2018).

The PA levels of individuals with ID may correlate with personal factors. As highlighted in two previous studies, the PA levels of adults with ID were influenced by their levels of ID, age, gender, residence in care settings, and health status (Dairo et al., 2016; Stancliffe & Anderson, 2017). It was reported that the walking capacity of adults with ID residing in group homes was linked with their PA participation (Chow et al., 2018). Therefore, the relationships between PA and personal factors should be explored within a specific cohort of adults with ID to provide tailored considerations in developing feasible and sustainable interventions for this population.

This study examined the data collected during the baseline phase of the larger randomised controlled trial analysed in this thesis. The trial staff and researchers gathered these data from a cohort of Australian adults with ID. Further information can be obtained from the protocol (Appendix 1-A), which was previously published (Lante et al., 2014). This trial included a submaximal cycle ergometer exercise test, an isometric muscle strength test, and a 6-Minute Walk Test (6MWT) to gather physical fitness data, which required participation in MVPA during the tests, especially the aerobic fitness test. In Chapter 2 of this thesis, although most studies reviewed assessed the aerobic fitness of individuals with ID using a treadmill test (see Chapter 2, Table 2.1), some used a cycle

ergometer (Boer et al., 2014; Calders et al., 2011; Rimmer et al., 2004). This trial opted for a cycle ergometer instead of a treadmill to reduce potential risks and minimise refusals if the individual was apprehensive (e.g., they might fall). The cycle ergometer featured electronic resistance adjustment to assist the individual in maintaining a consistent cycling power output, making cycling easier for inexperienced riders. To further enhance safety and participant confidence, the chosen cycle ergometer was seated, equipped with a wide chair-like seat and backrest for greater comfort and safety, allowing the individual to avoid balancing on a traditional cycle saddle. Other tests were selected because they have been used in prior studies for similar purposes among individuals with ID. For instance, assessing muscle strength using a dynamometer (Calders et al., 2011; Rimmer et al., 2004), functional walking capacity via the 6MWT (Boer et al., 2014; Chow et al., 2018), and PA levels using an accelerometer (Chow et al., 2018).

The original trial assessed the PA levels, aerobic fitness, muscle strength, and functional walking capacity in a cohort of Australian adults with ID. The current study analysed the data to determine whether the participants encountered problems with low PA and fitness levels and whether they could perform MVPA and complete the physical assessments satisfactorily. It also examined the relationships between MVPA level and physical measures (fitness and functional capacity).

3.2 Methods

This study was a post hoc cross-sectional analysis of the baseline data collected during a randomised controlled trial of PA interventions in a community-resident ID population (see the protocol by Lante et al. (2014) in Appendix 1-A). The original trial was registered on the International Standard Randomised Controlled Trial Number Registry (ISRC TN77889248), approved by The University of Sydney Human Research Ethics Committee (HREC 05-2011/13821) (Appendix 3-A), and funded by the Australian National Health and Medical Research Council Partnership Grant (APP 1012692) and two disability service partner organisations (Lorna Hodgkinson Sunshine Home and House with No Steps). The funders had no role in the present study.

Outcome assessments were conducted in a research laboratory at The University of Sydney. To minimise potential underperformance due to unfamiliarity, a separate training session was scheduled to familiarise participants with the assessments, the assessors, and the test environments, thereby, strengthening the accuracy and validity of each assessment. The researchers in this study, who have prio experience and knowledge in working with adults with ID, collected data.

3.2.1 Participants

Participants were independently mobile adults with ID who could fully use their hands and arms. Their ages ranged from 19 to 54 years. They resided in group homes and other supported living facilities within the metropolitan areas of Sydney, Australia. Moreover, they each received regular disability service support from one of four disability service organisations. Interested participants were assessed for their safety and readiness to perform PA using the Physical Activity Readiness Questionnaire (PAR-Q) (Expert Advisory Committee of the Canadian Society for Exercise Physiology, 2002) or medical clearance when necessary. Written informed consent was collected from each participant, their guardian, or the person responsible (usually a family member). Participants were recruited on a rolling schedule.

3.2.2 Measurements

Participant characteristic data, including age, gender, living facility, overall health, and ID and Down syndrome diagnoses, were sourced from the records held by the disability service organisations.

The participants' sedentary and PA times were assessed using accelerometry (Actigraph GT1M/GT3X, Pensacola, FL, USA). With reminders and support from caregivers, the participants wore the accelerometer during waking hours for seven consecutive days except during water-based activities. The accelerometer collected data in activity counts per minute, which were used to categorise the activity into sedentary (< 100 counts/min), light (100 to 1951 counts/min), moderate (1952 to 5724 counts/min), and vigorous activities (≥ 5725 counts/min). The total time for each was accumulated in minutes per week (Chow et al., 2018; Freedson et al., 1998). This extensively researched device has proven to be pragmatic and valid in the PA and health fields (Plasqui &

Westerterp, 2007). Previous studies have also utilised it to assess the PA levels of adults with ID (Barnes et al., 2013; Chow et al., 2018).

According to the general PA guidelines (Bull et al., 2020; Physical Activity Guidelines Advisory Committee, 2018), adults should engage in at least 150 minutes of MVPA per week. This study combined the time spent on moderate and vigorous PA and used the guidelines to determine whether participants possessed sufficient (≥ 150 minutes) or insufficient (< 150 minutes) MVPA in their daily lives.

A multi-stage submaximal exercise test was conducted using a cycle ergometer to predict aerobic fitness. Previous studies have utilised similar tests to estimate peak maximal oxygen consumption (VO_2peak) in adults with ID or similar populations (Boer et al., 2014; Calders et al., 2011; Ohwada et al., 2005; Rimmer et al., 2004). During the test, participants engaged in three separate stages of seated leg cycling at incremental power outputs (Isokinetic Cycle Ergometer [Vision Fitness R2250] for wave one and Lode Corival 5.4.0 Recumbent Ergometer for waves two, three, and four), with workloads adjusted to achieve target heart rates of approximately 45%, 55%, 65% and 75% of age-adjusted peak heart rate. A heart rate monitor (Polar RS400 HR monitor) recorded steady-state heart rates. The power outputs and corresponding heart rates were used to predict maximal power outputs (Watt) based on age-adjusted maximum heart rates (American College of Sports Medicine & Pescatello, 2014). These values were subsequently converted to predict VO_2peak (ml/kg/min) using the ACSM's metabolic equations (American College of Sports Medicine & Pescatello, 2014). An expert in the field reviewed the data to exclude invalid VO_2peak data based on the heart rates and test duration. Appendix 3-B provides an example calculation for VO_2peak.

An expert examined the data from the submaximal exercise test for validity. The data were deemed invalid if an individual could not complete the test with sufficient intensity to raise their heart rate high enough to "predict" a peak value. Most often, the individual had an exercise heart rate of less

than 100 beats per minute or completed the test in less than three minutes. Since this test necessitates vigorous exercise, these criteria may cause challenges during the assessment.

Functional walking capacity was assessed using the 6MWT, which has been demonstrated to be both valid and reliable for adults with ID (Boer & Moss, 2016; Calders et al., 2011; Nasuti et al., 2013a). During the test, participants walked for six minutes at a self-selected, maximum walking pace along an approximate 40-metre square circuit consisting of flat, hard-surfaced corridors indoors. They were permitted to stop briefly if necessary. The outcome measured using a measuring wheel was the total distance (metres) walked during the test. A heart rate monitor (Polar, Port Washington, NY, USA) recorded heart rates each minute.

Isometric tests measured muscle strength using a dynamometer (Dell Intel Core i.5vPro), including peak handgrip strength, triceps extension strength, biceps flexion strength, and knee extension strength. Two trained assessors conducted the tests. Each test allowed the participant three attempts to achieve the highest score, and all results were displayed in kilograms. In previous studies, dynamometry was recommended and commonly used to assess muscle strength (Boer & Moss, 2016; Calders et al., 2011; Pitetti & Fernhall, 2005). For the handgrip strength assessment, participants used their dominant hand to hold each contraction for 3-5 seconds with a minimum of 30 seconds of recovery between each attempt. To assess knee extension strength, participants stood on a wooden board with their knees bent at 135 degrees and grasped the handles linked to the dynamometer with their hands. In assessing biceps flexion strength, participants were supine. They attached the wrist strap to the dynamometer, and then their forearm was at a 90-degree angle to the humerus with the forearm supinated towards their shoulder. In assessing triceps extension strength, participants were in a supine position. They attached the wrist strap to the dynamometer and aligned their forearm at a 90-degree angle with the forearm pronated towards their feet.

The Innerscan Body Composition Monitor (Tanita BC-541, Tsimshatsui East, Kowloon, Hong Kong) was used to estimate body fat (percentage). Participants' body mass and height were measured and

used to calculate their body mass index (BMI). Participants with a BMI ≥ 25 kg/m^2 were categorised as overweight or obese (Commonwealth of Australia, 2022).

3.2.3 Statistical Analysis

The sample size calculation was based on the different outcomes observed in the original trial, as described in the published protocol (see Appendix 1-A) (Lante et al., 2014). This study re-evaluated whether this sample size was appropriate for measuring PA levels. In prior studies included in a systematic review, the percentages of adults with ID who did not meet the PA guidelines ranged from 54% to 100% (Dairo et al., 2016). This study assumed that 70% of Australian adults with ID did not achieve 150 minutes of MVPA per week. With a precision level of 10% and a 95% confidence interval (CI), a sample size of 80 participants was required. Considering a 20% non-response rate, 96 participants were needed.

The trial data were managed and analysed using IBM SPSS Statistics (version 28). They were examined using statistical and visual methods to identify extreme values or outliers. Descriptive statistics were calculated for the following variables: age, gender, living facility, Down syndrome, BMI, body fat, duration of each activity category, VO_2peak, distance in the 6MWT, and muscle strength. Outcome data included means and standard deviations.

Multiple regression analyses were conducted to explore the relationships between PA levels and fitness variables while adjusting for age, gender, living facility, and Down syndrome. These variables were selected based on previous studies that indicated their influence on the PA levels of individuals with ID (Dairo et al., 2016; Stancliffe & Anderson, 2017). Means of outcome variables (PA, aerobic fitness, muscle strength, and functional walking capacity) were calculated by gender. The statistical significance level for differences was set at $p < 0.05$. Where significant differences were found, Cohen's d (d) was calculated as an effect size using the category descriptors of Funder and Ozer (2019) and Sawilowsky (2009) which were derived from Cohen (1988).

3.3 Results

Table 3.1. Characteristics of study participants

Characteristic	*n* (%)
Age (year) [a]	
n, Mean (*SD*)	94, 38.4 (9.3)
Gender	
Men	55 (57.3%)
Women	41 (42.7%)
Smoker	
Yes	5 (5.2%)
No	91 (94.8%)
Down syndrome	
Yes	37 (38.5%)
No	59 (61.5%)
Living facility	
Group home	50 (52.1%)
Other facilities	46 (47.9%)
BMI (kg/m^2) [a]	
BMI ≥ 25 [b]	77 (81.9%)
BMI < 25 [b]	17 (18.1%)
MVPA (min/week) [a]	
≥ 150	24 (31.2%)
< 150	53 (68.8%)
Vigorous PA (min/week) [a]	
= 0	59 (76.6%)
> 0	18 (23.4%)

Note. N = 96 participants at randomisation. BMI = body mass index. PA = physical activity. MVPA = moderate and vigorous PA.
[a] Missing value.
[b] BMI ≥ 25 kg/m^2 = overweight (Commonwealth of Australia, 2022).

Table 3.1 shows the participants' characteristics. This study recruited 55 men (57.3%) and 41 women (42.7%). Their mean age was 38.4 years (*SD* = 9.3). Five (5.2%) were smokers, 50 (52.1%) lived in group homes, 37 (38.5%) had Down syndrome, and 77 (81.9%) had a BMI of 25 kg/m^2 or higher. In their daily living activities, 53 (68.8%) participants did not achieve an MVPA level of 150 min/week, and 59 (76.6%) did not engage in vigorous PA.

Table 3.2. Measures of physical activity, functional walking capacity, and muscle strength [a]

Outcomes	*n*	Mean (*SD*)	95% CI
Body composition			
Height (cm)	94	159.8 (13.3)	[157.1, 162.5]
Weight (kg)	94	80.5 (21.9)	[76.1, 85.0]
BMI (kg/m^2)	94	31.5 (7.5)	[29.9, 33.0]
Body fat (%)	94	31.5 (10.4)	[29.3, 33.6]
Muscle strength			
Hand grip (kg)	87	26.6 (14.0)	[23.6, 29.5]
Triceps extension (kg)	85	28.4 (9.6)	[26.4, 30.5]
Biceps flexion (kg)	83	35.5 (13.0)	[32.7, 38.4]
Knee extension (kg)	82	34.5 (15.9)	[31.0, 38.0]
6-Minute Walk Test			
Distance (m)	94	540.6 (112.2)	[517.7, 563.6]
Aerobic fitness test			
Predicted maximal power output (W)	75	135.8 (57.8)	[122.5, 149.1]
VO_2peak (ml/kg/min)	74	26.2 (7.9)	[24.3, 28.0]
Accelerometry			
Accelerometer days [b]	77	5.7 (2.0)	[5.2, 6.1]
Sedentary behaviour (min/week)	77	2718 (1264)	[2431, 3005]
Light PA (min/week)	77	1667 (792)	[1488, 1847]
Moderate PA (min/week)	77	122.7 (115.0)	[96.5, 148.8]
Vigorous PA (min/week)	77	3.2 (13.6)	[0.1, 6.3]
MVPA (min/week)	77	125.8 (121.9)	[98.2, 153.5]

Note. *N* = 96 participants at randomisation. CI = confidence interval. BMI = body mass index. MVPA = moderate and vigorous PA. VO_2peak = maximal oxygen consumption.

[a] Data are raw means except for VO_2peak and 6-Minute Walk Test adjusted for age, sex, and body mass index.

[b] Values reflect the average number of days in the 7-day assessment during which accelerometer worked validly.

Table 3.2 presents the results of outcome assessments, including the number of participants who completed these assessments satisfactorily. One participant withdrew from the study for personal reasons. Missing values were noted in all outcome measurements: 19 for PA levels, 22 for aerobic fitness, 9 to 14 for muscle strength, 2 for functional walking capacity, and 2 for body composition assessments. In the assessments for aerobic fitness and muscle strength, the reasons for missing outcome data were primarily related to the individual's inability to perform the physical tasks

correctly, thereby generating invalid data or reluctance to comply with the assessment requirements. In the assessment for PA levels, participants failed to consistently wear the accelerometer for sufficient days to compute valid PA data, resulting in incomplete data for PA levels.

Sedentary Behaviour and Physical Activity

As shown in Table 3.2, on average, the accelerometer was worn and worked validly for 5.7 days (*SD* = 2.0) during the seven consecutive days of an assessment, presenting a total of 2718 min/week (*SD* = 1264, 95% CI [2431, 3005]) for sedentary behaviour, 1667 (792, 792, 95% CI [1488, 1847]) and 122.7 (115, 95% CI [96.5, 148.8]) for engaging in light and moderate PA respectively. The MVPA level was 125.8 min/week (121.9, 95% CI [98.2, 153.5]). Caregiver shortages were linked to the improper and inconsistent use of the accelerometer. This device needed to be worn throughout the day during routine activities. Caregivers were required to supervise and support participants for this to occur consistently, so missing accelerometer data often resulted from failure to wear the device consistently, which in turn was frequently due to inadequate caregiver supervision and support, particularly at home (e.g., in a group home). The accelerometer device had to be put on first thing in the morning, if not, it might remain unworn for the day (e.g., at a day service centre). One or two accelerometers were misplaced during the time with participants.

Aerobic Fitness

In the submaximal exercise aerobic fitness test, 74 participants provided valid data to calculate the VO_2peak after an expert examined the raw data and excluded invalid heart rate and power output data. Despite prior familiarisation and support during the testing protocol, some participants failed to meet the criteria for valid data (see Section 3.2.2 for more details). They may have had an insufficient ability to complete the physical tasks or understand the test requirements (e.g., sufficient high submaximal exercise effort), such as being unwilling or unable to pedal the bike at a suitably high intensity for longer than three minutes. These data were deemed invalid and thus were excluded, resulting in missing outcome data. Based on the valid data, the mean of predicted maximal power

outputs in the leg cycling exercises was 135.8 Watts (*SD* = 57.8, 95% CI [122.5, 149.1]), which corresponded to a mean VO_2peak of 26.2 ml/kg/min (*SD* = 7.9, 95% CI [24.3, 28.0]).

Functional Walking Capacity

Ninety-four participants completed the 6MWT satisfactorily. On average, participants walked 540.6 metres (*SD* = 112.2, 95% CI [517.7, 563.6]) during the test.

Muscle Strength

Most participants performed the physical tasks satisfactorily in these tests. However, some individuals were unable to achieve peak strength scores because they struggled to understand what a maximal effort entailed or were unwilling to comply sufficiently with the test requirements. The mean estimates were 26.6 kg (*SD* = 14.0, 95% CI [23.6, 29.5]) for peak dominant hand grip strength, 28.4 kg (*SD* = 9.6, 95% CI [26.4, 30.5]) for peak triceps extension strength, 35.5 kg (*SD* = 13.0, 95% CI [32.7, 38.4]) for peak biceps flexion strength, and 34.5 kg (*SD* = 15.9, 95% CI [31.0, 38.0]) for peak knee extension strength.

Body Composition

The mean BMI was 31.5 kg/m^2 (*SD* = 7.5, 95% CI [29.9, 33.0]), indicating an overweight or obese status for most participants (82%) (Commonwealth of Australia, 2022). The mean body fat percentage was 31.5 (*SD* = 10.4, 95% CI [29.3, 33.6]).

Relationships between Physical Activity and Other Factors

A multiple regression analysis was conducted to investigate the relationships between PA levels and various factors, including age, gender, living facility, Down syndrome, aerobic fitness, muscle strength, and functional walking capacity. The analysis revealed that time spent in MVPA increased significantly by 2.1 minutes per week (95% CI [0.3, 4.0], $p = .025$, $r = 0.3$) with each 1-kg increase in

peak knee extension strength. The effect size was large (Funder & Ozer, 2019; Sawilowsky, 2009). No other significant relationships between PA and the other factors were identified.

Outcomes by Gender

Women exhibited 8.8% higher body fat (95% CI [4.3%, 13.4%], $p < .001$, $d = 0.8$) than men. In comparison to women, men demonstrated greater peak hand grip strength by 7.7 kg (95% CI [1.7, 13.7], $p = 0.012$, $d = 0.6$), peak triceps extension strength by 8.6 kg (95% CI [4.8, 12.3], $p < .001$, $d = 1.0$), peak biceps flexion strength by 11.3 kg (95% CI [6.4, 16.1], $p < .001$, $d = 1.0$), and peak knee extension strength by 12.3 kg (95% CI [5.7, 19.0], $p < .001$, $d = 0.8$). No other outcomes showed significant differences by gender.

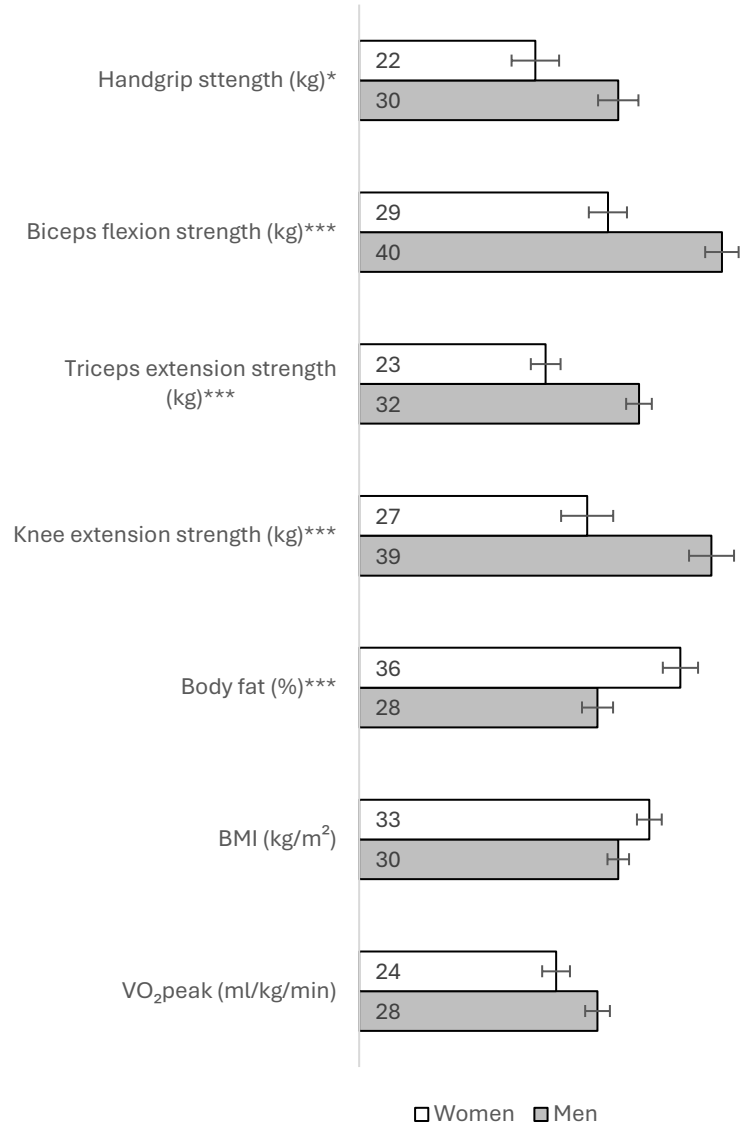

Figure 3.1. Means (*SE*) of aerobic fitness, muscle strength, and body composition by gender
Note. Data are means and standard errors estimated from linear mixed models adjusted for age and body mass index. MVPA = moderate and vigorous physical activity. BMI = body mass index. VO_2peak = maximal oxygen consumption. 6MWT = 6-Minute Walk Test.
*$p < .05$. ***$p < .001$.

Other results

Some outcome data showed statistically extreme values and outliers, including sedentary time, MVPA level, VO_2peak, 6MWT distance, and muscle strength. For instance, an individual participant engaged in 648 minutes of MVPA per week. Nevertheless, these values were deemed plausible and were therefore included in the analyses. No adverse events were reported during any of the assessments.

3.4 Discussion

This study aimed to gather local data regarding PA from a cohort of Australian adults with ID. Its findings evaluated whether the study participants fell well below recommended PA levels and could, therefore, benefit from the proposed interventions in the controlled trial. The findings indicated that participants engaged in insufficient PA daily, with the majority not participating in vigorous PA. On average, during their waking hours, participants spent 6.5 hours in sedentary behaviours, four hours in light PA, and only 18 minutes in MVPA daily. According to the ACSM's fitness categories (American College of Sports Medicine & Pescatello, 2014), the study population exhibited poor aerobic fitness and muscle strength. MVPA levels showed a positive correlation with peak knee extension strength but were not significantly associated with other factors and did not vary by gender. Despite a shortage of caregivers and participants' limited abilities in performing and understanding test requirements, which resulted in missing outcome data, most participants were able to complete the physical assessments with support and training, indicating that these assessments are feasible for this population. Based on the number of participants who satisfactorily completed the physical assessments, the best performance was observed in the 6MWT, while the results for other assessments, such as the submaximal exercise test, were significantly lower. The primary reason for this was that participants better understood and complied with the requirements for 6MWT than those for the other assessments.

The study population exhibited issues related to their low PA levels. Only 31% of participants engaged in sufficient regular MVPA to meet the ACSM guidelines (see Section 3.2.2), which fell within the reported percentage range (0-46%) for similar populations with ID included in Dairo et al.'s (2016) systematic review. However, this percentage was considerably lower than that of other Australian adults. In Victoria, approximately 54% of adults with ID aged 18 to 39 years achieved a sufficient MVPA level, and 49% of those aged 40 to 59 years did so (Victorian Department of Health and Human Services, 2015). Moreover, around 62% of the Victorian population undertook adequate MVPA (Victorian Department of Health and Human Services, 2016). An insufficient level of PA is one of the leading risk factors for diseases and health problems in individuals with ID and the general

population (Abbasi-Kangevari et al., 2020; Victorian Department of Health and Human Services, 2015). These findings suggest an inequity in health between the studied population and other adult populations, including those with ID, as well as the broader community residing in various regions of Australia. Additionally, participants' activities included four hours of light PA and 6.5 hours of sedentary behaviour on a typical day. These figures were comparable to the daily activities of adults with ID residing in group homes: less than ten minutes spent on MVPA, nearly four hours on light PA, and over eight hours on sedentary behaviour (Chow et al., 2018). Although there is insufficient evidence supporting a dose-response relationship between sedentary time and health problems (World Health Organization, 2020), sedentary behaviour is associated with serious health issues, such as all-cause mortality and cardiovascular diseases (Park et al., 2020; Wu et al., 2022). Furthermore, light PA is insufficient to benefit individuals' health (Physical Activity Guidelines Advisory Committee, 2018). Therefore, this study has confirmed the low PA levels among adults with ID in Sydney, highlighting a serious problem that requires urgent interventions to improve these levels.

The study participants demonstrated sufficient functional capability to potentially engage in more MVPA. The functional capacity assessment yielded encouraging results, indicating that the walking distance of 541 metres in the 6MWT closely aligned with the 570-metre distance typically observed in healthy adults (Casanova et al., 2011). This suggests that the study population possessed sufficient physical capability to engage in PA. The results from this study's 6MWT were consistent with previous studies of adults with ID (Boer & Moss, 2016; Calders et al., 2011) or better than those conducted in Hong Kong (434 metres) (Chow et al., 2018), in Canada (approximately 430 metres) (Casey et al., 2012), and in another region (around 445 metres) (Obrusnikova et al., 2021). Furthermore, the participants in the two prior investigations (Boer & Moss, 2016; Calders et al., 2011) possessed similar levels of aerobic fitness and muscle strength to those in the current study, indicating their ability to engage in MVPA.

A limitation of this study was its narrow representation of the population. It specifically focused on adults with ID living in group homes and possessing adequate physical mobility. In other words,

individuals living with family members and those with physical disabilities were excluded. A second limitation was the incomplete assessments, which resulted in missing outcome values for some participants. This primarily occurred because some participants were unable to complete the physical tasks involved in an assessment. Furthermore, caregiver shortages were also associated with missing data for PA levels, as mentioned previously.

The findings of this study offer valuable insights for promoting PA participation among the study population, which engages in nearly four hours of light PA daily. While these routine activities are sustainable, they do not provide sufficient intensity. This presents a dilemma between sustainability and intensity in the promotion of PA for adults with ID (Stanish & Draheim, 2007; Temple et al., 2000). One potential solution is to enhance the intensity of light PA to meet the MVPA recommendations without altering the daily living activities of adults with ID. Previous studies have shown that adults with ID can achieve this with suitable support and training (Marconi et al., 2018; Obrusnikova et al., 2021). In this study, most participants demonstrated the physical capability to engage in MVPA with assistance and training provided during familiarisation sessions. Moreover, the observed gender differences in muscle strength and the positive correlation between MVPA and leg extension strength enable the tailoring of PA interventions for the study population. Further work is required to examine the effectiveness and feasibility of this lifestyle approach in the PA promotion of adults with ID.

The issue of incomplete assessments is significant for future research. Presenting incomplete outcome data in evaluating PA and fitness among adults with ID may be a common challenge (van Schijndel-Speet et al., 2017). The reasons for incomplete assessments may include behavioural problems, health issues, motivation to comply with or continue performing assessments, logistic problems, and the number of consecutive days required for an assessment (van Schijndel-Speet et al., 2017). Other reasons may be linked to the risk and fear associated with a physical task (e.g., the possibility of falling) and the refusal or inability of individual participants to perform a physical task (Rimmer et al., 2004). Some of these challenges were encountered in the current study. Therefore, upcoming studies

should comprehensively investigate pertinent assessments in these areas. For instance, the 6MWT may be used to evaluate aerobic fitness (American College of Sports Medicine & Pescatello, 2014). The 6MWT has been used to predict the VO_2peak of healthy adults (Mänttäri et al., 2018), patients with cardiopulmonary disorders (Ross et al., 2010), and adults with ID (Nasuti et al., 2013b). Given that almost all the participants in this study demonstrated satisfactory results on the 6MWT, further research should be undertaken to evaluate its validity in predicting VO_2peak within the study population.

In conclusion, this study highlights a significant issue of insufficient PA among a physically capable cohort of Australian adults with ID. This underscores the necessity for an intervention study aimed at increasing PA levels. Furthermore, this study revealed that most participants could complete the MVPA-related assessments satisfactorily with appropriate familiarisation training and support. Given the comparable evidence in physical fitness and capability from previous studies, the population involved in this study can engage in MVPA, which may serve as a pragmatic approach to developing lifestyle PA interventions based on their routine daily activities.

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The author of this thesis analysed the data from a randomised controlled trial (Lante et al., 2014). The views expressed are those of the current author and not necessarily those of the trial researchers.

Declaration of interests

The authors declare no competing interests.

3.5 References

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CHAPTER FOUR

Effect of Exercise Combined with Caregiver Training on the Physical Activity Level of Adults with Intellectual Disability: A Randomised Controlled Trial

Abstract

Objectives: Currently, there is no compelling intervention for increasing the physical activity (PA) of adults with intellectual disability (ID) to a level that promotes improved health. This study incorporated exercise specialists and caregiver training into lifestyle physical activity (LSPA) and structured exercise (STEX) interventions to encourage PA participation among adults with ID. It sought to investigate whether these two interventions were effective, feasible, and sustainable in increasing and maintaining their PA levels in the short and longer term, while quantifying changes in PA participation. Additionally, it examined whether either of the two interventions had better feasibility and sustainability.

Methods: This three-arm randomised controlled trial was conducted in a community setting, comparing the two interventions (LSPA and STEX) with the non-PA usual care (Control). The participants were physically capable adults with ID, recruited from four local disability service organisations and randomly allocated to each group. The 12-week LSPA and STEX interventions included 150 minutes of moderate-to-vigorous PA per week. The LSPA was tailored individually for participants, with exercise specialists providing support for 60 minutes of LSPA participation each week. Caregivers supported the participants for the remainder of the time. The STEX was delivered thrice weekly by exercise specialists through small group classes. During the intervention periods, exercise specialists trained caregivers to deliver the interventions. The Control group continued their usual daily activities without engaging in additional PA. Mean PA levels were assessed at baseline, three months post-baseline, and nine months post-baseline and were expressed as metabolic equivalents minutes per week (MET-min/week). Comparisons between and within trial groups were performed using linear mixed-models analysis.

Results: Ninety-six randomly allocated participants were equally divided among the three trial groups. Fourteen participants were withdrawn during the study. Compared to the Control group after the first three months of intervention, the mean PA level was significantly higher by 857 MET-

min/week (95% CI [219, 1496], p = .01, Cohen's d = 0.8) in the LSPA group and by 733 MET-min/week (95% CI [80, 1387], p = .029, d = 0.7) in the STEX group. Within the LSPA group, the mean PA level was significantly higher from baseline by 602 MET-min/week (95% CI [245, 960], p = .001, d = 0.5) at three months and by 621 MET-min/week (95% CI [60, 1182], p = .031, d = 0.5) at nine months. For the STEX group, it was significantly higher by 601 MET-min/week (95% CI [166, 1037], p = .008, d = 0.6) at three months only. The mean PA levels in the Control group remained unchanged throughout the trial.

Conclusions: The findings indicate that LSPA and STEX significantly improved the PA levels of adults with ID. The LSPA approach showed greater feasibility and sustainability over time. The effect size was moderate, and the observed increases in PA were clinically meaningful. Moreover, this authentic research has demonstrated that caregiver training is effective and practical in disability service practice, suggesting that policymakers should consider integrating these two interventions into routine disability services provided to adults with ID.

Funding: The funding sources were the Australian National Health and Medical Research Council (Partnership Project Grant: APP1012692) and two Australian disability service organisations (the Lorna Hodgkinson Sunshine Home and the House with No Steps).

Trial registration: This study was registered with the International Standard Randomised Controlled Trial Number Registry (ISRCTN77889248) on April 18, 2012.

4 Effect of Exercise Combined with Caregiver Training on The Physical Activity Level of Adults with Intellectual Disability: A Randomised Controlled Trial

4.1 Introduction

Engaging in sufficient physical activity (PA) is widely recognised as an essential factor that contributes to numerous benefits for population health (Physical Activity Guidelines Advisory Committee, 2018). Many researchers have reported that participating in adequate PA regularly can also be advantageous for the health of individuals with intellectual disability (ID), such as improving aerobic fitness and blood pressure (Moss, 2009), enhancing balance, muscle strength, and overall well-being (Carmeli et al., 2005), and reducing depressive symptoms (Carraro & Gobbi, 2014), and inappropriate behaviours (Borland et al., 2022; Elliott et al., 1994). Conversely, insufficient PA has been estimated to be one of the top five risk factors for death, significantly contributing to the global health burden (World Health Organization, 2009). However, reports indicate that over 90% of adults with ID may be either wholly sedentary or not engaging in sufficient PA (Dairo et al., 2016), which is notably higher than the proportions seen in the general population (Bauman et al., 2009; Stancliffe & Anderson, 2017). Consequently, adults with ID may face an increased risk of chronic health issues or diseases, such as obesity and hypertension (Schroeder et al., 2020). Increasing PA can be a crucial and practical step for adults with ID to achieve significant health benefits.

It is challenging to consistently engage adults with ID in suitable PA programs, such as lifestyle physical activity (LSPA) or structured exercise (STEX) programs (see the definitions in the next section). Two systematic reviews have revealed a lack of compelling evidence for effective and sustainable interventions to increase the PA level of individuals with ID (Hassan et al., 2019; Katie et al., 2015). For improving health, the intensity of PA is crucial (Physical Activity Guidelines Advisory Committee, 2018). For instance, while individuals with ID may participate in LSPA, its intensity often falls short of what is necessary to achieve the desired health benefits (Temple et al., 2000). PA programs must possess an appropriate volume and intensity to ensure that individuals with ID can accept and engage in them, allowing their caregivers to provide long-term support. In their daily lives,

adults with ID often require assistance from caregivers (Stancliffe & Anderson, 2017). However, caregivers' skills and knowledge in promoting PA are limited (Dixon-Ibarra et al., 2017; Heller et al., 2003; Michalsen et al., 2024). Hence, addressing these gaps is crucial for increasing and sustaining PA levels (Westrop et al., 2024). To the best of this author's knowledge, no existing research has focused on training caregivers to promote PA among adults with ID. Furthermore, there is scant evidence regarding which types of PA are more feasible and sustainable for this population.

Active Support is a powerful technique that can enhance participation in functional activities among adults with ID and simultaneously equip caregivers with the skills needed to facilitate such participation (Mansell et al., 2002; Stancliffe et al., 2008). It focuses on helping adults with ID engage in activities using authentic materials in real-world settings and provides on-site training for caregivers to assist their clients (Stancliffe et al., 2008). Although previous research has demonstrated that Active Support successfully increased activity participation among Australian adults with ID living in group homes (Clement & Bigby, 2008; Stancliffe et al., 2007), its application in research promoting PA within this population has not yet been explored.

Active Support was one of the critical intervention components in this study, along with employing accredited exercise specialists and caregiver training to promote PA among adults with ID. Further details about Active Support can be found in Chapter 1 (Tables 1.1 and 1.2) and Chapter 7 of this thesis. This study conducted a retrospective analysis to investigate whether Active Support combined with LSPA or STEX programs could increase the PA levels of adults with ID in the short and longer term. It also compared the two approaches to identify which was more feasible and sustainable.

4.2 Methods

4.2.1 Study Design

This three-arm randomised controlled trial was conducted in Sydney, Australia. This report adhered to the guidelines of the Consolidated Standards of Reporting Trials Statement (Moher et al., 2010). The study was registered with the International Standard Randomised Controlled Trial Number Registry

(ISRCTN77889248) and obtained ethics approval (Appendix 3-A) from The University of Sydney. The study protocol (Appendix 1-A) had been published previously (Lante et al., 2014). The current study expressed the PA level as metabolic equivalent (MET) minutes per week (MET-min/week). One MET represents the metabolic level under resting conditions derived from population data and is equivalent to approximately 3.5 ml/kg/min of oxygen consumption (American College of Sports Medicine & Pescatello, 2014). According to a scientific report (Physical Activity Guidelines Advisory Committee, 2018), the threshold level for obtaining PA-related health benefits is to accumulate 500 MET-min/week (or 150 minutes per week) of moderate-to-vigorous physical activity (MVPA). Moderate PA requires 3-6 METs, while vigorous PA requires six or more METs of exercise intensity (American College of Sports Medicine & Pescatello, 2014).

The participants were initially recruited from two disability service organisations in Sydney involving over 3000 adults with ID who lived in disability housing and/or attended day program centres or sheltered workshops. When insufficient participants were available from the first two disability service organisations, two additional partner organisations were brought in to achieve the intended sample size. Eligible participants were adults with ID aged 19 to 54 years, who had been sedentary for the past 12 months or longer and could attempt to participate in the required PA and assessments. The study participants referred to the research by the four organisations were screened for PA suitability using scientific tools, and, if necessary, written approval from a medical practitioner was obtained. Those who were not suitable were excluded. After discussing the consent content, all participants or their guardians provided signed informed consent. The trial protocol (Appendix 1-A) offers more details about participant selection (Lante et al., 2014).

The trial utilised a random number generator to allocate participants among the three trial groups on a rolling schedule. This trial did not employ blinding, as the interventions were observable, and all outcomes were measured objectively using well-established and standardised assessments, including the International Physical Activity Questionnaire – Intellectual Disability (IPAQ-ID) (Lante, 2007) and the 6-Minute Walk Test (6MWT) which was previously used in research for adults with ID

(Chow et al., 2018). Additional information regarding the measurements can be found in the study protocol (Appendix 1-A) (Lante et al., 2014). Outcome assessments were conducted by research staff who delivered the intervention. Based on the data collected by the trial researchers, the current author of this thesis performed retrospective analyses.

The Control participants maintained their usual lifestyle without engaging in additional PA. The other participants were assigned to one of two interventions, either moderate-intensity LSPA or moderate-to-vigorous-intensity STEX. The Active Support technique was employed in both interventions to facilitate participation in PA (Stancliffe et al., 2008). Over the 12-week intervention period, accredited exercise specialists from The University of Sydney provided in-person support and training to participants and caregivers. The LSPA programs were individualised for each individual based on their routine activities and interests, such as walking for transport, swimming, jogging, gardening, and exercising during television advertisement breaks. Of the 150 minutes of LSPA per week, exercise specialists supervised 60 minutes, while the remaining 90 minutes were administered independently by caregivers. The STEX sessions occurred thrice weekly in local community settings, involving small groups with three to six participants. Each weekly STEX session consisted of 30 to 45 minutes of cardiovascular exercises and 15 to 20 minutes of muscular strength exercises, including brisk walking, jogging, and callisthenics. Exercise specialists delivered all three sessions of the STEX. All STEX participants were monitored using a multi-sensor armband and heart rate monitor during the interventions. Caregivers maintained daily logs to record the time of the participant's involvement in the interventions. This data was used to estimate intervention compliance, which in this study was defined as the total time (in minutes) spent performing PA interventions each week divided by the planned 150 minutes and expressed as a percentage. As previously mentioned, further details about the interventions can be obtained from the published protocol (Appendix 1-A) (Lante et al., 2014). After the interventions incorporating the Active Support component concluded, caregivers independently continued to support the LSPA and STEX for a six-month follow-up period without the involvement of exercise specialists.

4.2.2 Outcomes

The primary trial endpoint was the mean PA level assessed at three months post-baseline. Using the IPAQ-ID through proxy responses from caregivers (Lante, 2007), PA levels were assessed at baseline, three months post-baseline, and nine months post-baseline. Each specific type of PA was assigned a MET value based on its intensity, allowing for the estimation of cumulative METs from various types of PA to represent an average PA level. Further details regarding the MET values and calculation methods can be found in Appendix 4-A. The mean PA level at nine months post-baseline served as the secondary outcome, reflecting the longer-term effects of the interventions supported by caregivers independently. These results demonstrate the feasibility and sustainability of the interventions in both the short and longer term. The changes in PA levels from baseline within trial groups and the comparisons of PA levels between trial groups revealed the effects of exercise programs combined with the Active Support approach on enhancing PA levels.

4.2.3 Statistical Analysis

The sample size was estimated based on previous research findings (Rimmer et al., 2004), which reported substantial improvements in aerobic fitness for a 12-week cardiovascular and strength exercise intervention compared to controls (Cohen's $d = 0.9$). Assuming a conservative effect size ($d = 0.8$) with a significance level of 0.05 and 95% power, this three-arm trial required a total sample size of 69 participants with 23 participants per trial group. With a preference for conservative assumptions (e.g., a smaller effect size and 20% loss to follow-up), each group required 30 participants resulting in a total sample size of 90 (Appendix 1-A) (Lante et al., 2014). However, this study recruited 96 participants with 32 participants per trial group.

Data were analysed using linear mixed models (LMM) in IBM SPSS Statistics software (version 28). The LMM estimated the means while adjusting for age, sex, and body mass index. The mean differences between various measurement points within a trial group and the mean differences between trial groups at the same measurement point were tested for statistical significance. Where significant differences were found, Cohen's d (d) was calculated as an effect size using the category

descriptors of Funder and Ozer (2019) and Sawilowsky (2009) derived from Cohen (1988). Subgroup analyses were planned to examine the potential effects of personal characteristics and environmental factors, adjusting for age, sex, Down syndrome, sitting time measured by IPAQ-ID, and body mass index (BMI). As the number of participants in each trial group was relatively small, one or two variables were included in the LMM each time to assess their significance.

4.2.4 Roles of the Partner Disability Agencies

The roles of the participating disability agencies were essential in implementing the Active Support paradigm as applied to PA promotion in this study. They acted as integrated research partners and engaged deeply in co-designing the interventions and managing the implementation. This strategy helped ensure that trial participants accepted and could undertake the interventions effectively. The Australian National Health and Medical Research Council funded the trial but had no role in its implementation.

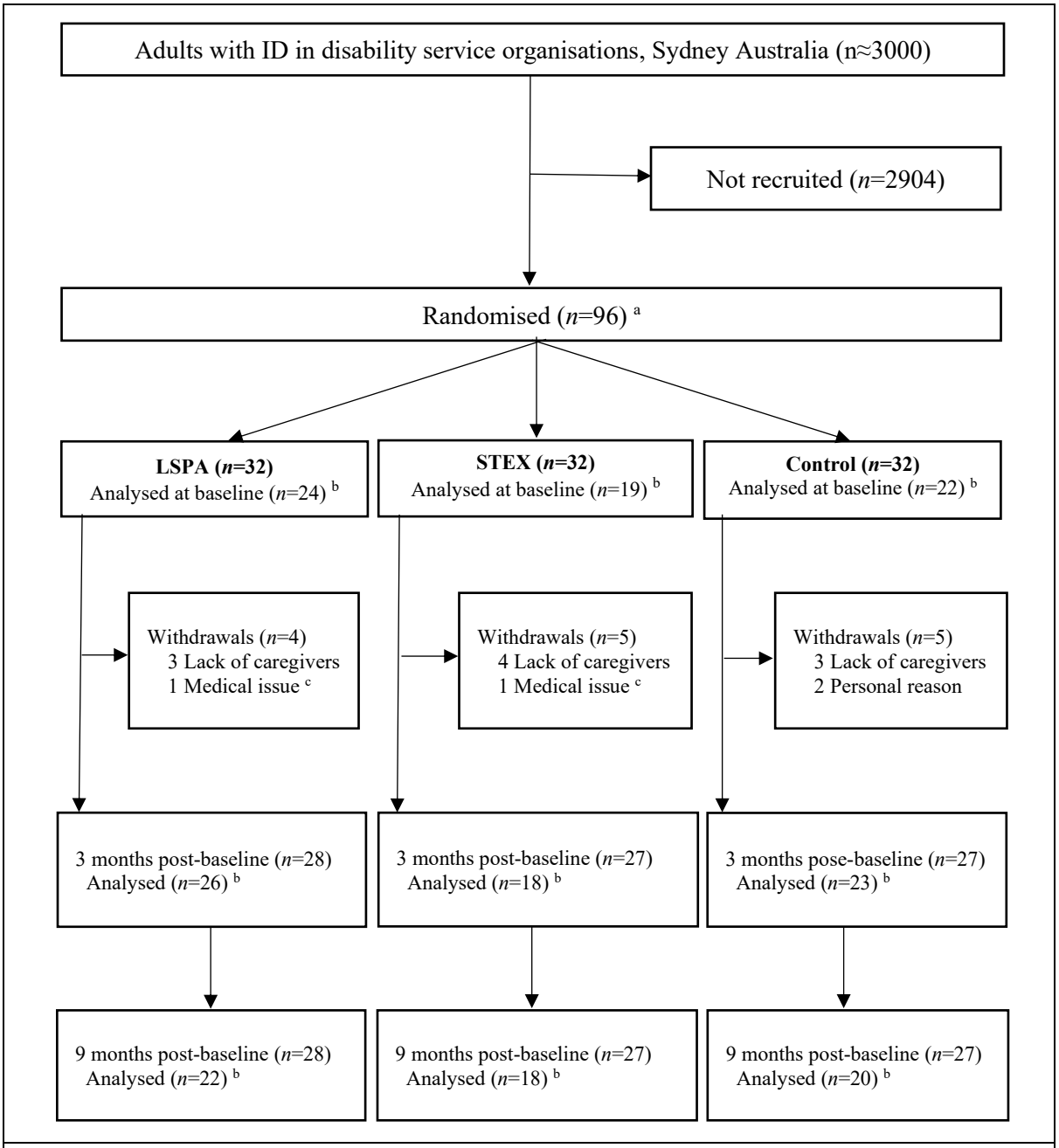

Figure 4.1. Participant flow diagram

Note. ID = intellectual disability. LSPA = lifestyle physical activity group. STEX = structured exercise group. Control = usual care group.

[a] Number of participants exceeded the calculated sample size of 90.

[b] Missing cases mainly due to incomplete or poor-quality data.

[c] Withdrawal due to a medical issue unrelated to participation in the trial.

4.3 Results

Between August 2011 and November 2013, of the 96 participants randomised, as shown in the participant flow diagram (Figure 4.1), 14 (15%) withdrew from the trial. Most of the withdrawn participants came from the same organisation. The main reason for withdrawal was the lack of caregivers to support client participation. Missing outcome data were observed for each outcome at every measurement time point. Other than withdrawals, the primary source for missing data was incomplete and poor-quality assessments. For example, a caregiver could not respond to an IPAQ-ID item for vigorous PA, leading to missing data for vigorous PA and, consequently, for MVPA (the sum of moderate and vigorous PA). This resulted in the number of participants analysed varying at each measurement time point. Furthermore, some participants had missing outcome data across one or two of the three outcome assessments, resulting in an unbalanced number of cases with valid data. Nevertheless, these participants were included in the LMM analyses.

Baseline characteristics were measured before randomisation, as illustrated in Table 4.1. There were no statistically significant differences between trial groups at baseline. Some variables had missing values, including age, BMI, PA levels, and 6MWT distance. Overall, the mean age of the study participants was 38.4 years (*SD* = 9.3). Of the 96 participants, 55 (57%) were men, 50 (52%) resided in group homes, 37 (38.5%) had Down syndrome, and 77 (81%) had a BMI of 25 kg/m^2 or higher, indicating that they were overweight or obese (Commonwealth of Australia, 2022).

On average, the MVPA level was 612 (*SD* = 1061) MET-min/week. Nearly 70% of the participants did not meet the threshold (500 MET-min/week) for sufficient PA (Physical Activity Guidelines Advisory Committee, 2018). They spent an average of nearly eight hours sitting and 22 minutes walking each day. An issue with using the MVPA level was the wide range of volumes from a minimum of zero to a maximum of 6030 MET-min/week, resulting in a mean higher than 500 MET-min/week with a considerable standard deviation. However, the prevalence of participants with low levels of MVPA is consistent with that assessed using an objective assessment (see Chapter 3 for further information).

Table 4.1. Demographic and physical characteristics of the participants at baseline

	Control (n = 32)	**LSPA** (n = 32)	**STEX** (n = 32)	**Overall** (N = 96)
Age (year) [a]				
Mean (*SD*)	40.3 (9.4)	38.4 (9.5)	36.6 (8.9)	38.4 (9.3)
Range	21 to 54	19 to 54	19 to 50	19 to 54
Gender				
Female	16 (50%)	11 (34.4%)	14 (43.8%)	41 (42.7%)
Male	16 (50%)	21 (65.6%)	18 (56.3%)	55 (57.3%)
Living facility				
Group home	18 (56.3%)	18 (56.3%)	14 (43.8%)	50 (52.1%)
Other types	14 (43.8%)	14 (43.8%)	18 (56.3%)	46 (47.9%)
BMI (kg/m^2) [a]				
Mean (*SD*)	30.7 (7.9)	32.3 (8.3)	31.4 (6.4)	31.5 (7.5)
< 25.0 [b]	8 (25.8%)	5 (15.6%)	4 (12.9%)	17 (18.1%)
≥ 25.0 [b]	23 (74.2%)	27 (84.4%)	27 (87.1%)	77 (81.9%)
Down syndrome				
Yes	14 (43.8%)	13 (40.6%)	10 (31.3%)	37 (38.5%)
No	18 (56.3%)	19 (59.4%)	22 (68.8%)	59 (61.5%)
Smoker				
Yes	1	1	3	5 (5%)
No	31	31	29	91 (95%)
PA levels [a, c] [Mean (SD)]				
Time sitting (min/week)	3523 (1406)	3176 (1313)	3310 (1023)	3326 (1245)
Time walking (min/week)	142 (254)	147 (136)	171 (201)	153 (201)
MVPA (MET-min/week)	615 (988)	657 (1087)	534 (999)	612 (1061)
MVPA < 500 [d]	17 (77.3%)	14 (58.3%)	14 (69.2%)	45 (69.2%)
MVPA ≥ 500 [d]	5 (22.7%)	10 (41.7%)	5 (30.8%)	20 (30.8%)
6MWT distance (m) [a]				
Participants	31 (97%)	32 (100%)	31 (97%)	94 (98%)
Mean (*SD*)	533 (89)	565 (108)	525 (131)	541 (112)

Note. Data are means (*SD*) or *n* (%) unless otherwise indicated. *N* = sample size (96) at randomisation. Data are raw means except for MVPA (MET-min/week) and 6MWT distance, which were estimated from linear mixed models and adjusted for age, sex, and body mass index.
PA = physical activity. Control = usual care group. LSPA = lifestyle PA group. STEX = structured exercise group. BMI = body mass index. MVPA = moderate-to-vigorous PA. 6MWT = 6-Minute Walk Test.
[a] These variables have missing data.
[b] BMI ≥ 25.0 kg/m^2 denotes overweight (Commonwealth of Australia, 2022).
[c] PA levels were assessed using the International Physical Activity Questionnaire – Intellectual Disability.
[d] MVPA ≥ 500 MET-min/week denotes the threshold of meeting the PA recommendation.

In the 6MWT, participants walked 541 (*SD* = 112) metres, which was close to the level expected for healthy adults (571 metres) (Casanova et al., 2011), suggesting that the study participants possessed near-normal physical function while walking.

The study outcomes comprised MVPA levels assessed using the IPAQ-ID. The mean (standard deviation) MVPA levels (MET-min/week) were estimated using the LMM analyses (Table 4.2), while adjusting for age, sex, and body mass index. These results are displayed in Figure 4.2. The baseline outcomes were compared, revealing no statistically significant differences between the trial groups.

Table 4.2. Mean moderate-to-vigorous physical activity levels (MET-min/week)

	Control	**LSPA**	**STEX**
Baseline	*n* = 22 615 (988)	*n* = 24 657 (1087)	*n* = 19 534 (999)
3 months post-baseline	*n* = 23 402 (1053)	*n* = 26 1259 (1164)	*n* = 18 1135 (1104)
9 months post-baseline	*n* = 20 915 (1365)	*n* = 22 1278 (1344)	*n* = 18 1149 (1392)

Note. Data are means (*SD*) estimated from linear mixed models adjusted for age, sex, and body mass index. *n* = number of participants analysed. Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group.

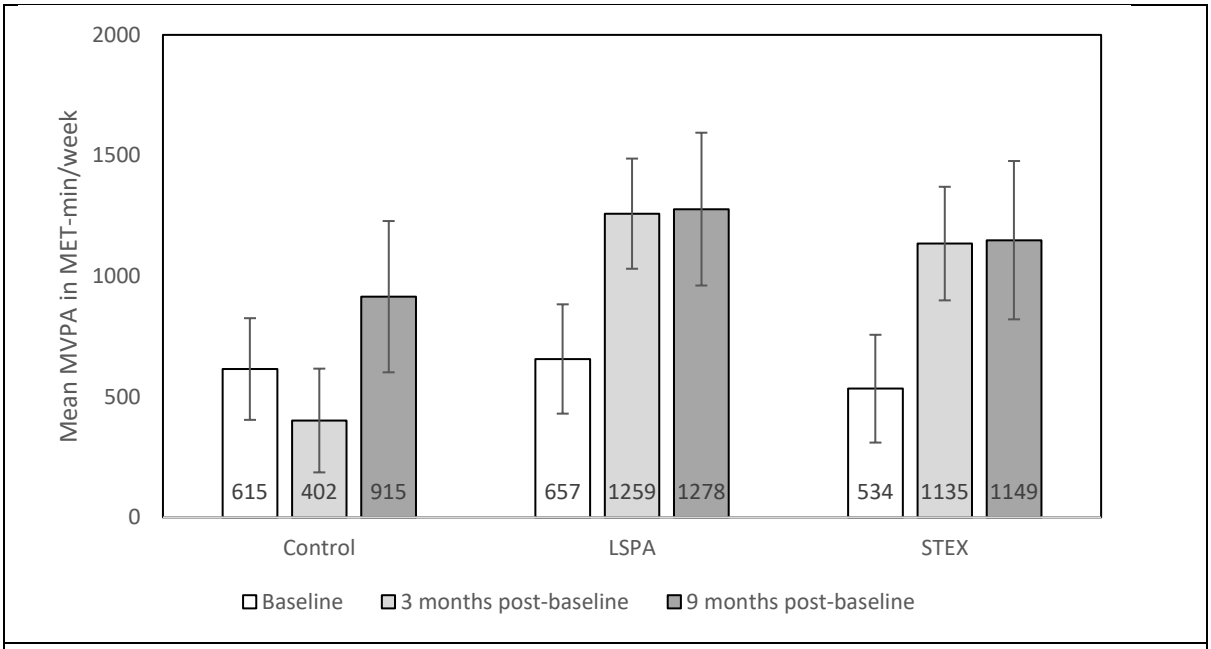

Figure 4.2. Mean MVPA levels (MET-min/week)
Note. Data are means (*SE*) estimated from linear mixed models adjusted for age, sex, and body mass index. MVPA = moderate-to-vigorous physical activity. LSPA = lifestyle physical activity group. STEX = structured exercise group. Control = usual care group. Measurement time points are at baseline, three months post-baseline, and nine months post-baseline.

Mean differences in adjusted PA levels with 95% confidence intervals (CIs) were estimated between the trial groups (Table 4.3) and within the trial groups over time (Table 4.4). As shown in Table 4.3, the comparisons among the three groups did not significantly differ at baseline. When compared to the Control group after the completion of the 12-week interventions, the mean MVPA level at three months post-baseline was significantly higher by 857 MET-min/week (95% CI [219, 1496], $p = .01$, $d = 0.8$) in the LSPA group and by 733 (95% CI [80, 1387], $p = .029$, $d = 0.7$) in the STEX group. Both effect sizes were medium to large, and the increments exceeded 500 MET-min/week, indicating that these results are clinically meaningful (Physical Activity Guidelines Advisory Committee, 2018). MVPA levels between the two intervention groups did not differ significantly. Additionally, no statistically significant differences were observed among the trial groups nine months post-baseline.

Table 4.3. Mean differences in physical activity levels (MET-min/week) between trial group pairs

	Baseline	3 months	9 months
LSPA vs Control	42 [-580, 663]	857 [219, 1496]**	363 [-529, 1255]
STEX vs Control	-82 [-701, 537]	733 [80, 1387]*	234 [-673, 1142]
LSPA vs STEX	-123 [-792, 546]	-124 [-778, 531]	-129 [-1046, 788]

Note. Data are mean differences [95% CI] estimated from linear mixed models adjusted for age, sex, and body mass index. 95% CI: 95% confidence interval. Control = usual care group. LSPA = lifestyle PA group. STEX = structured exercise group.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 4.4. Mean differences in physical activity levels (MET-min/week) within groups over time

	Control	LSPA	STEX
3 months vs baseline	-213 [-609, 182]	602 [245, 960]***	601 [166, 1037]**
9 months vs baseline	300 [-296, 896]	621 [60, 1182]*	616 [-22, 1253]
9 months vs 3 months	513 [-91, 1117]	19 [-551, 589]	14 [-652, 681]

Note. Data are mean differences [95% CI] estimated from linear mixed models adjusted for age, sex, and body mass index. 95% CI: 95% confidence interval. Control = usual care group. LSPA = lifestyle PA group. STEX = structured exercise group.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 4.4 illustrates the within-group over time comparisons (Figure 4.2). The changes in mean PA levels in the Control group were not statistically significant across the three measurement time points. Within the LSPA group, the mean PA level was significantly higher from baseline by 602 MET-min/week (95% CI [245, 960], $p = .001$, $d = 0.5$) at three months post-baseline and by 621 MET-min/week (95% CI [60, 1182], $p = .031$, $d = 0.5$) at nine months post-baseline. For the STEX group, it was significantly higher by 601 MET-min/week (95% CI [166, 1037], $p = .008$, $d = 0.6$) at three months only.

Statistical outliers were identified during the data examination in preparation for statistical analyses (see Appendix 4-B). However, the analyses included these data as they were plausible and did not significantly impact the results when the outliers were removed. There was insufficient data to perform subgroup analyses. The participants involved in the two interventions reported no adverse events or harm.

During the intervention period, the intervention compliance rates for the LSPA group were 114% (95% CI [83%, 146%]) over the 150-minute PA intervention, whereas the STEX group had rates of 95% (95% CI [86%, 104%]). During the follow-up period (which spanned three to nine months), the intervention compliance rates were 104% (95% CI [77%, 131%]) for the LSPA group and 52% (95% CI [36%, 67%]) for the STEX group.

4.4 Discussion

The findings of this trial indicate that the LSPA and STEX programs, which included exercise specialists and caregiver training, significantly enhanced MVPA participation among adults with ID. The trained caregivers demonstrated their ability to continue supporting these interventions without the involvement of exercise specialists in the longer term. Comparisons of the 6-month follow-up effects and compliance rates of the two interventions revealed that the LSPA intervention was more feasible and sustainable for the study population, with the STEX group compliance rate only half that of the LSPA group by nine months post-baseline. Moreover, the quantitative findings provided clinically significant information to assist practitioners in promoting PA for adults with ID.

The changes in MVPA volumes showed both statistical significance and clinical importance, as both interventions substantially increased the amount of MVPA by more than 500 MET-min/week, which is the threshold amount of MVPA necessary for obtaining health benefits (Physical Activity Guidelines Advisory Committee, 2018). Compared to the Control group, both intervention groups significantly increased their MVPA levels by over 700 MET-min/week during the 3-month intervention period. Moreover, the magnitudes of the differences between the intervention and

Control groups were considerable, with Cohen's *d* being 0.8 for the LSPA group and 0.7 for the STEX group relative to the Control group (Funder & Ozer, 2019; Sawilowsky, 2009). As illustrated in Figure 4.2, the Control group showed a marked increase from three to nine months post-baseline. Consequently, the mean differences between the intervention and Control groups were not statistically significant at nine months post-baseline, despite the increments in the LSPA and STEX groups remaining consistent with those observed at three months post-baseline.

When compared to the baseline outcomes within the trial groups (see Table 4.4 and Figure 4.2), the LSPA group provided solid evidence supporting clinically meaningful improvement (> 500 MET-min/week) in MVPA levels during the intervention. This significant progress was maintained during the follow-up period. The STEX group also demonstrated a substantial increase during the intervention period; however, this change was not statistically significant throughout the follow-up period. Nevertheless, the STEX group recorded an absolute increase of 616 MET-min/week at nine months post-baseline, which was slightly higher than the increase observed at three months post-baseline. This implies a lasting effect even if the statistical analysis did not achieve statistical significance compared to the baseline outcome. The findings suggest that the Active Support approach effectively enhances the PA levels of adults with ID. In other words, adults with ID could undertake both PA interventions if instructed by individuals with exercise-related skills, and caregivers could be trained to provide them with good quality PA support independently.

The compliance rates of the two interventions provided further insights into their feasibility and sustainability for the study ID population. Regarding the changes in intervention compliance rates, the rate in the STEX group dropped to 52% by nine months post-baseline from 95% by three months post-baseline. In contrast, the LSPA group sustained compliance rates exceeding 100% of the intended PA participation time at both three and nine months post-baseline, indicating that it may be more feasible and sustainable in the long term.

The findings of this study partially align with existing evidence. In a previous study seeking to promote a healthy lifestyle among adults with ID (Bazzano et al., 2009), a program incorporating educational and exercise components significantly improved participants' PA levels within a community setting. This program, which most participants could engage in, also enhanced the abilities and confidence of adults with ID regarding PA participation. Bazzano et al. (2009) employed educational classes delivered by professionals and utilised adults with developmental disabilities as peer mentors. In other words, their intervention did not include caregivers assisting adults with ID to participate in PA, so it was not considered Active Support. Furthermore, a follow-up period was not implemented to demonstrate the sustainability of the intervention. Another study (Shields et al., 2013) that implemented a student-led structured exercise program in a gym environment reported significant improvement in PA levels among a similar population. Notably, Jo et al. (2018) reported in their research that a combined exercise program could significantly enhance the PA levels and PA self-efficacy of adults with ID, suggesting that their confidence in perceiving and performing PA increased. Since self-efficacy is a crucial factor in facilitating behavioural changes (U.S. Department of Health and Human Services, 2018), such programs may potentially lead to sustained improvement and long-term lifestyle changes, as demonstrated by the Active Support approach in this study (see Chapter 6 for more information on self-efficacy for exercise).

This trial had several strengths. It was a community-based collaboration integrating research into practice with disability service providers. The research partners contributed substantially to the co-design, implementation, and monitoring of interventions, ensuring that the PA programs were both acceptable and feasible for the study participants. With exercise specialists employed to deliver the interventions and train caregivers, the quality of the trial implementation was enhanced and maximised. All these factors contribute to a significant innovation in promoting PA in individuals with ID – the combination of Active Support and PA promotion, which involves training caregivers to acquire skills for consistently delivering PA programs that their clients can accept and engage in during their everyday lives. The studies mentioned in the previous paragraph lacked these features. As

a three-arm trial, a noteworthy strength is that the comparisons between the two interventions allowed us to identify a sustainable and feasible PA approach that better suits adults with ID.

Some limitations may constrain the findings of this study. The inconsistent responses resulting in missing data for individuals across three measurement time points present a significant limitation. Consequently, numerous incomplete outcome values were observed, leading to unbalanced data between and within trial groups at different measurement time points. Furthermore, the withdrawal of 14 study participants also resulted in missing values. Although no significant differences in PA levels were observed between the trial groups at baseline, such discrepancies could introduce bias. Nevertheless, despite individual variants, the LMM analysis was employed to address these issues statistically by incorporating both fixed and random effects. Another limitation arose from observing some extreme values and/or statistical outliers, which may influence the results differently. However, these values remained plausible in the real world and were not excluded from the analyses. The analyses excluding extreme values indicated that these did not dramatically alter the results.

An additional challenge related to the implementation of the trial procedures was noted. The primary reason for participant withdrawal stemmed from staffing issues that could affect the feasibility of the interventions, as there were insufficient caregivers to deliver the intervention on top of their other responsibilities. This issue might particularly impact the STEX interventions due to the randomisation process. The STEX intervention was a small-group program involving three or more participants from various locations, making it time-consuming for caregivers to transport participants from other locations and return them after the session was finished. This requirement likely resulted in missed intervention sessions and declines in compliance rates. Although no data were collected, it is reasonable to assume that during the unsupervised six-month follow-up phase, caregivers might choose to support a client from the intervention group along with other clients, including members of the Control group, thereby including the Control participant in intervention activities. This could potentially explain the nonsignificant but notable increase in PA levels observed in the Control group at nine months post-baseline. This speculation warrants further examination in future research.

In addition to the limitations already mentioned, the results displayed wide confidence intervals and massive standard deviations, suggesting varied effects for individual participants. Therefore, it is important to acknowledge that there may be uncertainties when applying these findings to practice for individuals with ID. Future research should investigate the characteristics of participants who benefit the most and least, enabling the targeting and tailoring of future interventions.

The findings presented as a single MET-min value collected from various PA components offer crucial information for clinical practitioners developing PA programs. By using these values, practitioners can design and tailor their services for adults with ID, including a flexible combination of PA types, the necessary and achievable PA levels, and the amount of time they should dedicate to performing PA rather than relying on fixed interventions. Moreover, this study was integrated into providing disability services for adults with ID, allowing the research partner organisations to continue implementing these interventions within their workplaces.

A key message for future research is to scale up these interventions as public health approaches and evaluate their implementation in populations with ID (Milat et al., 2016). Given the substantial improvement found in the current study, translating these interventions into everyday practice is likely to achieve significant health benefits. Future research is required to conduct a cost-effectiveness analysis for implementing these interventions in real-world settings.

In conclusion, this trial has made significant progress in demonstrating that both the LSPA and STEX programs are likely to benefit adults with ID in engaging in more PA and that the LSPA approach is potentially more sustainable and acceptable to this population. In particular, it is feasible to train caregivers to implement these programs. The pragmatic processes and outcomes provide vital information for disability service organisations and caregivers to design and implement suitable PA programs in their work with adults with ID. In other words, this research will benefit individuals and the broader community by enabling a more effective use of publicly funded disability support resources.

Declaration of Interests

The author declared no competing interests.

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The author of this thesis analysed the data from a randomised controlled trial (Lante et al., 2014). The views expressed are those of the current author and not necessarily those of the trial researchers.

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CHAPTER FIVE

Effect of Lifestyle Physical Activity and Structured Exercise on Physical Fitness of Adults with Intellectual Disability: A Randomised Controlled Trial

Abstract

Background: Despite evidence that physical activity (PA) can improve the physical fitness of adults with intellectual disability (ID), its effectiveness and sustainability in routine disability service practices for this population remain uncertain. By comparing two different delivering methods of moderate-to-vigorous physical activity (MVPA) interventions - lifestyle physical activity (LSPA) and structured exercise (STEX) - with usual care (Control), this pragmatic research sought to assess the effectiveness and sustainability of the two interventions for improving the physical fitness of adults with ID in the short- and longer-term (3- and 9-months post-baseline respectively).

Methods: An intervention-based randomised controlled trial was conducted in a community setting in Sydney, Australia. Participants were physically capable adults with ID aged 19-54 years. They were randomly allocated into LSPA, STEX, or Control groups. The LSPA was an individualised program embedded in routine daily activities, and the STEX was a scheduled exercise class with 3-6 members per group. Accredited exercise specialists led the interventions and provided caregiver training simultaneously. Outcomes were measured at baseline, three months post-baseline, and nine months post-baseline. The primary outcome was aerobic fitness assessed by a submaximal exercise test. It was presented as predicted maximal oxygen consumption (VO_2peak). Secondary outcomes included functional walking capacity, measured by the distance walked in the 6-Minute Walk Test (6MWT), muscle strength (peak handgrip, biceps flexion, triceps extension, and knee extension strength), and body composition (body mass index [BMI] and body fat). Linear mixed models were used to estimate the means of outcomes and compare them between groups and within groups over time.

Results: Among the 96 participants recruited, the mean age was 38.4 years (*SD* = 9.3), 77 (82%) had a BMI of 25 kg/m^2 or higher, and 14 (15%) were withdrawn from the trial. The mean VO_2peak was significantly higher in the Control group at baseline than in the two intervention groups but did not differ significantly between cohorts at 3- and 9-months post-baseline. The VO_2peak of the STEX group significantly increased from baseline by 3.7 ml/kg/min (95% CI [0.3, 7.1], p = .034, Cohen's d = 0.4) at nine months post-baseline, representing a clinically meaningful change. The body fat at

baseline was significantly lower in both the Control and LSPA groups compared to the STEX group. No significant differences were found at baseline among other outcomes between trial groups. The mean body fat of the STEX group was significantly lower than baseline by 3.4% (95% CI [1.3, 5.6], p = .002, d = 0.6) at nine months post-baseline. The mean knee extension strength of the STEX group was higher than baseline by 3.4 kg (95% CI [0.6, 6.2], p = .017, d = 0.3) at nine months post-baseline. The mean triceps extension strength of the LSPA group increased from baseline by 3.7 kg (95% CI [1.6, 5.8], p < .001, d = 0.5) at nine months post-baseline. Compared to the Control, the mean biceps flexion strength was significantly higher at nine months post-baseline by 12.8 kg (95% CI [1.7, 24.0], p = .024, d = 0.8) for the LSPA and 11.9 kg (95% CI [0.3, 23.5], p = .044, d = 0.7) for the STEX groups, respectively. The mean biceps flexion strength was significantly increased from baseline in both intervention groups at three and nine months post-baseline by 3-8 kg. The mean 6MWT distance increased by 63.8 m (95% CI [19.4, 108.1], p = .006, d = 0.8) at nine months post-baseline in the LSPA group compared with the Control group. Both interventions significantly increased the mean 6MWT distance from baseline at three and nine months post-baseline by 17-30 m.

Conclusions: The findings support the view that the LSPA and STEX approaches are effective and sustainable in improving the physical fitness of adults with ID in the longer term.

Trial registration: Registered with the International Standard Randomised Controlled Trial Number Register (ISRCTN77889248) on April 18, 2012

Funding: The funding sources were the Australian National Health and Medical Research Council (Partnership Project Grant: APP1012692) and the two research partners (the Lorna Hodgkinson Sunshine Home and the House with No Steps).

5 Effect of Lifestyle Physical Activity and Structured Exercise on Physical Fitness of Adults with Intellectual Disability: A Randomised Controlled Trial

5.1 Introduction

In everyday life, people must engage in numerous daily activities related to lung function, muscle power, and functional capacity, such as climbing, running, or lifting heavy loads. According to a scientific report from the Physical Activity Guidelines Advisory Committee (2018), the core components of physical fitness include aerobic fitness, muscle strength, and physical function, and they must be maintained at an appropriate level to perform daily activities effectively. Notably, this scientific report highlighted that physical fitness is a crucial factor or mediator of population health, positively influencing an individual's health status and other health outcomes. Moreover, low levels of physical fitness have been reported to be associated with a decline in the ability to perform the aforementioned daily activities in adults with intellectual disability (ID) (Chow et al., 2018; Oppewal et al., 2014). Previous research, however, found that adults with ID often have poor levels of physical fitness (Chow et al., 2018; Hilgenkamp et al., 2012; Oppewal et al., 2013). This can lead to adverse health consequences that may significantly affect the quality of life of adults with ID, such as increased all-cause mortality or a heightened risk of developing various diseases (Ross et al., 2016). Consequently, improving the physical fitness of adults with ID in their everyday lives is essential.

There is compelling evidence that physical activity (PA) benefits physical fitness among individuals with intellectual and developmental disabilities (Boer & Moss, 2016; Calders et al., 2011; Ordonez et al., 2014; Oviedo et al., 2014; Rimmer et al., 2004). In these studies, PA interventions lasted between 10 and 20 weeks, meaning that only relatively short-term benefits or effectiveness were investigated. Furthermore, these interventions were designed to examine the effects of PA on specific research outcomes rather than focusing on the feasibility and sustainability of PA interventions over a longer duration in daily life. These studies employed exercise equipment and specialists during the implementation of the interventions, which is not usually the case in everyday community and disability service environments. For example, in Rimmer et al.'s (2004) study, the intervention was

delivered by registered exercise physiologists in a university facility. Such interventions and specialised settings would not usually be accessible to adults with ID and were likely unavailable even to study participants after the research project ended. However, Dairo et al. (2016) reported in their systematic review that adults with ID often lack PA in their daily routines, resulting in insufficient PA-related health benefits to maintain physical fitness. Importantly, effects gained from interventions, such as increased aerobic fitness, quickly revert to pre-intervention levels once aerobic fitness training ceases after four weeks (Mujika & Padilla, 2001). Similar findings were reported in a different cohort of adults with ID (Boer, 2018; Rosety-Rodriguez et al., 2014). So, interventions must be designed to enhance long-term PA participation while improving physical fitness. To the current author's knowledge, there is little evidence available in these areas.

Chapter 2 of this thesis presented clinically meaningful evidence that PA interventions substantially increase the VO_2peak of individuals with ID, demonstrating a large effect size (d = 0.8) compared to non-PA controls. In Chapter 4, this thesis demonstrated that the two PA interventions (lifestyle physical activity [LSPA] and structured exercise [STEX]) employed in this study effectively engaged adults with ID in higher levels of moderate-to-vigorous physical activity (MVPA) over both short-term and longer-term periods. By comparing the two interventions with usual care (Control) and analysing intervention effects within groups over time, this chapter sought to examine whether the two interventions improved physical fitness among adults with ID and whether these improvements were sustained over the longer term.

5.2 Methods

This study utilised the data collected from a three-arm, community-based, randomised, controlled trial. It was reported following the CONSORT guidelines (Moher et al., 2010), was registered with the International Standard Randomised Controlled Trial Number Registry (ISRCTN77889248), and received ethical approval for human research ethics from The University of Sydney (Appendix 3-A). As the trial protocol (Appendix 1-A) has been previously published (Lante et al., 2014), further details can be obtained from it. However, a brief description is provided below.

5.2.1 Study Design and Participants

This pragmatic research was conducted in the metropolitan areas of Sydney, Australia. The target population consisted of over 3000 adults with ID from four local disability service organisations. They resided in group homes or other supported living facilities in Sydney and received routine disability services for their daily activities, such as attending day program centres or working in supported workshops.

Eligible participants were adults with ID aged 19 to 54 years who had led inactive lifestyles over the previous 12 months and could attempt to participate in the PA programs and assessments required for the trial. The study participants referred by the four organisations underwent screening for PA suitability using the Physical Activity Readiness Questionnaire (Expert Advisory Committee of the Canadian Society for Exercise Physiology, 2002) or written approval from their doctors. Those deemed unsuitable were excluded. Following a discussion about the project, written informed consent was obtained and signed by all individuals or guardians participating in the trial.

A random number generator was employed for randomisation, and participants were randomly allocated to each of the three trial groups. In all processes, blinding was not possible in the study due to the observable nature of the interventions. In any case, the outcomes were measured objectively using standardised assessments. The author of this thesis only analysed the trial data retrospectively.

5.2.2 Interventions and Comparison

The interventions were carried out in everyday community and disability service environments using authentic locales, such as participants' living environments, research partners' facilities, local parks, and low-cost community gyms. The intervention lasted 12 weeks and involved accredited exercise specialists and caregiver training. Following the initial 12 weeks, caregivers continued to support the interventions during a 24-week follow-up period without the involvement of exercise specialists.

The LSPA programs were individualised for participants based on their routine activities and interests, such as walking for transportation, swimming, jogging, running, gardening, and exercising

during television advertisement breaks. Accredited exercise specialists supported participants in performing these activities at moderate intensity levels for 60 minutes each week and simultaneously trained caregivers. Caregivers supervised the remaining 90 minutes of the weekly LSPA. The STEX programs consisted of small group classes with three to six participants. Accredited exercise specialists led these scheduled classes and instructed participants to perform MVPA thrice weekly, incorporating 150 minutes of structured cardiovascular and muscular strength exercises. The Control participants received the usual care without engaging in additional PA.

5.2.3 Outcomes

In this trial, trained research staff conducted outcome assessments and collected data on outcomes at baseline, three months post-baseline, and nine months post-baseline. Participants and assessors were not blinded during the outcome assessments, but they underwent familiarisation sessions before the formal assessments.

The primary outcome was aerobic fitness, a crucial component of physical fitness (Physical Activity Guidelines Advisory Committee, 2018). This was predicted from VO_2peak measured in millilitres of oxygen per kilogram of body mass per minute (ml/kg/min). During a multi-stage submaximal exercise test, participants undertook up to four bouts of five-minute leg cycling on a seated isokinetic cycle ergometer (Isokinetic Cycle Ergometer [Vision Fitness R2250] for the first wave one of participant intake or Lode Corival 5.4.0 Recumbent Ergometer for waves two, three, and four intakes), with resistance adjusted to achieve target heart rates of approximately 45%, 55%, 65% and 75% of age-adjusted peak heart rate. A heart rate monitor (Polar RS400 HR monitor) recorded steady-state heart rates. The power outputs in Watts and steady-state heart rates were recorded and used in conjunction with the ACSM metabolic equations (American College of Sports Medicine & Pescatello, 2014) to estimate and predict VO_2peak (see Appendix 3-B for an example of a detailed calculation). This assessment has been successfully utilised in previous studies for the same purpose (Boer et al., 2014; Calders et al., 2011; Ohwada et al., 2005; Rimmer et al., 2004). An expert examined the test data for validity (see Chapter 3 for further details).

The secondary outcomes included peak knee extension strength, peak triceps extension strength, peak biceps flexion strength, peak dominant handgrip strength, functional walking capacity, body mass index (BMI), and body fat percentage. Muscle strength outcomes were expressed in kilograms and assessed using isometric dynamometry tests, as conducted in previous studies (Boer & Moss, 2016; Calders et al., 2011; Pitetti & Fernhall, 2005). Functional walking capacity was assessed using the 6-Minute Walking Test (6MWT), which measured the total distance (m) walked over the elapsed time. The 6MWT has been demonstrated to be a valid and safe assessment tool for adults with ID (Boer & Moss, 2016; Chow et al., 2018; Nasuti et al., 2013). According to the ACSM's guidelines (American College of Sports Medicine & Pescatello, 2014), BMI (kg/m^2) was calculated using participants' weight and height data. Participants were classified as overweight or obese if their BMIs were 25 kg/m^2 or higher (Commonwealth of Australia, 2022). Body fat percentage was measured using the Innerscan Body Composition Monitor (Tanita BC-541, Tsimshatsui East, Kowloon, Hong Kong).

Demographic characteristics, such as age, gender, smoking status, living facilities, and Down syndrome, were collected. Participants' body weight and height were recorded at each outcome assessment.

5.2.4 Statistical Analyses

To calculate the required sample size for the trial, data from a relevant study (Rimmer et al., 2004) were utilised, which reported substantial aerobic fitness improvement for PA interventions relative to non-PA controls (Cohen's $d = 0.9$). Assuming a conservative effect size ($d = 0.8$) with a significance level of 0.05, a power of 0.95, and a correlation of 0.5 for repeated measures, the three-arm trial required a total sample size of 69 participants (23 per group). Since the researchers preferred to make conservative assumptions (a smaller effect size and 20% loss to follow-up), each trial group required thirty participants, resulting in a total sample size of 90 individuals with ID (see Appendix 1-A) (Lante et al., 2014). However, this trial recruited 96 participants with 32 participants in each trial group.

Data were managed and analysed using IBM SPSS software (version 28). As outcomes were measured at three different time points, it was anticipated that an individual participant might not provide valid data for all three measurements, resulting in unbalanced data. As illustrated in Figure 5.1, the number of participants in the analyses varied between groups at the same measurement time and within groups over time. If only those participants who completed all three outcome assessments were included in traditional repeated-measures analyses, there would be a greater loss of cases. In this context, it was deemed preferable to deploy linear mixed models (LMM) in the analyses to accommodate all the available data (West, 2009). Baseline data were compared to identify any significant differences between trial groups.

The mean values of each outcome were estimated using the LMM and compared between trial groups at each measurement time point and within each trial group over time. The level of statistical significance was set at 0.05, accompanied by a 95% confidence interval (CI). Age and gender have been reported to have different influences on the outcomes (Oppewal et al., 2013). Therefore, the analyses were adjusted for age and gender when performing LMM analyses. Age and gender served as covariates in the LMM.

5.2.5 Roles of the Funding Sources

One funder was the Australian National Health and Medical Research Council (Project Partnership Grant APP1012692), which had no role in the trial. The other two funders were the Lorna Hodgkinson Sunshine Home (LHSH) and the House with No Steps (HWNS), both of which co-designed the interventions and jointly managed their implementation.

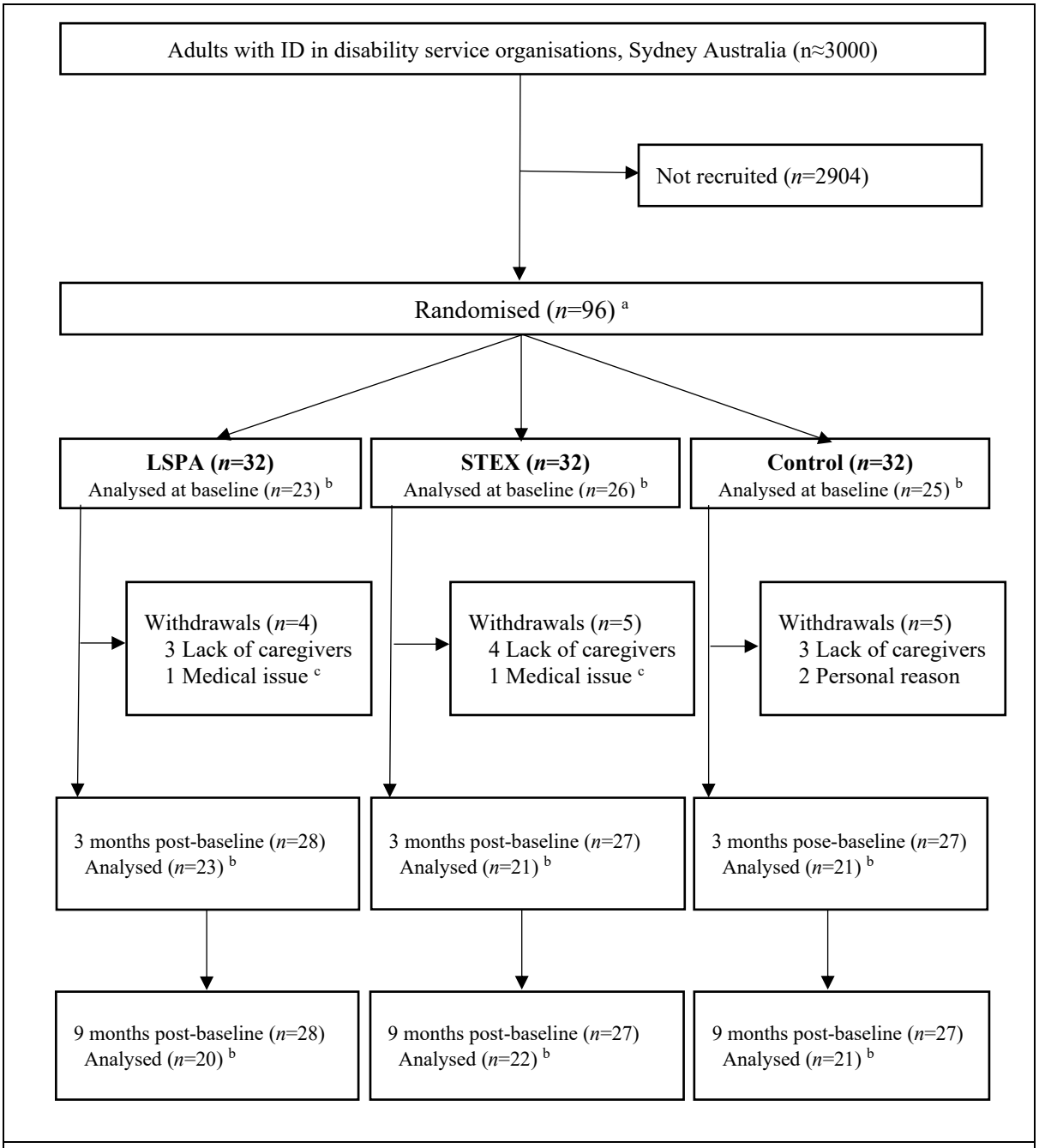

Figure 5.1. Participant flow diagram
Note. ID = intellectual disability. LSPA = lifestyle physical activity group. STEX = structured exercise group. Control = usual care group.
[a] Participants were more than the calculated sample size (90).
[b] Missing cases mainly due to incomplete or poor-quality data.
[c] Withdrawal due to a medical issue unrelated to participation in the trial.

5.3 Results

The trial recruited 96 adults with ID from August 2011 to November 2013. As portrayed in Figure 5.1, each group was initially assigned 32 participants through randomisation. There were 14 withdrawals from the trial, primarily due to a shortage of caregivers accompanying their participants to carry out the outcome assessments. The participant flow diagram (Figure 5.1) presents data based on the trial's primary outcome, which was predicted peak aerobic fitness. Missing outcome data were noted at each measurement time point, leading to different participant numbers between trial groups analysed in the LMM. Aside from withdrawals, missing data resulted from some participants' inability or unwillingness to comply with the specific assessment requirements, leading to incomplete or insufficient quality data for inclusion in the analyses. For example, some VO_2peak data were excluded by the expert because those participants provided poor-quality data (e.g., steady-state heart rates of less than 100 beats per minute or cycling for less than three minutes). No adverse events or harm were reported during the trial.

Table 5.1 displays the baseline characteristics of the participants. The participants were aged from 19 to 54 years, with a mean age of 38.4 years (*SD* = 9.3). Among all participants, 37 (38.5%) had Down syndrome, 41 (42.7%) were women, and 50 (52%) resided in group homes. The mean BMI was nearly 32 kg/m^2 (*SD* = 7.5), and 77 (81.9%) of participants had a BMI of 25 or greater, indicating they were overweight or obese (Commonwealth of Australia, 2022). Baseline characteristics were contrasted, and no significant differences were observed between the trial groups.

Table 5.1. Baseline characteristics of the study participants [a]

	Control (*n* = 32)	**LSPA** (*n* = 32)	**STEX** (*n* = 32)	**Overall** (*N* = 96) [a]
Age (year)				
Mean (*SD*)	40.3 (9.4)	38.4 (9.5)	36.6 (8.9)	38.4 (9.3)
Range	21 to 54	19 to 54	19 to 50	19 to 54
Gender				
Female	16 (50%)	11 (34.4%)	14 (43.8%)	41 (42.7%)
Male	16 (50%)	21 (65.6%)	18 (56.3%)	55 (57.3%)
Living facility				
Group home	18 (56.3%)	18 (56.3%)	14 (43.8%)	50 (52.1%)
Other types	14 (43.8%)	14 (43.8%)	18 (56.3%)	46 (47.9%)
BMI (kg/m^2)				
Mean (*SD*)	30.7 (7.9)	32.3 (8.3)	31.4 (6.4)	31.5 (7.5)
< 25.0 [b]	8 (25.8%)	5 (15.6%)	4 (12.9%)	17 (18.1%)
≥ 25.0 [b]	23 (74.2%)	27 (84.4%)	27 (87.1%)	77 (81.9%)
Down syndrome				
Yes	14 (43.8%)	13 (40.6%)	10 (31.3%)	37 (38.5%)
No	18 (56.3%)	19 (59.4%)	22 (68.8%)	59 (61.5%)
Smoker				
Yes	1	1	3	5 (5%)
No	31	31	29	91 (95%)

Note. Data are raw means (*SD*) or *n* (%). Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group. BMI = body mass index.
[a] Sample size at randomisation, which is more than the calculated sample size (90).
[b] BMI ≥ 25.0 kg/m^2 denotes overweight (Commonwealth of Australia, 2022)

Table 5.2 presents the adjusted means (*SD*) for all trial outcomes by trial groups and measurement time points. The LMM analysis assessed baseline study outcomes between groups (see Table 5.3). The aerobic fitness and body fat results revealed significant differences at baseline (see further details below). No other differences were identified between trial groups at baseline. Table 5.3 presents the between-group comparisons of mean differences in study outcomes, while Table 5.4 displays the within-group comparisons over time.

Table 5.2. Means of the study outcomes between the trial time points

Outcomes	Control	LSPA	STEX
VO_2peak (ml/kg/min)			
Baseline	*n* = 25 28.3 (7.6)	*n* = 23 24.2 (6.7)	*n* = 26 25.8 (8.9)
3 months post-baseline	*n* = 21 27.3 (8.0)	*n* = 23 27.0 (7.5)	*n* = 21 29.0 (9.0)
9 months post-baseline	*n* = 21 26.7 (7.5)	*n* = 20 27.1 (6.5)	*n* = 22 29.5 (8.7)
BMI (kg/m^2)			
Baseline	*n* = 31 30.7 (7.6)	*n* = 32 32.3 (8.2)	*n* = 31 31.4 (6.3)
3 months post-baseline	*n* = 25 31.1 (6.7)	*n* = 27 31.9 (7.5)	*n* = 24 31.1 (5.5)
9 months post-baseline	*n* = 26 31.4 (7.2)	*n* = 26 32.4 (7.6)	*n* = 25 30.9 (6.0)
Body fat (%)			
Baseline	*n* = 31 31.3 (5.6)	*n* = 32 30.9 (6.2)	*n* = 31 35.2 (6.1)
3 months post-baseline	*n* = 25 33.1 (9.0)	*n* = 27 29.8 (8.3)	*n* = 24 33.6 (10.3)
9 months post-baseline	*n* = 26 31.3 (5.1)	*n* = 26 29.8 (5.1)	*n* = 25 31.8 (5.5)
Knee extension strength (kg)			
Baseline	*n* = 26 32.0 (14.4)	*n* = 31 33.7 (17.4)	*n* = 25 33.9 (13.3)
3 months post-baseline	*n* = 24 30.9 (12.9)	*n* = 25 35.9 (14.9)	*n* = 22 37.3 (11.6)
9 months post-baseline	*n* = 16 32.6 (10.5)	*n* = 19 34.4 (12.7)	*n* = 17 35.5 (9.9)
Triceps extension strength (kg)			
Baseline	*n* = 29 28.3 (8.9)	*n* = 30 29.6 (8.5)	*n* = 26 27.7 (11.2)
3 months post-baseline	*n* = 25 27.3 (8.4)	*n* = 24 28.2 (7.5)	*n* = 23 28.0 (9.8)
9 months post-baseline	*n* = 17 28.4 (22.0)	*n* = 19 31.9 (6.5)	*n* = 17 30.6 (7.0)
Biceps flexion strength (kg)			
Baseline	*n* = 27 36.8 (10.2)	*n* = 30 34.8 (12.6)	*n* = 26 35.8 (15.3)
3 months post-baseline	*n* = 24 35.3 (9.7)	*n* = 24 38.3 (11.2)	*n* = 22 36.3 (13.8)
9 months post-baseline	*n* = 17 30.0 (21.0)	*n* = 18 42.8 (9.5)	*n* = 17 41.9 (11.4)
Handgrip strength (kg)			
Baseline	*n* = 29 27.2 (13.1)	*n* = 31 25.3 (15.6)	*n* = 27 24.8 (13.4)
3 months post-baseline	*n* = 25 21.2 (6.5)	*n* = 25 24.7 (9.2)	*n* = 23 24.4 (6.9)
9 months post-baseline	*n* = 17 25.4 (7.3)	*n* = 19 24.3 (9.4)	*n* = 17 24.6 (7.7)
6MWT distance (m)			
Baseline	*n* = 31 532.6 (89.3)	*n* = 32 565.1 (107.7)	*n* = 31 524.7 (131.0)
3 months post-baseline	*n* = 25 536.8 (73.5)	*n* = 27 582.6 (91.6)	*n* = 24 555.6 (109.2)
9 months post-baseline	*n* = 26 522.5 (70.6)	*n* = 25 586.2 (86.8)	*n* = 25 554.1 (112.4)

Note. Data are means (*SD*) estimated from linear mixed models adjusted for age, sex, and body mass index. *n* = number of participants analysed. Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group. VO_2peak = predicted maximal oxygen consumption from aerobic fitness test. BMI = body mass index. 6MWT = 6-Minute Walk Test.

Table 5.3. Mean differences in study outcomes between trial groups

Outcomes	Baseline	3 months	9 months
VO_2peak (ml/kg/min)			
LSPA vs Control	-4.1 [-8.2, 0.0]*	-0.3 [-5.0, 4.5]	0.4 [-4.0, 4.8]
STEX vs Control	-2.5 [-7.1, 2.1]	1.7 [-3.5, 7.0]	2.8 [-2.2, 7.8]
STEX vs LSPA	1.6 [-2.8, 6.1]	2.0 [-3.0, 7.0]	2.4 [-2.3, 7.1]
BMI (kg/m^2)			
LSPA vs Control	1.6 [-2.3, 5.6]	0.8 [-3.2, 4.7]	1.0 [-3.1, 5.1]
STEX vs Control	0.7 [-2.8, 4.3]	0.0 [-3.5, 3.5]	-0.5 [-4.1, 3.2]
STEX vs LSPA	-0.9 [-4.6, 2.8]	-0.8 [-4.4, 2.9]	-1.5 [-5.3, 2.4]
Body fat (%)			
LSPA vs Control	-0.4 [-3.3, 2.4]	-3.3 [-8.1, 1.6]	-1.4 [-4.3, 1.4]
STEX vs Control	3.9 [1.0, 6.8]**	0.5 [-5.0, 6.1]	0.5 [-2.5, 3.5]
STEX vs LSPA	4.4 [1.3, 7.4]**	3.8 [-1.5, 9.1]	2.0 [-1.0, 5.0]
Knee extension strength (kg)			
LSPA vs Control	1.7 [-6.8, 10.1]	5.0 [-3.0, 13.0]	1.8 [-6.1, 9.7]
STEX vs Control	1.9 [-5.9, 9.7]	6.4 [-0.9, 13.7]	2.9 [-4.3, 10.1]
STEX vs LSPA	0.2 [-8.0, 8.5]	1.4 [-6.4, 9.2]	1.1 [-6.5, 8.6]
Triceps extension strength (kg)			
LSPA vs Control	1.3 [-3.2, 5.8]	0.9 [-3.6, 5.4]	3.5 [-7.6, 14.5]
STEX vs Control	-0.7 [-6.1, 4.8]	0.7 [-4.5, 6.0]	2.2 [-9.0, 13.4]
STEX vs LSPA	-2.0 [-7.3, 3.4]	-0.2 [-5.2, 4.9]	-1.3 [-5.8, 3.2]
Biceps flexion strength (kg)			
LSPA vs Control	-1.9 [-8.0, 4.1]	3.0 [-3.1, 9.0]	12.8 [1.7, 24.0]*
STEX vs Control	-1.0 [-8.2, 6.3]	1.0 [-6.2, 8.3]	11.9 [0.3, 23.5]*
STEX vs LSPA	0.9 [-6.7, 8.6]	-1.9 [-9.5, 5.7]	-0.9 [-8.2, 6.4]
Handgrip strength (kg)			
LSPA vs Control	-1.9 [-9.2, 5.5]	3.5 [-1.1, 8.0]	-1.1 [-6.8, 4.5]
STEX vs Control	-2.4 [-9.5, 4.6]	3.2 [-0.7, 7.1]	-0.8 [-6.0, 4.4]
STEX vs LSPA	-0.6 [-8.1, 7.0]	-0.2 [-4.9, 4.5]	0.3 [-5.4, 6.1]
6MWT distance (m)			
LSPA vs Control	32.5 [-17.3, 82.3]	45.8 [-0.1, 91.7]	63.8 [19.4, 108.1]**
STEX vs Control	-7.8 [-64.5, 48.9]	18.8 [-34.7, 72.2]	31.7 [-21.6, 84.9]
STEX vs LSPA	-40.3 [-100.6, 19.9]	-27.0 [-83.7, 29.7]	-32.1 [-89.0, 24.8]

Note. Data are mean differences [95% confidence interval] estimated from linear mixed models adjusted for age, sex, and body mass index. Data are calculated as Intervention group minus Control group or STEX group minus LSPA group.
Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group. VO_2peak = predicted maximal oxygen consumption from aerobic fitness test. BMI = body mass index. 6MWT = 6-Minute Walk Test.
*< .05, **< .01, ***< .001.

Table 5.4. Mean differences in study outcomes within trial groups over time

	Control	LSPA	STEX
VO_2peak (ml/kg/min)			
3 months vs Baseline	-1.0 [-4.9, 2.9]	2.8 [-1.2, 6.9]	3.2 [-0.7, 7.1]
9 months vs Baseline	-1.6 [-5.0, 1.7]	2.9 [-0.6, 6.4]	3.7 [0.3, 7.1]*
9 months vs 3 months	-0.6 [-4.0, 2.8]	0.1 [-3.4, 3.6]	0.5 [-3.0, 3.9]
BMI (kg/m^2)			
3 months vs Baseline	0.4 [-0.3, 1.1]	-0.5 [-1.2, 0.2]	-0.3 [-1.1, 0.4]
9 months vs Baseline	0.7 [-1.2, 0.6]	0.0 [-0.8, 0.9]	-0.5[-1.1, 0.4]
9 months vs 3 months	0.3 [-0.3, 0.8]	0.5 [0.0, 1.0]	-0.2[-0.7, 0.4]
Body fat (%)			
3 months vs Baseline	1.8 [-1.4, 5.0]	-1.0 [-3.7, 1.6]	-1.6 (-5.4, 2.2)
9 months vs Baseline	0.0 [-1.8, 1.7]	-1.0 [-2.6, 0.5]	-3.4 (-5.6, -1.3)**
9 months vs 3 months	-1.8 [-5, 1.4]	0.0 [-2.7, 2.7]	-1.8 (-5.7, 2.1)
Knee extension strength (kg)			
3 months vs Baseline	-1.1 [-3.8, 1.6]	2.2 [-0.4, 4.9]	3.4 [0.6, 6.2]*
9 months vs Baseline	0.6 [-2.7, 3.9]	0.7 [-2.3, 3.8]	1.6 [-1.6, 4.7]
9 months vs 3 months	1.7 [-1.4, 4.7]	-1.5 [-4.4, 1.4]	-1.8 [-4.8, 1.1]
Triceps extension strength (kg)			
3 months vs Baseline	-1.0 [-3.6, 1.5]	-1.5 [-3.7, 0.8]	0.3 [-3.6, 4.2]
9 months vs Baseline	0.1 [-10.5, 10.7]	2.2 [-0.4, 4.9]	3.0 [-1.5, 7.4]
9 months vs 3 months	1.1 [-9.3, 11.6]	3.7 [1.6, 5.8]***	2.6 [-0.9, 6.1]
Biceps flexion strength (kg)			
3 months vs Baseline	-1.5 [-4.4, 1.5]	3.4 [0.8, 6.0]**	0.5 [-4.0, 5.1]
9 months vs Baseline	-6.8 [-16.7, 3.1]	8.0 [5.5, 10.4]***	6.1 [1.8, 10.4]**
9 months vs 3 months	-5.3 [-15.1, 4.5]	4.6 [2.5, 6.6]***	5.6 [2.0, 9.2]**
Handgrip strength (kg)			
3 months vs Baseline	-6.0 [-10.6, -1.3]*	-0.6 [-5.5, 4.2]	-0.3 [-5.2, 4.5]
9 months vs Baseline	-1.8 [-5.3, 1.8]	-1.0 [-4.6, 2.5]	-0.1 [-3.7, 3.5]
9 months vs 3 months	4.2 [1.3, 7.1]**	-0.4 [-3.3, 2.5]	0.2 [-2.8, 3.1]
6MWT distance (m)			
3 months vs Baseline	4.3 [-11.3, 19.8]	17.5 [4.2, 30.8]*	30.8 [12.0, 49.6]**
9 months vs Baseline	-10.1 [-30.3, 10.1]	21.2 [2.3, 40.0]*	29.4 [2.8, 56.0]*
9 months vs 3 months	14.4 [-32.5, 3.8]	3.6 [-13.1, 20.3]	-1.4 [-24.9, 22.0]

Note. Data are mean differences [95% confidence interval] estimated from linear mixed models adjusted for age, sex, and body mass index. Data are calculated as post-baseline minus baseline or 9-month – 3-month post-baseline.
Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group. VO_2peak = predicted maximal oxygen consumption from aerobic fitness test. BMI = body mass index. 6MWT = 6-Minute Walk Test.
*< .05, **< .01, ***< .001.

Aerobic fitness

At baseline, 74 participants provided valid assessment data for analyses. The overall mean VO_2peak was 26.1 ml/kg/min (*SD* = 7.7; 95% CI [24.3, 27.9]). According to the ACSM's fitness categories for

general populations (American College of Sports Medicine & Pescatello, 2014), this finding indicates that the trial participants, with a mean age of 38.4 years, exhibited “poor” aerobic fitness. The mean VO_2peak at baseline was significantly higher by 4.1 ml/kg/min (95% CI [-8.2, 0.0]) in the Control group compared to the LSPA group. Although not statistically significant, the absolute mean VO_2peak of the Control group was 2.5 ml/kg/min higher than the STEX group. According to the LMM analyses, aerobic fitness did not vary significantly between the trial groups at post-baseline (Table 5.3).

Within the STEX group (Table 5.4), the mean VO_2peak showed a significant increase at nine months post-baseline, rising by 3.7 ml/kg/min (95% CI [0.3, 7.1], p = .03, Cohen’s d = 0.4) compared to baseline. The effect size was medium (Funder & Ozer 2019; Sawilowsky 2009). In the Control group, the aerobic fitness outcomes did not differ significantly between measurement time points. Figure 5.2 illustrates the changes within the trial groups. The aerobic fitness trend of the Control group declined over time, while both intervention groups exhibited an increasing trend. The LSPA group showed no significant changes over time.

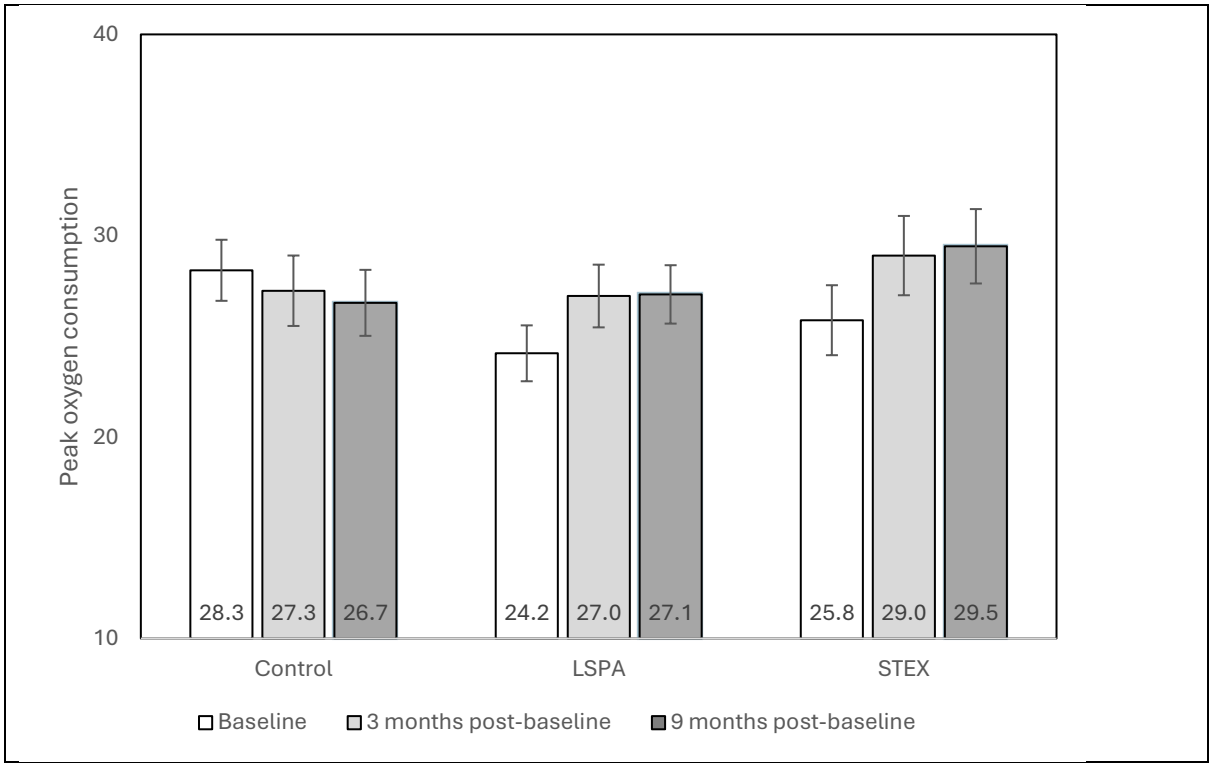

Figure 5.2. Mean peak oxygen consumption (ml/kg/min) within-group comparisons
Note. Data are means and standard errors estimated from linear mixed models. LSPA = lifestyle physical activity group. STEX = structured exercise group. Control = usual care group.

Functional walking capacity

The mean 6MWT distance at baseline was 541 m (*SD* = 111, 95% CI [518, 564]) among 94 participants. This result is close to that (571 m) for healthy adults (Casanova et al., 2011), suggesting that the trial participants may possess a healthy range of functional walking capacity.

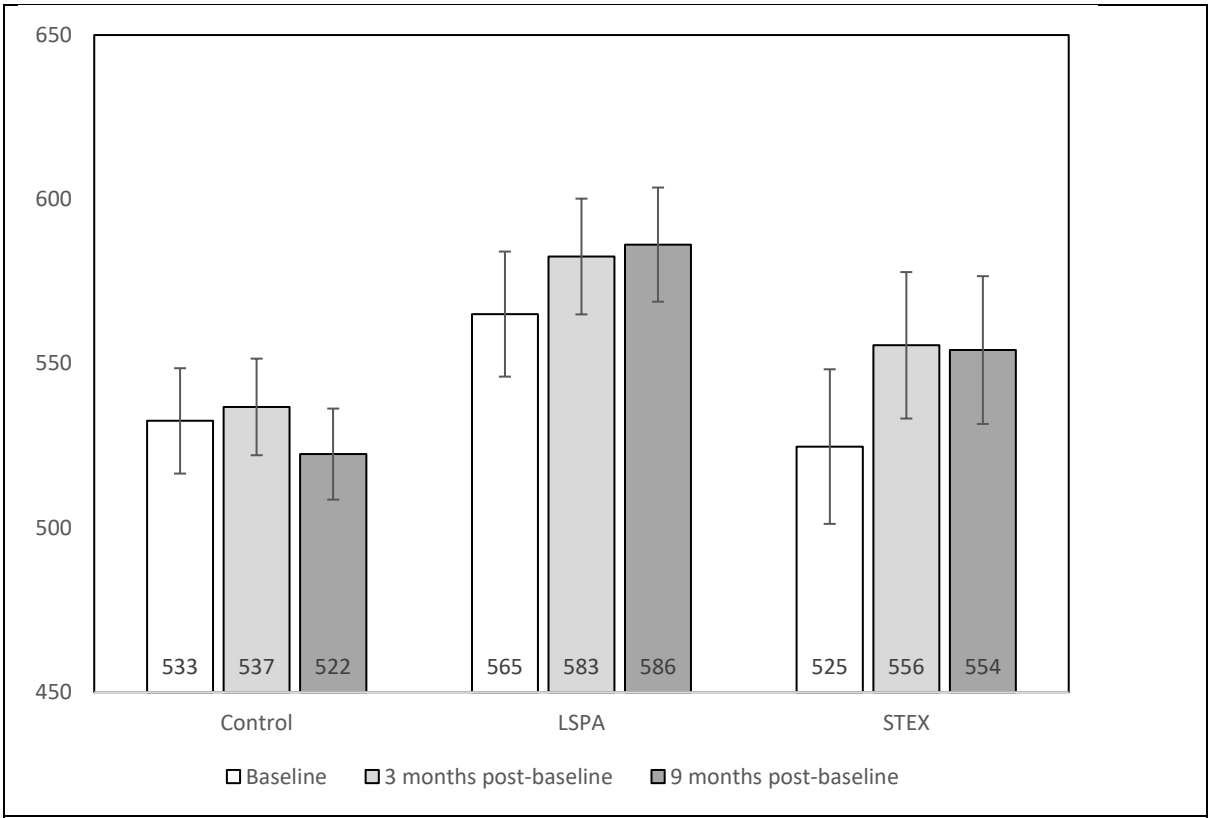

Figure 5.3. Mean distance (m) walked during the 6-Minute Walk Test within-group comparisons
Note. Data are means and standard errors estimated from linear mixed models. LSPA = lifestyle physical activity group. STEX = structured exercise group. Control = usual care group.

Compared to the Control group (Table 5.3), the mean 6MWT distance at nine months post-baseline was significantly higher in the LSPA group by 64 m (95% CI [19, 108], $p = .006$; $d = 0.8$). The mean 6MWT distance did not significantly differ between the STEX and Control groups. The comparisons between the two intervention groups showed no significant differences.

Compared to baseline within the trial groups (Table 5.4 and Figure 5.3), the mean 6MWT distance was significantly higher at three months post-baseline in the LSPA group by 17.5 m (95% CI [4.2, 30.8], $p = .01$, $d = 0.2$) and in the STEX group by 30.8 m (95% CI [12.0, 49.6], $p = .03$, $d = 0.3$), and maintained significant increases at nine months post-baseline in the LSPA group by 21.2 m (95% CI [2.3, 40.0], $p = .002$, $d = 0.2$) and in the STEX group by 29.4 m (95% CI [2.8, 56.0], $p = .03$, $d = 0.3$). The Control group remained unchanged across the measurement time points.

Body Mass Index

The LMM did not detect any significant changes in BMI between trial groups (see Table 5.3) or within trial groups at different measurement time points (see Table 5.4). However, the findings revealed some interesting trends, although not statistically significant. Throughout the study period, the BMI slightly increased in the Control group, decreased somewhat in the STEX group, and remained unchanged in the LSPA group.

Body fat percentage

The mean body fat at baseline was 32.5% ($SD = 5.8\%$, 95% CI [31.3, 33.6%] among 94 participants. The mean body fat was significantly higher in the STEX group than in the Control and LSPA groups by 3.9% (95% CI [1%, 6.8%], $p = .009$) and 4.4% (95% CI [1.3%, 7.4%], $p = .006$) respectively (see Table 5.3). The LMM analyses revealed no significant differences among the trial groups at the post-baseline time points.

Within the STEX group, the mean body fat at nine months post-baseline had decreased by 3.4% (95% CI [1.3%, 5.6%], $p = .002$, $d = 0.6$) compared to baseline, demonstrating a medium magnitude effect size with a decreasing trend over time (Figure 5.4). The mean body fat in the LSPA and Control groups did not differ significantly over time.

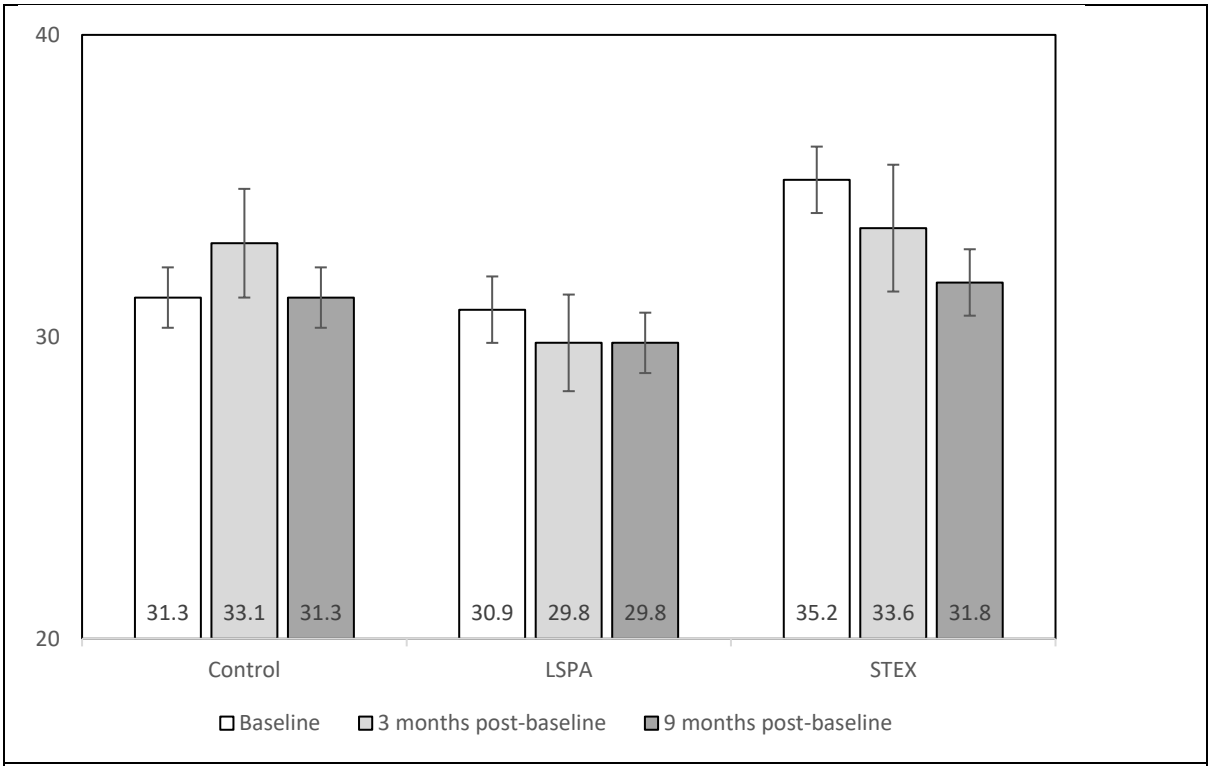

Figure 5.4. Mean body fat (%) within-group comparisons
Note. Data are means and standard errors estimated from linear mixed models adjusted for age, sex, and body mass index. LSPA = lifestyle physical activity group. STEX = structured exercise group. Control = usual care group.

Knee extension strength

The mean knee extension strength at baseline among 82 participants was 33.2 kg (*SD* =15.0, 95% CI [29.9, 36.5]). The mean knee extension strength comparisons among the trial groups showed no significant differences throughout the trial.

Within the STEX group, the mean knee extension strength significantly increased by 3.4 kg (95% CI [0.6, 6.2], $p = .02$, $d = 0.3$) at three months post-baseline compared to baseline (see Table 5.4). This effect decreased at nine months post-baseline, resulting in no significant changes compared to baseline and three months post-baseline. The mean knee extension strength in the LSPA and Control groups showed no significant changes across measurement time points.

Triceps extension strength

At baseline, the mean triceps extension strength of 85 participants was 28.5 kg (*SD* = 9.7, 95% CI [26.5, 30.6]). The LMM analyses found no significant differences among the trial groups throughout the trial.

In the LSPA group, the mean triceps extension strength was increased by 3.7 kg (95% CI [1.6, 5.8], $p < .001$, $d = 0.5$) at nine months post-baseline compared to three months post-baseline, demonstrating a medium magnitude effect size with an increasing trend over time (see Table 5.4). Other within-group comparisons did not show significant differences in the analyses.

Biceps flexion strength

At baseline, the average biceps flexion strength among 84 participants was 35.8 kg (*SD* = 13.0, 95% CI [33.0, 38.6]).

In comparison to the Control group at nine months post-baseline (see Table 5.3), the mean biceps flexion strength was significantly higher in the LSPA group by 12.8 kg (95% CI [1.7, 24.0], $p = .02$, $d = 0.8$) and in the STEX group by 11.9 kg (95% CI [0.3, 23.5], $p = .04$, $d = 0.7$). Both effect sizes showed a large magnitude.

In the comparisons within trial groups (see Table 5.4 and Figure 5.5), the mean biceps flexion strength in the LSPA group was significantly increased by 3.4 kg (95% CI [0.8, 6.0], $p = .01$, $d = 0.3$) at three months post-baseline compared to the baseline. At nine months post-baseline, the mean biceps flexion strength in the LSPA group increased from baseline by 8.0 kg (95% CI [5.5, 10.0], $p < .001$, $d = 0.7$) and from three months post-baseline by 4.6 kg (95% CI [2.5, 6.6], $p < .001$, $d = 0.4$), the mean biceps flexion strength in the STEX group increased from baseline by 6.1 kg (95% CI [1.8, 10.4], $p = .006$, $d = 0.5$) and from three months post-baseline by 5.6 kg (95% CI [2.0, 9.2], $p = .003$, $d = 0.4$). Figure 5.6 shows that biceps flexion strength increased in both intervention groups and decreased in the Control group across measurement time points.

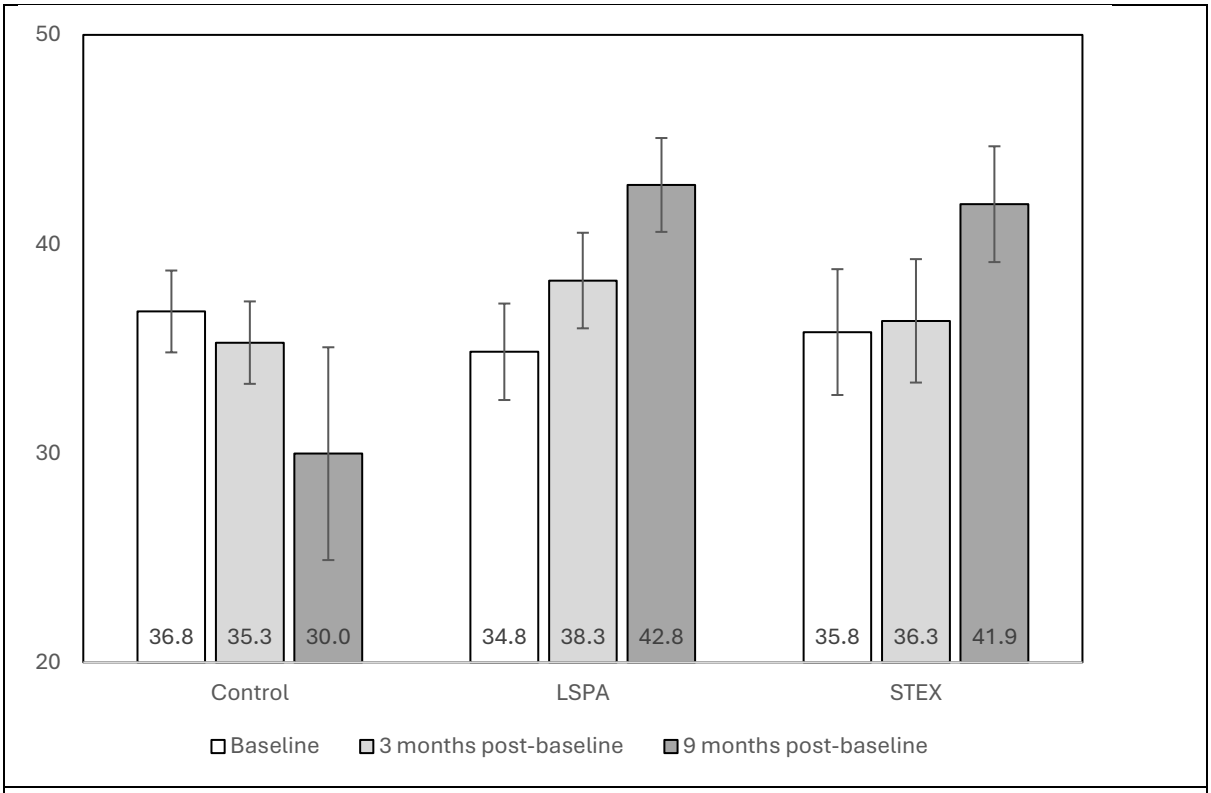

Figure 5.5. Mean biceps flexion strength (kg) within-group comparisons
Note. Data are means and standard errors estimated from linear mixed models adjusted for age, sex, and body mass index. LSPA = lifestyle physical activity group. STEX = structured exercise group. Control = usual care group.

Handgrip strength

At baseline, the mean handgrip strength among 87 participants was 25.7 kg (*SD* = 14.0, 95% CI [22.8, 28.7]). The LMM analyses revealed no statistically significant differences in the results of the interventions.

Subgroup and adjusted analyses

Upon initial investigation, outliers were identified in some variables. However, excluding these values from the analyses did not significantly change the findings. Moreover, these values were deemed plausible in the real world and were, therefore, retained in the analyses.

Among all participants at baseline, significant gender differences were observed in body fat, knee extension strength, triceps extension strength, biceps flexion strength, and handgrip strength (see

Chapter 3, Figure 3.1). Gender did not have a differential influence on functional walking capacity, aerobic fitness, and BMI among the study participants. Generally, male adults with ID exhibited a lower percentage of body fat and higher muscle strength. These gender differences align with the American College of Sports Medicine guidelines (ACSM & Pescatello, 2014). Additionally, the interaction between the trial group, measurement time, age, and sex did not significantly affect the analytical models.

5.4 Discussion

Overall, the findings of this study demonstrated that both the LSPA and STEX programs significantly improved the physical fitness of adults with ID and maintained their effectiveness throughout the trial (three and nine months post-baseline), with mostly small to large effect sizes for the changes. The mean comparisons within the intervention groups over the measured time points (Table 5.4) revealed significant improvements primarily by nine months post-baseline. The three significant improvements noted between the two interventions and the Control groups were also found at nine months post-baseline (see Table 5.3). These results suggest that the LSPA and STEX programs may require a longer duration to improve the physical fitness of adults with ID. Fortunately, the LSPA intervention demonstrated significant feasibility and sustainability for adults with ID in the longer term, and the STEX intervention was potentially sustainable (see Chapter 4, Table 4.4). Of the eight planned outcomes, the STEX programs showed improvements in five, whereas the LSPA programs improved in three, indicating that the STEX was likely more "dose-potent" than the LSPA for these outcomes.

The primary outcome, peak aerobic fitness, revealed some unexpected findings: the mean differences were not statistically significant except for one result within the STEX group (see Tables 5.3 and 5.4). The mean VO_2peak within the STEX group was significantly higher by 3.7 ml/kg/min at nine months post-baseline compared to baseline, indicating a medium-magnitude effect size (d = 0.4) in this change (Funder & Ozer, 2019; Sawilowsky, 2009). One essential component of the interventions in the current study was the involvement of Australian accredited exercise specialists in their implementation during the trial. This strategy had been employed in previous studies that reported

significant improvement in aerobic fitness among individuals with ID (Boer & Moss, 2016; Calders et al., 2011; Oviedo et al., 2014; Rimmer et al., 2004). Furthermore, the forest plot (see Appendix 2-D) in Chapter 2 of this thesis revealed consistent evidence that PA delivered by exercise professionals resulted in significant and clinically meaningful increases in the aerobic fitness of individuals with ID. In the current study, the mean estimates of aerobic fitness were comparable to those of the aforementioned studies. For instance, Oviedo et al. (2014) reported similar pre- and post-aerobic fitness measures (26.8 and 29.3 ml/kg/min, respectively) within their intervention group, resulting in a significant increase of 2.5 ml/kg/min. Such differences were observed in the current study, although not statistically significant. Therefore, like previous studies, the current study was expected to identify significant improvement in aerobic fitness. However, the VO_2peak was significantly higher at baseline in the Control group than the LSPA group. Such unbalanced baseline data might play a key role in the non-significant results, despite the ability of the LMM analyses to take this into account. Regarding the involvement of exercise professionals in implementing PA interventions, exercise specialists in the current study directly engaged for 150 minutes each week with the STEX group but only 60 minutes with the LSPA group. This disparity factor may partly explain the better overall results observed in the STEX group, as exercise specialists may have been more effective in delivering exercise and PA programs that had beneficial effects for these outcomes.

Figure 5.2 portrays the mean changes of each trial group over time. As age increased, the aerobic fitness of adults with ID gradually declined (Fernhall, 1993; Oppewal et al., 2013). Although nine months may not be long enough, Figure 5.2 shows a similar trend for the Control group. This may indirectly support the decline over time in the Control group that did not participate in sufficient MVPA (see Chapter 3 for more information). In contrast, participants in the STEX group improved their aerobic fitness, thereby countering any age-related decrease. Furthermore, the mean VO_2peak in the Control group was significantly higher at baseline by 4.1 ml/kg/min than in the LSPA group (Table 5.3). This represents a rare but not unknown failure of randomisation to eliminate baseline group differences. However, after completing the interventions, this significant difference for the LSPA group was reduced to non-significance. Notably, a 3.7 ml/kg/min increase within the STEX

group is clinically important (Ross et al., 2016). Overall, although the aerobic fitness results were not statistically significant, the improvements in the intervention groups should be considered clinically meaningful for adults with ID who typically exhibit poor fitness.

The results for the secondary outcomes are consistent with those of other studies. The review by Fernhall (1993) had noted that most exercise programs can substantially improve the muscle strength of individuals with ID. Newer studies continue to update and support this original finding (Calders et al., 2011; Oviedo et al., 2014; Rimmer et al., 2004; van Schijndel-Speet et al., 2017). Therefore, it is unsurprising that the LSPA and STEX programs could significantly improve strength, given that an exercise program can elicit strength gains relatively quickly. Regarding functional walking capacity, the results of the current study are also supported to a great degree by available evidence (Boer & Moss, 2016; Calders et al., 2011).

The primary strength of the current study was its investigation into the longer-term feasibility and sustainability of the two interventions. As concluded in the review by Fernhall (1993), individuals with ID require a long-term lifestyle change to obtain health benefits from PA participation. The studies mentioned above implemented PA programs in unique settings, such as university gyms (Rimmer et al., 2004), involving exercise professionals and equipment, which are unlikely to be feasible in disability services and local environments for adults with ID in the long term. Furthermore, these interventions were group PA programs that required participants to travel to the intervention sites from various locations. As observed in the STEX of the current trial, these interventions were costly for adults with ID and time-consuming for caregivers, leading to a low PA compliance rate (see Chapter 4 for more information). The current trial was conducted in the participants' everyday community (e.g., their homes, local park, and other nearby facilities). In particular, the LSPA was integrated into the daily routine activities of the study participants, thus satisfactorily maintaining a long-term PA compliance rate (see Chapter 4).

Another significant strength was the on-site caregiver training provided during the implementation of PA programs. However, employing exercise specialists to promote PA for adults with ID is not

typical within disability services, while caregivers do provide everyday disability services for adults with ID but possess limited skills and knowledge in exercise to support their engagement in PA (Dixon-Ibarra et al., 2017).

A third strength was that the current trial was a pragmatic collaborative project involving intervention users (e.g., adults with ID and their caregivers) in an everyday community setting. It significantly enhances the potential to translate the findings into routine disability service practice. To the current author's knowledge, this study was the first to apply these strategies to investigate the long-term feasibility and sustainability of PA interventions for adults with ID.

Several limitations of this study may constrain the findings. One key limitation was that the outcomes (e.g., aerobic fitness and body fat) were higher at baseline in the Control group than in the two intervention groups. This may be attributed to a randomisation process that could not satisfactorily eliminate differences between the trial groups. A second limitation stemmed from the adults with ID themselves: their capacity and willingness to comply with instructions and correctly complete physical assessments. During an assessment, they might cease exercising if they did not wish to continue, occasionally resulting in missing data or failing to reach the required assessment levels to obtain valid data. For example, some aerobic fitness outcome values were excluded from the analyses because the submaximal cycle stages lasted less than three minutes (i.e., heart rate was not in a steady state) or the collected data did not meet the criteria for a "good assessment", according to the data cross-examination conducted by a person with expertise in aerobic testing. In turn, this issue raises the question of what assessment of aerobic fitness is suitable for most or all adults with ID to attempt satisfactorily.

The third limitation was related to maintaining the quality of the interventions. During the follow-up period, exercise specialists could no longer work with participants and their caregivers. Caregivers were solely responsible for the interventions, but no systematic approach was employed to monitor and evaluate their performance. This issue may jeopardise the long-term implementation of the Active Support approach (Clement & Bigby, 2008). Furthermore, in the Australian disability service sector,

there are high caregiver turnover rates and a lack of permanent positions for caregivers (Behavioural Economics Team of the Australian Government, 2023; Workforce Innovation and Development Institute, 2022). In this trial, no information was gathered regarding caregiver turnover during the follow-up phase. As a result, it was impossible to evaluate the effect of trained caregivers leaving the disability service on intervention implementation, compliance, or quality. In addition to the above, the trial recruited participants with relatively healthy motor skills and exercise abilities, excluding those with physical impairments. Therefore, the representativeness of the study sample is limited when generalising the findings of this study.

The present findings imply that the LSPA and STEX programs may be integrated into the routine practice of disability services for adults with ID, aligning with the overarching aim of the trial. The findings help adults with ID and their caregivers understand how to perform PA with sufficient intensity to improve and maintain healthy physical fitness. Since the two interventions were implemented using authentic materials and activities available in the service users' living environment, their feasibility and sustainability were demonstrated in everyday settings, rather than special intervention facilities, resulting in significant improvements in physical fitness. In particular, the LSPA was tailored for individuals and incorporated into their daily routines, enabling participants and caregivers to continue the intervention programs over the long term. That said, the turnover of trained caregivers may necessitate periodic retraining of new caregivers to ensure ongoing implementation and fidelity. Another important implication is to inform policymakers to adjust or develop new strategies for supporting adults with ID. Indeed, the research partner organisations involved in this trial began recruiting new staff possessing knowledge and skills in exercise.

In the present study, participants devoted considerable time to light-intensity PA in their daily lives (see Chapter 3), but the intensity of these activities was insufficient to attain the desired health benefits, as indicated by findings from previous research (Stanish & Draheim, 2007; Temple et al., 2000). Balancing PA level and intensity is challenging. This study has provided detailed information on the intervention procedures, such as examining an individual's readiness to participate in PA

before exercise, identifying opportunities for exercise (e.g., walking for transport), and being aware of intensity of a specific PA by its MET value (e.g., cycle shows a MET of 6.0, indicating vigorous intensity; walking for transport shows a MET of 3.3, indicating moderate intensity) (see Appendix 4-A for further information). The insights gained from this trial can assist relevant stakeholders in improving the long-term physical fitness levels of adults with ID.

Further work is required to establish a method for ensuring the consistency and quality of Active Support-related PA interventions delivered by caregivers (Clement & Bigby, 2008; Stancliffe et al., 2007). The LSPA and STEX programs have been developed using the Active Support approach (see further details in Chapters 1 and 7). Clement and Bigby (2008) have successfully integrated Active Support strategies into the daily lives of adults with ID and engaged them in more daily activities within group home environments. Their report highlighted several barriers affecting the implementation of Active Support and suggested a system to supervise caregivers' performance and address these obstacles. Similar concerns regarding exercise interventions should be taken into account.

In conclusion, this study has demonstrated that, with support from exercise specialists and trained caregivers, adults with ID can consistently participate in both LSPA and STEX programs, thereby improving their physical fitness levels over the longer term. The STEX intervention led to more significant improvements in physical fitness outcomes.

Acknowledgements

The author of this thesis analysed the data from a randomised controlled trial (Lante et al., 2014). The views expressed are those of the current author and not necessarily those of the trial researchers.

Declaration of interests

The authors declare no competing interests.

5.5 References

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CHAPTER SIX

Psychosocial Impacts of Physical Activity Programs among Adults with Intellectual Disability: A Randomised Controlled Trial

Abstract

Objectives: A lack of self-efficacy and social support poses barriers for adults with intellectual disability (ID) in participating in physical activity (PA). This study incorporated the involvement of exercise specialists and caregiver training into lifestyle physical activity (LSPA) and structured exercise (STEX) interventions to promote PA among adults with ID. It aimed to assess whether the two interventions could enhance the self-efficacy and social support of these individuals and whether they proved effective in the long term.

Methods: This study analysed data from a three-arm randomised controlled trial involving Australian adults with ID who led sedentary lifestyles but were physically capable. The LSPA programs consisted of individualised activities, while the STEX programs involved small-group exercises with three to six participants three times a week. Exercise specialists implemented the two interventions directly during the first 12 weeks and trained caregivers to continue these interventions. Over the following 24 weeks, caregivers were solely responsible for maintaining the interventions. The comparison group continued with their usual care (Control). Outcomes included self-efficacy and social support for PA, participation in domestic activities, and exercise outcome expectations, each assessed using a scale. Mean scale points were measured and compared between groups at each measurement point and within groups over time. Linear mixed models were utilised for the statistical analyses.

Results: This trial randomly allocated 96 participants to three groups. Of these, 14 were withdrawn. Participants resided in supported living facilities and received everyday disability services. The demographic and baseline characteristics were similar across the three trial groups. Self-efficacy increased by 2.4 scale points (95% CI [0.8, 4.1], $p = .004$, Cohen's $d = 1.0$) in the LSPA group at 3 months post-baseline compared to the Control group. Self-efficacy in the LSPA group increased by 3.4 scale points (95% CI [2.0, 4.7], $p < .001$, $d = 1.4$) at 3 months post-baseline compared to baseline, increased by 1.8 scale points (95% CI [0.2, 3.4], $p = .024$, $d = 0.7$) at 9 months post-baseline compared to baseline, and reduced by 1.6 scale points (95% CI [0.2, 2.9], $p = .024$, $d = 0.6$) at 9

months post-baseline compared to 3 months post-baseline. Social support at 3 months post-baseline increased by 2.6 scale points (95% CI [0.9, 4.4], $p = .004$, $d = 1.0$) in the STEX group compared to the Control group. Compared to baseline, social support in the STEX group increased by 3.1 scale points (95% CI [1.6, 4.6], $p < .001$, $d = 1.2$) at three months post-baseline and by 1.9 scale points (95% CI [0.4, 3.4], $p = .014$, $d = 0.7$) at nine months post-baseline. Social support in the LSPA group increased from baseline by 1.5 scale points (95% CI [0.0, 3.0], $p = .046$, $d = 0.6$) at 3 months post-baseline, but this increment fell at 9 months post-baseline compared to 3 months post-baseline by 1.5 scale points (95% CI [0.2, 2.7], $p = .021$, $d = 0.6$). Participants in the LSPA group engaged in more domestic activities at 3 months post-baseline by 1.2 scale points (95% CI [0.1, 2.4], $p = .03$, $d = 0.3$) and at 9 months post-baseline by 1.8 scale points (95% CI [0.4, 3.3], $p = .01$, $d = 0.4$) compared to baseline. Participants in the STEX group increased their participation in domestic activities at 3 months post-baseline by 1.8 scale points (95% CI [0.4, 3.3], $p = 0.01$, $d = 0.3$). Participants in the LSPA group enhanced their exercise outcome expectations from baseline by 1.0 scale points (95% CI [0.1, 1.8], $p = 0.03$, $d = 0.5$) at 3 months post-baseline.

Conclusions: The LSPA and STEX programs, which included exercise specialists and caregiver training, enhanced self-efficacy and social support for PA among adults with ID. They encouraged participants to engage in more domestic activities and improved their expectations towards exercise outcomes during the intervention period. The LSPA group experienced more benefits than the STEX group. However, these improvements may not be sustained in the long term.

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Trial registration: ISRCTN77889248 (18 April 2012).

6 Psychosocial Impacts of Physical Activity Programs among Adults with Intellectual Disability: A Randomised Controlled Trial

6.1 Introduction

According to behaviour theories of health promotion practice (U.S. Department of Health and Human Services, 2018), psychosocial factors significantly influence behaviour changes, such as the transition from a sedentary lifestyle to engaging in regular physical activity (PA). Furthermore, there are reciprocal relationships between these factors and behaviours, with behavioural changes also affecting psychosocial factors. Self-efficacy and social support are two crucial psychosocial factors related to PA participation as these factors can be both barriers and facilitators to PA participation (Dixon-Ibarra et al., 2017). For instance, the review by McAuley et al. (2011) identified that self-efficacy might be an important mediator of the effects of PA interventions. In their study investigating the relationships between social support and PA, Stapleton et al. (2015) found strong evidence that social support significantly influenced PA behaviours within an adult population.

As one of the most important personal factors in behavioural change, self-efficacy is defined as an individual's confidence in their ability to perform PA successfully (U.S. Department of Health and Human Services, 2018). Social support, as its name implies, refers to the support for PA participation from an individual's social networks, such as skills and companionship (U.S. Department of Health and Human Services, 2018). In the current study, the term PA generally refers to moderate- or vigorous-intensity physical activity (MVPA), which is recognised as effective for gaining health benefits (Physical Activity Guidelines Advisory Committee, 2018).

When promoting PA participation among adults with intellectual disability (ID), self-efficacy and social support are critically important (Westrop et al., 2024). In an investigation into barriers to PA, Dixon-Ibarra et al. (2017) reported that adults with ID experienced inadequate self-efficacy and social support, which resulted in resistance to participating in PA. Indeed, self-efficacy and social support among adults with ID can significantly predict PA participation (Peterson et al., 2008). In an inquiry into the association between social support and PA participation in adults with ID, Brooker (2018)

found a mutually beneficial relationship. That is, social support and PA participation reciprocally facilitate one another. However, a lack of self-efficacy and social support can hinder participation in PA (Dixon-Ibarra et al., 2017; U.S. Department of Health and Human Services, 2018). Therefore, innovative approaches are required to improve self-efficacy and social support for PA among adults with ID, which will benefit them by promoting greater participation in PA.

Adults with ID primarily receive social support from their caregivers (Lippold & Burns, 2009; Peterson et al., 2008; Stancliffe & Anderson, 2017). Therefore, caregivers' support is key to enabling individuals with ID to participate in PA. Adults with ID often require assistance from caregivers for their daily living activities. This reliance also contributes to a dependence on social support for PA participation. For instance, Stancliffe and Anderson (2017) found that 78% of adults with ID in the United States received support when going out into the community to exercise, with caregivers being the most common source of this support. However, in the Australian disability service sector, there is a high turnover rate of caregivers and a lack of permanent positions (Behavioural Economics Team of the Australian Government, 2023; Workforce Innovation and Development Institute, 2022). This situation leads to frequent changes of support workers for adults with ID, likely resulting in caregivers not knowing their clients well enough to recognise when and how best to assist their activities, including PA. Therefore, social support is often inconsistent and unskilled due to their unstable social networks and variations in available support (Brooker, 2018). In other words, adults with ID may have low PA participation partly due to unstable or insufficient support (Westrop et al., 2024). Furthermore, caregivers are less inclined to encourage adults with ID to participate in PA when they have misunderstandings (e.g., harm and low expectations) related to PA (Kreinbucher-Bekerle et al., 2022). Therefore, caregivers must be trained to acquire knowledge and skills in deploying PA and exercise, enabling them to support adults with ID in PA actively and skilfully (Kreinbucher-Bekerle et al., 2022; Michalsen et al., 2023).

PA is crucial for population health (Physical Activity Guidelines Advisory Committee, 2018). Adults with ID should be strongly encouraged to engage in sufficient PA, as they typically maintain lower

levels than required in their daily lives (Dairo et al., 2016; Stancliffe & Anderson, 2017). Numerous research studies have been undertaken to facilitate this behaviour change. However, they have yielded little consistent evidence that any intervention is effective in the long term (Hassan et al., 2019).

One vital reason is that existing interventions for individuals with ID may inadequately address their needs in certain aspects, such as their attitudes and capacities towards PA (Willems et al., 2018). However, as personal factors are critical elements of interventions for behaviour change in adults with ID (Bondár et al., 2020), PA programs must be tailored to meet the needs of adults with ID to engage them successfully (Physical Activity Guidelines Advisory Committee, 2018). Furthermore, examining which types of PA are better suited to improving self-efficacy and social support among adults with ID and their caregivers in the short and long term is critical. As recommended by Kreinbucher-Bekerle et al. (2022), professional knowledge and skills are necessary to tackle these issues. Michalsen et al. (2023) provided a worked example in which individuals with ID increased their PA participation, where exercise professionals designed personalised programs by considering the participants' interests and abilities as well as the contributions of their caregivers.

Designing an intervention that enables adults with ID to participate in more MVPA, whilst simultaneously enhancing their self-efficacy and social support in the long term, is challenging. Although evidence suggests that specific interventions incorporating PA components can improve self-efficacy and social support levels in adults with ID during the intervention (Heller et al., 2004; Jo et al., 2018; Pérez-Cruzado & Cuesta-Vargas, 2016), these interventions were not specifically tailored for individuals. Instead, they were structured exercise programs designed for groups without considering the roles of caregivers. Moreover, these studies did not examine the feasibility and sustainability of the interventions as long-term support for adults with ID in the real world, but typically delivered time-limited interventions in a research environment, such as a university gym (Rimmer et al., 2004). Little research has addressed these issues. The current study was the first to take on this challenge. The interventions were separated into lifestyle physical activity (LSPA) and structured exercise (STEX) programs (see more details in the following section). The design and

implementation of the two interventions were conducted collaboratively with researchers, exercise specialists, adults with ID, caregivers, and other relevant stakeholders.

In Chapter 4 of this thesis, the Active Support approach, which incorporates the involvement of exercise specialists and caregiver training into the LSPA and STEX interventions (see Chapters 1 and 7 for further details regarding Active Support), has been shown to increase the PA levels of adults with ID in the long term. The present study sought to investigate whether these approaches could enhance self-efficacy and social support for PA participation among adults with ID and sustain their effectiveness over time. It also examined which of the two interventions was more suitable for the study population in terms of these psychosocial outcomes.

6.2 Methods

6.2.1 Study Design

The data for this study were obtained from a randomised controlled trial involving three groups: the LSPA, STEX, and usual care (Control) groups. It was conducted in community settings and everyday disability service environments within the metropolitan areas of Sydney, Australia. The trial was registered with the ISRCTN registry (ISRCTN77889248). Approval from the Human Research Ethics Committee (Appendix 3-A) was obtained from The University of Sydney (HREC 05-2011/13821). The trial protocol (Appendix 1-A) has been published earlier (Lante et al., 2014), from which readers can seek further information. The funding agencies included the Australian National Health and Medical Research Council (Partnership Grant APP1012692), which had no role in the trial, and two disability service providers, Lorna Hodgkinson Sunshine Home and House with No Steps, which provided financial support and acted as research partners. Contributions from these two organisations were integrated into the intervention design and implementation.

The trial investigators who specialised in disability research, public and occupational health, and exercise science designed the trial (Appendix 1-A) (Lante et al., 2014). Research staff were trained to conduct interviews, administer outcome assessments, collect data using validated forms, and manage data. The accredited exercise specialists from The University of Sydney instructed participants to

undertake PA programs and trained caregivers to acquire relevant skills. Considering the participants' personal factors and resources, the settings where the interventions were delivered could include the backyards of study participants' homes, local leisure facilities, parks, or gyms. Some differences existed between the LSPA and STEX groups. The LSPA intervention was much more individualised, as it was delivered individually rather than in small groups. In contrast, the STEX programs may have varied slightly from one STEX small group to another but were generally consistent for individuals within the same group.

6.2.2 Participants

The two funding agencies previously mentioned served as the initial sources of study participants. When recruitment targets were unmet, participants were drawn from two additional disability service organisations. All of these were located in metropolitan Sydney or nearby centres.

Eligible participants were adults with ID aged between 19 and 54 years who led physically inactive lifestyles in the past 12 months, could attempt to participate in planned PA interventions and outcome assessments, and resided within a 1.5-hour commute of the testing site. Individuals were excluded if they had contraindications to participating in interventions or outcome assessments as advised by the primary care physician or presented risks of self-harm as judged by their caregivers. After a discussion with an investigator, written consent was signed and obtained from each participant or guardian involved in this trial. Participants lived in group homes or other supported living facilities. All individuals regularly received daily disability support services from the four disability service organisations, such as community living support in their homes, attending day program centres, or employment workplaces. The diagnosis of ID was based on each participant's record. Participants' sedentary status was estimated according to their caregivers' information using the ACSM criteria (American College of Sports Medicine & Pescatello, 2014).

If interested, participants were recommended to the trial by their service providers and randomly assigned to one of the three trial groups. Since the interventions and outcome assessments were observable and objective, neither the research staff nor any relevant stakeholders were blinded.

6.2.3 Interventions and Comparison

As detailed in the published protocol (Appendix 1-A), the LSPA and STEX interventions lasted 12 weeks, followed by a 24-week follow-up period (Lante et al., 2014). The LSPA programs were tailored to fit each participant's routine PA, including walking for transportation, swimming, jogging, gardening, and exercising during television advertisement breaks, with the intensity of PA increased from light to moderate or vigorous levels. It sought to accumulate 150 minutes of moderate-intensity PA each week, incorporating muscle strengthening and aerobic activities at or near the participant's home, such as brisk walking, swimming, and cycling. Accredited exercise specialists supported the LSPA programs for 60 minutes a week during the initial 12 weeks while also training caregivers. Caregivers independently provided an additional 90 minutes of support to the participants.

The STEX programs were moderate-to-vigorous activities designed for small groups of three to six individuals. They comprised 30 to 45 minutes of cardiovascular PA and 15 to 20 minutes of muscular strength and endurance training thrice a week. Accredited exercise specialists delivered the 150-minute intervention and trained caregivers simultaneously.

During the follow-up period, caregivers continued to support the two interventions without the involvement of exercise specialists. The Control participants maintained their usual care and did not engage in additional PA during the trial. Daily logs were utilised to record participants' time spent in the interventions. This data was used to estimate the intervention compliance rate, which was defined in this study as the total time spent performing PA interventions weekly divided by the planned 150 minutes per week (see Chapter 4 for further information regarding the results of the compliance rates). More information regarding the interventions can be sought from the trial protocol (Appendix 1-A) (Lante et al., 2014).

6.2.4 Outcomes

The outcome assessments were conducted at The University of Sydney at baseline, three months post-baseline, and nine months post-baseline. As part of the trial (Appendix 1-A) (Lante et al., 2014), this standalone paper focuses on reporting the psychosocial outcomes of adults with ID. Self-efficacy was

measured using the Self-Efficacy for Activity for Persons with ID (SE-AID) scale (Appendix 5-A), which includes six self-reported items from persons with ID, such as their abilities to make time for PA or to engage in PA every day even when feeling sad or lazy or after a hard day at work (Peterson et al., 2009). Social support was measured using the Social Support for Activity for Persons with ID (SS-AID) scale (Appendix 5-B), which comprises six items reported by caregivers. These items include whether caregivers remind, encourage, instruct, or transport their clients to participate in PA. (Peterson et al., 2009). The two scales are presented as total scale points ranging from 0 to 12, with higher scores indicating a better level of self-efficacy or social support.

Other outcomes included exercise outcome expectations and participation in domestic activity. The exercise outcome expectation was measured using the Exercise Perception Scale (EPS) (Appendix 5-C), which consists of nine items reported by individuals with ID (Heller et al., 2004). This scale assesses participants' attitudes and beliefs about whether PA benefits them, such as losing weight, feeling better or less tired, meeting new people, or improving their health. Its total scale points can range from 9 to 27, with higher scores suggesting a more favourable level of attitudes and beliefs.

The Index of Participation in Domestic Life (IPDL) scale (Appendix 5-D) (Raynes et al., 1994) was employed to measure participation in everyday domestic activities, such as cleaning, shopping, and gardening. The results of the 13-item IPDL are presented as total scale points, ranging from 0 to 26, with higher scores indicating participation in more areas of domestic life and more independent participation.

All four psychosocial assessments were specifically designed and validated for individuals with ID and had been utilised in previous research involving this population (Heller et al., 2004; Peterson et al., 2009; Raynes et al., 1994). Importantly, two scales (SE-AID and EPS) involved self-reports by participants with ID, and the other two scales (SS-AID and IPDL) used reports from caregivers.

6.2.5 Statistical Analysis

The sample size was estimated for a primary outcome of the trial, as detailed in the trial protocol (Appendix 1-A) (Lante et al., 2014). Briefly, using a design with three groups and three repeated measures (assuming Cohen's $d = 0.80$, alpha = .05, power = .95, and a correlation among repeated measures = 0.5), a sample size of 90 participants (30 in each trial group) was required to allow a 23% attrition rate. However, this trial recruited 96 participants with 32 in each group. In a previous study with similar objectives involving adults with ID, an intervention group comprising 23 participants yielded statistically significant findings (Jo et al., 2018). Therefore, the sample size of the current study was considered adequate.

An individual participant might have incomplete or missing values for one or two assessments across the three measurement time points, resulting in unbalanced data. For example, some participants had difficulty understanding the questions and/or communicating their answers to scales that required self-report by participants with ID (SE-AID and EPS). As shown in Figure 6.1, the number of participants with valid data differed between groups and thus varied in the analyses. Therefore, instead of using a repeated-measures analysis of variance approach that only includes participants with complete data, this study employed linear mixed models to accommodate all the possible data, including incomplete data, for the participants in the analyses (West, 2009). The analyses were conducted using IBM SPSS software (version 28) and means were adjusted for age, sex, and body mass index (BMI). Sensitivity analyses were conducted to assess the possible impacts of any extreme values or outliers.

All outcomes were reported as mean scale points with a standard deviation (*SD*) and 95% confidence interval (CI). Cronbach's Alpha (α) was estimated at baseline to indicate the reliability of the measurement scales. Mean scale points were compared between the trial groups and within groups over time. A significance level of 0.05 was used in the analyses to indicate a statistically significant result. Where significant differences were found ($p < .05$), Cohen's d was calculated as an Effect Size using the category descriptors of Sawilowsky (2009) and Funder and Ozer (2019) which were derived from Cohen (1988).

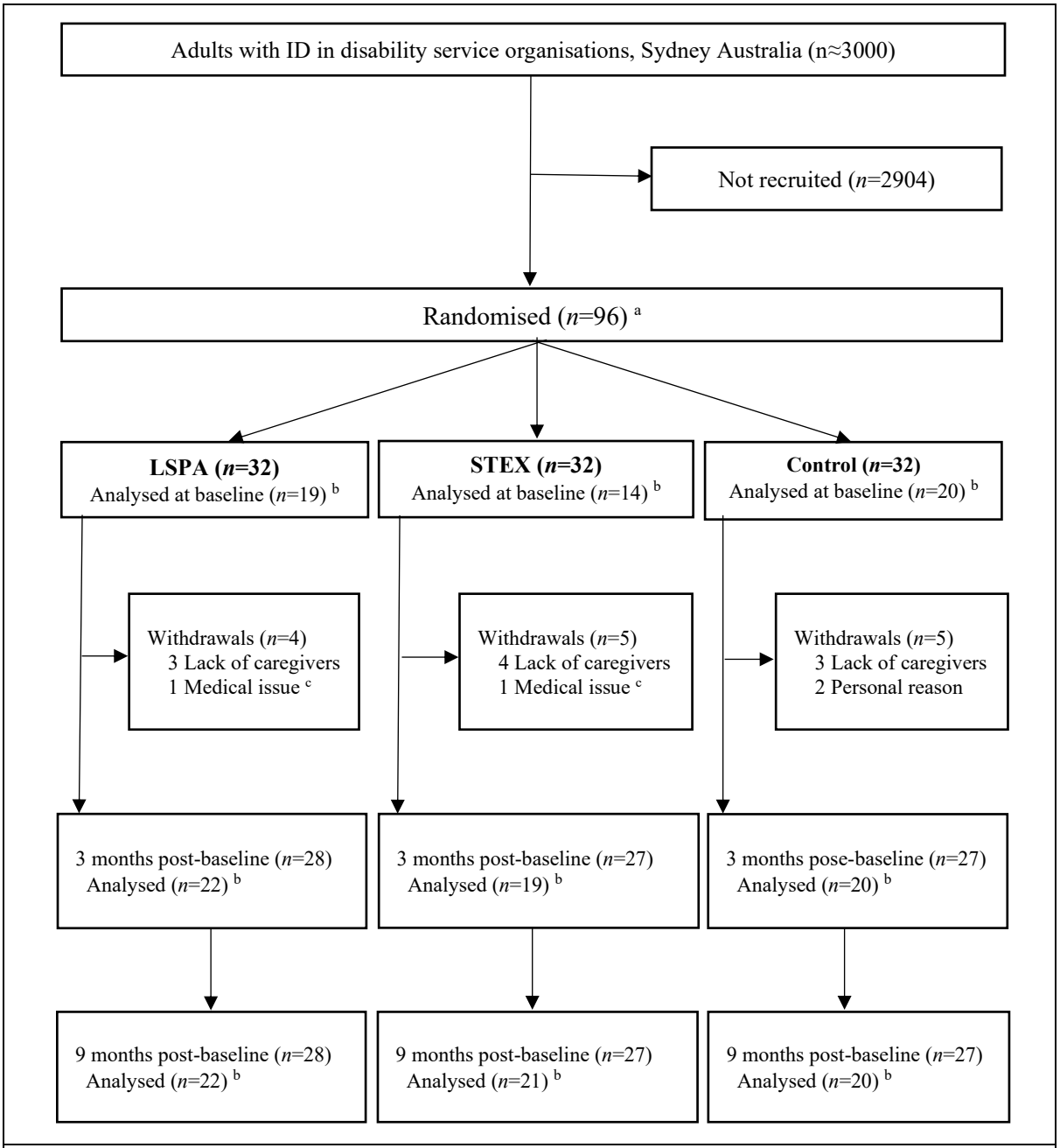

Figure 6.1. Participant flow diagram
Note. ID = intellectual disability. LSPA = lifestyle physical activity group. STEX = structured exercise group. Control = usual care group.
[a] Participants were more than the calculated sample size (90).
[b] Missing cases mainly due to incomplete or poor-quality data.
[c] Withdrawal due to a medical issue unrelated to participation in the trial.

6.3 Results

6.3.1 Participants

As illustrated in Figure 6.1, 96 eligible adults with ID were recruited for the trial from four disability service organisations in Sydney (Lorna Hodgkinson Sunshine Home, House with No Steps, Australian Foundation for Disability, and Flintwood Disability Services) between August 2011 and November 2013. They were randomly assigned to one of three trial groups. Fourteen participants were withdrawn, primarily due to a shortage of caregivers to support their participation. Missing outcome values arose from incomplete scale items. For instance, the absence of even one out of six items in a scale resulted in a missing outcome for that variable. Furthermore, the withdrawals also contributed to the absence of outcome data.

Table 6.1. Baseline characteristics [a]

	Control (*n* = 32)	**LSPA (*n* = 32)**	**STEX (*n* = 32)**	**Overall (N = 96) [a]**
Age (year) [b]				
Mean (*SD*)	40.3 (9.4)	38.4 (9.5)	36.6 (8.9)	38.4 (9.3)
Range	21 to 54	19 to 54	19 to 50	19 to 54
Gender				
Female	16 (50%)	11 (34.4%)	14 (43.8%)	41 (42.7%)
Male	16 (50%)	21 (65.6%)	18 (56.3%)	55 (57.3%)
Living facility				
Group home	18 (56.3%)	18 (56.3%)	14 (43.8%)	50 (52.1%)
Other types	14 (43.8%)	14 (43.8%)	18 (56.3%)	46 (47.9%)
BMI (kg/m^2) [b]				
Mean (*SD*)	30.7 (7.9)	32.3 (8.3)	31.4 (6.4)	31.5 (7.5)
<25.0 [c]	8 (25.8%)	5 (15.6%)	4 (12.9%)	17 (18.1%)
≥25.0 [c]	23 (74.2%)	27 (84.4%)	27 (87.1%)	77 (81.9%)
Down syndrome				
Yes	14 (43.8%)	13 (40.6%)	10 (31.3%)	37 (38.5%)
No	18 (56.3%)	19 (59.4%)	22 (68.8%)	59 (61.5%)
Smoker				
Yes	1	1	3	5 (5%)
No	31	31	29	91 (95%)

Note. Data are raw means (*SD*) or *n* (%). Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group. BMI = body mass index.
[a] Sample size at randomisation.
[b] These variables have missing data.
[c] BMI ≥ 25 denotes overweight or obese (Commonwealth of Australia, 2022).

The participants' demographic characteristics (Table 6.1) and baseline outcome data (Table 6.2) revealed no statistically significant differences between groups at baseline. Among the randomised participants, the mean age was 38.4 years (*SD* = 9.3), 55 (66.3%) were men, 50 (52.1%) resided in group homes, 37 (38.5%) had Down syndrome, and 77 (81.9%) had a BMI of 25 kg/m^2 or higher, suggesting that these participants were overweight or obese (Commonwealth of Australia, 2022). During the initial three-month intervention period, the intervention compliance rates in the LSPA group were 114% and 95% in the STEX group, while they were 104% in the LSPA group and 52% in the STEX group during the three to nine-month follow-up period (see Chapter 4 for further details regarding intervention compliance rates).

6.3.2 Outcomes

As in previous chapters, the outcomes were the LMM estimated means. Table 6.2 shows the mean scale points for each outcome assessment measured at each time point. Table 6.3 portrays the mean differences between trial groups, while Table 6.4 presents the mean differences within trial groups over time.

Table 6.2. Mean scale points in psychosocial outcomes

	Control	LSPA	STEX
SE-AID			
Baseline	*n* = 20, 6.3 (2.7)	*n* = 19, 5.6 (2.5)	*n* = 14, 6.7 (2.9)
3 months post-baseline	*n* = 20, 6.6 (2.7)	*n* = 22, 9.0 (2.5)	*n* = 19, 8.0 (3.0)
9 months post-baseline	*n* = 20, 6.6 (3.1)	*n* = 22, 7.4 (3.0)	*n* = 21, 6.9 (3.4)
SS-AID			
Baseline	*n* = 20, 6.5 (3.5)	*n* = 18, 6.5 (2.9)	*n* = 18, 6.0 (2.9)
3 months post-baseline	*n* = 19, 6.4 (3.1)	*n* = 19, 8.1 (2.4)	*n* = 20, 9.0 (2.4)
9 months post-baseline	*n* = 18, 6.3 (3.5)	*n* = 20, 6.6 (3.0)	*n* = 21, 7.9 (3.0)
IPDL			
Baseline	*n* = 27, 11.2 (5.7)	*n* = 25, 10.6 (4.7)	*n* = 24, 11.0 (6.0)
3 months post-baseline	*n* = 27, 11.2 (5.9)	*n* = 26, 11.8 (4.7)	*n* = 25, 12.9 (6.3)
9 months post-baseline	*n* = 26, 11.4 (6.1)	*n* = 27, 12.4 (5.2)	*n* = 25, 11.6 (6.9)
EPS			
Baseline	*n* = 21, 24.5 (4.9)	*n* = 23, 23.8 (2.3)	*n* = 19, 24.2 (2.5)
3 months post-baseline	*n* = 20, 23.7 (2.7)	*n* = 21, 24.7 (1.4)	*n* = 18, 24.9 (1.8)
9 months post-baseline	*n* = 19, 24.4 (4.6)	*n* = 23, 24.1 (2.0)	*n* = 21, 24.6 (2.6)

Note. Data are means (*SD*) estimated from linear mixed models adjusted for age, sex, and body mass index. *n* = number of participants analysed. Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group. SE-AID = Self-efficacy Scale for Activity for persons with intellectual disability. SS-AID = Social Support Scale for Activity for persons with intellectual disability. IPDL = Index of Participation in Domestic Life. EPS = Exercise Perception Scale.

Table 6.3. Mean differences between groups for study outcomes

	Baseline	3 months post-baseline	9 months post-baseline
SE-AID			
LSPA vs Control	-0.7 [-2.3, 1.0]	2.4 [0.8, 4.1]**	0.8 [-1.1, 2.7]
STEX vs Control	0.4 [-1.6, 2.4]	1.4 [-0.4, 3.2]	0.3 [-1.8, 2.3]
STEX vs LSPA	1.1 [-0.9, 3.0]	-1.0 [-2.8, 0.7]	-0.6 [-2.5, 1.4]
SS-AID			
LSPA vs Control	0.0 [-2.1, 2.1]	1.7 [-0.1, 3.5]	0.3 [-1.8, 2.4]
STEX vs Control	-0.6 [-2.7, 1.5]	2.6 [0.9, 4.4]**	1.5 [-0.6, 3.6]
STEX vs LSPA	-0.6 [-2.5, 1.4]	1.0 [-0.6, 2.5]	1.3 [-0.6, 3.1]
IPDL			
LSPA vs Control	-0.6 [-3.6, 2.3]	0.6 [-2.3, 3.5]	1.0 [-2.1, 4.1]
STEX vs Control	-0.2 [-3.5, 3.1]	1.7 [-1.7, 5.1]	0.2 [-3.5, 3.8]
STEX vs LSPA	0.5 [-2.6, 3.5]	1.1 [-2.1, 4.2]	-0.8 [-4.2, 2.6]
EPS			
LSPA vs Control	-0.7 [-3.1, 1.6]	1.0 [-0.3, 2.4]	-0.3 [-2.6, 2.0]
STEX vs Control	-0.3 [-2.7, 2.1]	1.2 [-0.3, 2.7]	0.2 [-2.3, 2.6]
STEX vs LSPA	0.4 [-1.1, 1.9]	0.2 [-0.9, 1.3]	0.5 [-0.9, 1.9]

Note. Data are mean differences in scale points [95% CI] estimated from linear mixed models adjusted for age, sex, and body mass index. Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group. SE-AID = Self-efficacy Scale for Activity for persons with intellectual disability. SS-AID = Social Support Scale for Activity for persons with intellectual disability. IPDL = Index of Participation in Domestic Life. EPS = Exercise Perception Scale.
*$p < .05$, **$p < .01$, ***$p < .001$.

Table 6.4. Mean differences within groups over time for study outcomes

	Control	LSPA	STEX
SE-AID			
3 months vs Baseline	0.3 [-1.0, 1.6]	3.4 [2.0, 4.7]***	1.3 [-0.2, 2.8]
9 months vs Baseline	0.3 [-1.3, 1.9]	1.8 [0.2, 3.4]*	0.2 [-1.5, 1.9]
9 months vs 3 months	0.0 [-1.4, 1.5]	-1.6 [-2.9, -0.2]*	-1.1 [-2.5, 0.3]
SS-AID			
3 months vs Baseline	-0.1 [-1.6, 1.3]	1.5 [0.0, 3.0]*	3.1 [1.6, 4.6]***
9 months vs Baseline	-0.2 [-1.7, 1.4]	0.1 [-1.5, 1.6]	1.9 [0.4, 3.4]*
9 months vs 3 months	-0.1 [-1.4, 1.2]	-1.5 [-2.7, -0.2]*	-1.2 [-2.4, 0.0]
IPDL			
3 months vs Baseline	0.0 [-1.2, 1.2]	1.2 [0.1, 2.4]*	1.8 [0.4, 3.3]*
9 months vs Baseline	0.2 [-1.4, 1.7]	1.8 [0.4, 3.3]*	0.5 [-1.4, 2.5]
9 months vs 3 months	0.2 [-1.4, 1.7]	0.6 [-0.8, 1.9]	-1.3 [-3.3, 0.7]
EPS			
3 months vs Baseline	-0.8 [-3.0, 1.3]	1.0 [0.1, 1.8]*	0.7 [-0.3, 1.8]
9 months vs Baseline	-0.1 [-2.9, 2.7]	0.3 [-0.7, 1.4]	0.4 [-0.9, 1.7]
9 months vs 3 months	0.7 ([-1.5, 3.0]	-0.6 [-1.4, 0.2]	-0.4 [-1.4, 0.7]

Note. Data are mean differences in scale points [95% CI] estimated from linear mixed models adjusted for age, sex, and body mass index. Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group. SE-AID = Self-efficacy Scale for Activity for persons with intellectual disability. SS-AID = Social Support Scale for Activity for persons with intellectual disability. IPDL = Index of Participation in Domestic Life. EPS = Exercise Perception Scale.
*$p < .05$, **$p < .01$, ***$p < .001$.

Self-efficacy for Activity

Among 53 participants with valid assessment values at baseline, the overall mean estimate for self-efficacy was 6.2 scale points (*SD* = 2.7, 95% CI [5.4, 6.9]). Cronbach's Alpha was 0.6, suggesting a minor concern regarding the reliability of the SE-AID scale. Some participants lacked the necessary capacity to complete all six items of an SE-AID, resulting in incomplete assessments. Consequently, these values were missing in the analyses.

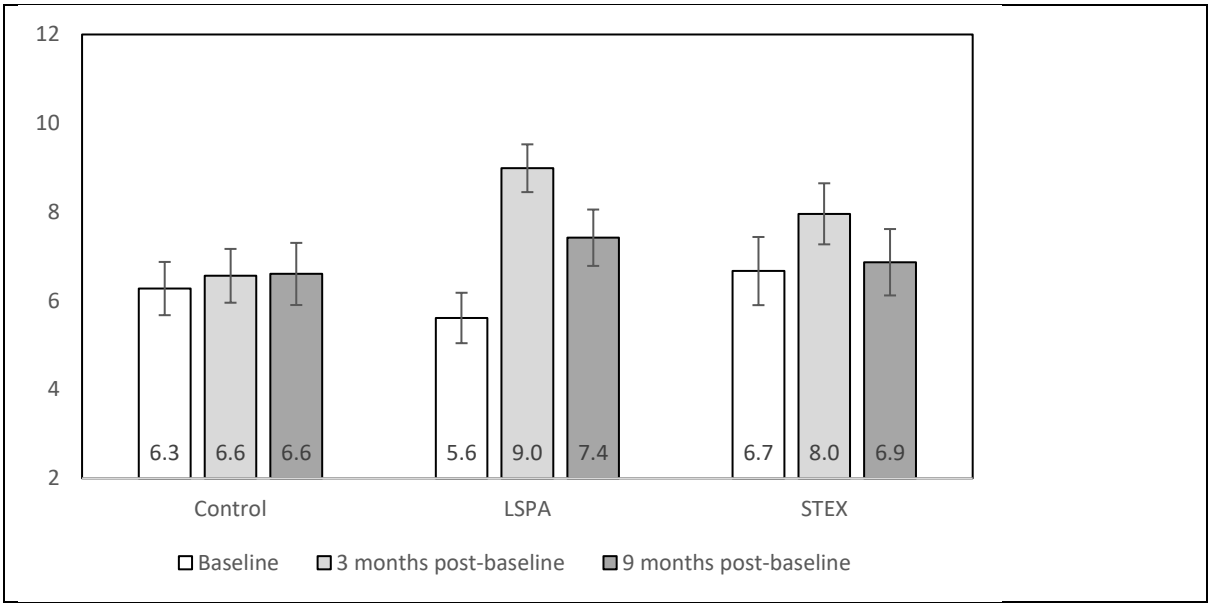

Figure 6.2. Self-efficacy for Activity for Persons with Intellectual Disabilities Scale

Note. Data are means and standard errors estimated from linear mixed models adjusted for age, sex, and body mass index. Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group.

Self-efficacy increased in the LSPA group compared to the Control group by 2.4 scale points (95% CI [0.8, 4.1], $p = .004$, $d = 1.0$) at three months post-baseline. Within the LSPA group, self-efficacy increased from baseline by 3.4 scale points (95% CI [2.0, 4.7], $p < .001$, $d = 1.4$) at three months post-baseline and by 1.8 scale points (95% CI [0.2, 3.4], $p = .024$, $d = 0.7$) at nine months post-baseline. The magnitudes of these effect sizes were large, indicating clinically meaningful results. However, self-efficacy in the LSPA group declined by 1.6 scale points (95% CI [0.2, 2.9], $p = .024$, $d = 0.6$)

from three to nine months post-baseline. Tables 6.3 and 6.4 show that all other between-group and within-group comparisons were not statistically significant.

As Figure 6.2 illustrates, self-efficacy in both intervention groups dropped from three to nine months post-baseline assessment, although this drop was not statistically significant in the STEX group. The Control group maintained similar mean scale points over time.

Social Support for Activity

Among 56 observations with valid assessment values at baseline, the overall mean estimate for social support for activity was 6.3 scale points (*SD* = 3.1, 95% CI [5.5, 7.2]). Cronbach's Alpha was 0.7, suggesting acceptable reliability for the SS-AID scale. The key reason for missing data was the incomplete assessment reported by caregivers. However, no further information was gathered on this matter.

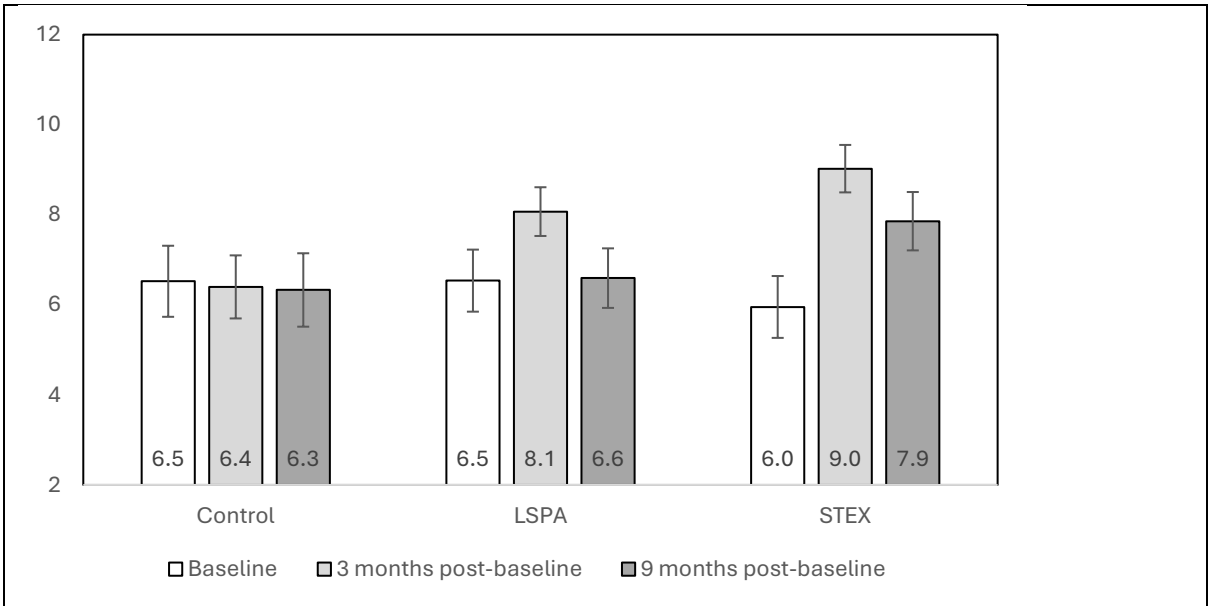

Figure 6.3. Social Support for Activity for Persons with Intellectual Disabilities Scale

Note. Data are means and standard errors estimated from linear mixed models adjusted for age, sex, and body mass index. Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group.

Social support at three months post-baseline increased by 2.6 scale points (95% CI [0.9, 4.4], $p = .004$, $d = 1.0$) in the STEX group compared to the Control group. Within the STEX group, social support increased from baseline by 3.1 scale points (95% CI [1.6, 4.6], $p < .001$, $d = 1.2$) at three months post-baseline and by 1.9 scale points (95% CI [0.4, 3.4], $p = .024$, $d = 0.7$) at nine months post-baseline. Within the LSPA group, social support increased from baseline by 1.5 scale points (95% CI [0.0, 3.0], $p = .046$, $d = 0.6$) at three months post-baseline but significantly decreased from three months post-baseline by 1.5 scale points (95% CI [0.2, 2.7], $p = .021$, $d = 0.6$) at nine months post-baseline. The effect size was large in the STEX group and medium in the LSPA group. As illustrated in Figure 6.3, the increments for social support dropped from three to nine months post-baseline. The Control group remained consistent over time. As shown in Tables 6.3 and 6.4, all other comparisons both between and within groups were nonsignificant.

Participation in Domestic Activity

Among 76 participants with valid assessment values at baseline, the overall mean estimate for participation in domestic activity was 10.9 scale points ($SD = 5.5$, 95% CI [9.7, 12.2]). Cronbach's Alpha was 0.8, indicating the good reliability of the IPDL scale. The primary reason for missing data was the withdrawals during the trial.

Figure 6.4 illustrates the changes in participants' domestic activities within groups over measurement time. The Control group did not show significant changes over time. The LSPA group exhibited a trend of increase over time. Within the LSPA group, participants engaged in more domestic activities by 1.2 scale points (95% CI [0.1, 2.4], $p = .031$, $d = 0.3$) at three months post-baseline and by 1.8 scale points (95% CI [0.4, 3.3], $p = .013$, $d = 0.4$) at nine months post-baseline, compared to baseline (Table 6.4). In the STEX group, participants engaged in more domestic activities by 1.8 scale points (95% CI [0.4, 3.3], $p = .013$, $d = 0.3$) at 3 months post-baseline compared to baseline, but this improvement returned to baseline level at nine months post-baseline. These effect sizes were of a small magnitude. No statistically significant differences were found between the trial groups (Table 6.3).

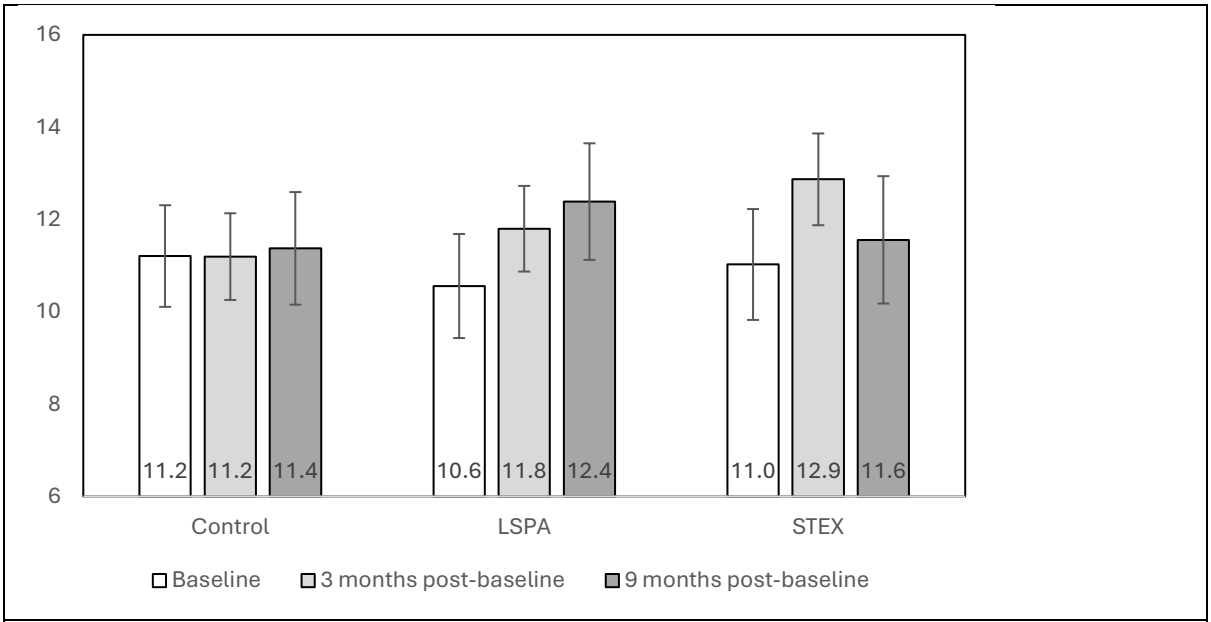

Figure 6.4. Index of Participation in Domestic Life scale

Note. Data are means and standard errors estimated from linear mixed models adjusted for age, sex, and body mass index. Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group.

Exercise Outcome Expectations

Among 63 participants with valid assessment values at baseline, the overall mean estimate for exercise outcome expectation was 24.1 scale points (*SD* = 3.4, 95% CI [23.3, 25.0]). Cronbach's Alpha was 0.4, suggesting that the reliability of the EPS scale may be questionable. Both incomplete assessments and withdrawals resulted in missing data during the trial.

In the LSPA group, participants' expectation of exercise outcome was higher by 1.0 scale points (95% CI [0.1, 1.8], $p = .03$, $d = 0.5$) at three months post-baseline than at baseline, indicating a medium magnitude of effect size. As shown in Tables 6.3 and 6.4, no other comparisons differed significantly. Figure 6.5 illustrates the changes in exercise outcome expectations in trial groups over measurement time. The Control and STEX groups did not show significant change over time.

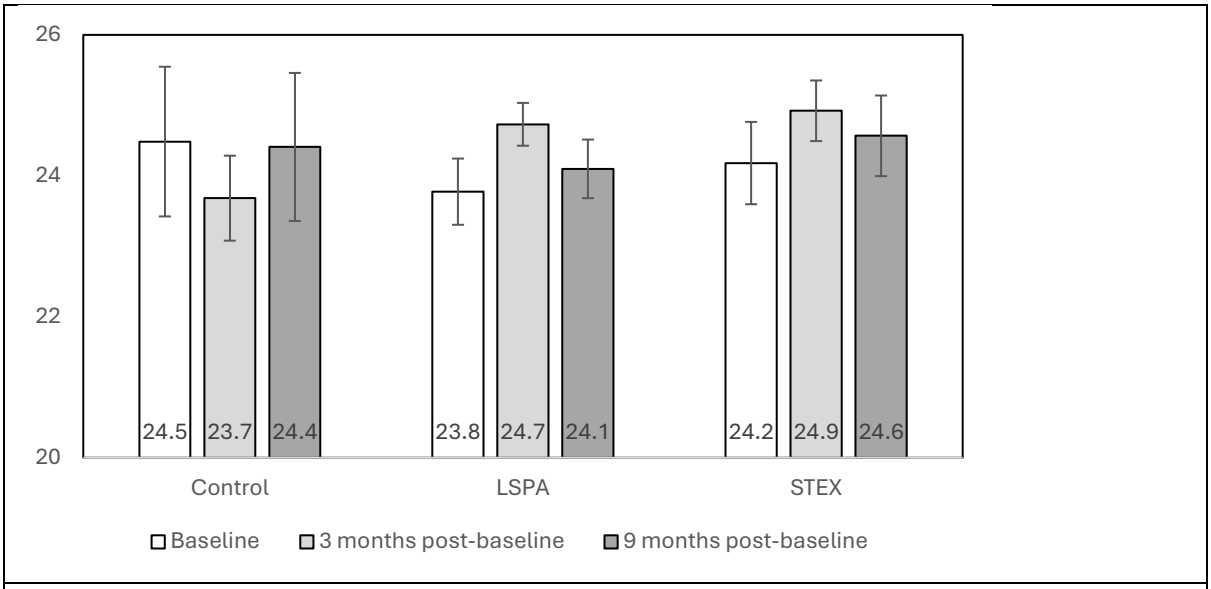

Figure 6.5. Exercise Perceptions Scale

Note. Data are means and standard errors estimated from linear mixed models adjusted for age, sex, and body mass index. Control = usual care group. LSPA = lifestyle physical activity group. STEX = structured exercise group.

Additional Analyses

The study outcomes did not significantly differ after adjusting for sex, age, or BMI. However, additional analysis was not conducted, as all extreme data were deemed plausible and therefore included in the analyses.

6.4 Discussion

This study was a pragmatic randomised controlled trial that utilised authentic materials in the group home and everyday environments of disability services for adults with ID or in nearby community facilities. It examined how the LSPA and STEX programs influenced the participants' psychosocial traits. Compared to the usual care controls, self-efficacy was improved in the LSPA group at three months post-baseline, and social support was improved in the STEX group at three months post-baseline (Table 6.3). Furthermore, most of these effect sizes exhibited a large magnitude. However, these incremental effects regressed at nine months post-baseline. When comparing the mean scale points before and after the intervention within the trial groups (Table 6.4), the LSPA intervention

proved effective in all four psychosocial outcomes. In contrast, the STEX intervention enhanced only social support and participation in domestic tasks. Regarding long-term effectiveness, participation in domestic activities consistently increased from baseline to nine months post-baseline in the LSPA group (Figure 6.4). However, as depicted in Figures 6.2-6.5, all other short-term (three-month) effects declined, indicating uncertain sustainability. Furthermore, the LSPA intervention generally exhibited better psychosocial outcomes in the trial than the STEX intervention, suggesting that the LSPA programs were more suitable for adults with ID.

The findings of this study broadly support previous research aimed at enhancing the psychosocial characteristics of adults with ID. Several studies have demonstrated that PA interventions improved self-efficacy levels for exercise among adults with ID (Heller et al., 2004; Jo et al., 2018; Marks et al., 2013; Ringenbach et al., 2023). Heller and colleagues (2004) implemented a training intervention in their study that combined an exercise program with health education classes for adult participants with ID. They found that self-efficacy levels significantly increased in the intervention group compared to the non-intervention group. Another intervention in Marks and co-authors' (2013) study, which included key elements such as training caregivers and tailoring PA programs for adults with ID to support them in their everyday lives, also significantly improved the self-efficacy of adults with ID. Moreover, cycling on a stationary recumbent bicycle effectively improved self-efficacy levels among adults with ID (Ringenbach et al., 2023). Jo et al. (2018) utilised expert advice to develop exercise programs tailored to the needs of adult participants with ID, including activities similar to the current study, such as the LSPA. In summary, the components of these interventions closely resembled those of the LSPA in the current study, particularly the one described in Marks and colleagues' (2013) study. The LSPA intervention significantly enhanced self-efficacy in the current study, indicating a large effect size, while the STEX intervention did not. The previously mentioned findings could partially explain the reasons the LSPA may have been more effective. Furthermore, the SE-AID items inquire about engaging in PA almost every day, even when busy, feeling lazy or after a hard day at work (see Appendix 5-A). Given the nature of the LSPA activities, which were personalised, part of daily routine, and individually preferred, it is perhaps not surprising that participants with ID were

more likely to self-report yes to such items compared to the STEX intervention, where the activities may have been more challenging and less preferred. An encouraging finding of this study was the confirmation of the views proposed by Bondár et al. (2020) and Westrop et al. (2024) in their reviews: caregivers' contributions and tailored PA positively influence self-efficacy for exercise among adults with ID.

Social support reciprocally facilitates PA participation among adults with ID (Brooker, 2018). In the current study, both the LSPA and STEX programs increase social support for PA, as a direct result of the interventions, with both caregivers and exercise specialists providing the support. These improvements are consistent with those of previous studies (Marks et al., 2013; Pérez-Cruzado & Cuesta-Vargas, 2016). However, during the six-month follow-up phase, the social support from exercise specialists was withdrawn, which may explain the decline in social support observed from three to nine months.

The expectation of exercise outcomes was enhanced in the LSPA group. This result is consistent with previous studies (Heller et al., 2004; Ringenbach et al., 2023). Ringenbach and colleagues' (2023) study divided cycling exercise into two groups by intensity levels. Only the cycling group with higher intensity increased this outcome. However, the STEX did not significantly enhance the expectation of exercise outcomes, although it was generally more demanding than the LSPA.

Enhancing participation in domestic activities among adults with ID was observed in the LSPA group, which is not surprising, as the Active Support approach can engage adults with ID in more daily routine activities (Clement & Bigby, 2008; Flynn et al., 2018; Stancliffe et al., 2007). As one of the aspects of community participation for individuals with ID, domestic life has been reported to receive less attention in previous studies (Verdonschot et al., 2009). The current study's findings address this gap, indicating a sustained improvement in the LSPA group. This finding suggests that the gains in PA made by this group also spilled over into greater participation in everyday domestic and community activities, possibly due to their increased physical capacity to engage in these activities. In addition, for some LSPA participants, several items assessed on the IPDL (e.g., shopping, various

types of housework, see Appendix 5-D for more details) formed part of their individually prescribed LSPA activities (e.g., walking to a local shop, taking washed clothes to and from the outdoor clothesline, cleaning), thus being directly enabled by the LSPA intervention.

The range of study outcomes in this research enabled comparisons between the LSPA and STEX programs to determine which is more suitable for the study population. The LSPA programs significantly improved all four psychosocial outcomes, while the STEX programs increased social support and IPDL results. Some previous explanations for each outcome may clarify why the LSPA did better. The LSPA programs were based on participants' everyday activities, interests, and capacities, so they were already familiar with the tasks. As a result, LSPA participants could execute these activities more effectively (Michalsen et al., 2023; Obrusnikova et al., 2021), thus significantly improving their self-efficacy. In contrast, the STEX programs were more demanding activities that required more effort from participants. Although exercise specialists worked directly with STEX participants, their self-efficacy remained unchanged. This issue should be addressed in practice and future research.

The main strength of the current study was the combination of Active Support and PA promotion in authentic community and everyday disability service environments. As a result, the findings can be directly applied to everyday disability service practice. Alongside the increased PA levels (see Chapter 4 of this thesis), these findings contribute to creating a virtuous circle because of the reciprocal relationship between promoting PA and improving self-efficacy and social support for PA (Brooker, 2018). Since the intervention procedures were conducted in participants' homes or nearby community facilities, they could more easily continue the activities under their caregivers' supervision. Furthermore, the onsite caregiver training provided in the current study enhances the capabilities of caregivers and their organisations to promote PA among their clients with ID. This Active Support approach can potentially strengthen such capabilities in the disability service sector if it is scaled up as a public health strategy. Further research is needed to explore the possibility of doing that.

Several limitations should be noted that may constrain the findings presented here. The trial aimed to examine the long-term sustainability of the interventions. As shown in Figure 6.4, the LSPA participants engaged significantly more in domestic activities post-baseline, indicating a rising trend throughout the trial. The STEX participants also increased their participation in domestic activities at three months post-baseline. However, this effect declined to the baseline from three to nine months post-baseline. Self-efficacy was significantly enhanced in the LSPA group (Figure 6.2). Nevertheless, this effect significantly decreased from three to nine months, although it remained significantly higher than the baseline. The results for social support (Figure 6.3) and exercise outcome expectations (Figure 6.5) also encountered similar issues. These findings raised concerns about the long-term sustainability of the LSPA and STEX interventions. Implementing Active Support needs to be monitored continuously to maintain long-term effectiveness (Clement & Bigby, 2008; Stancliffe et al., 2007). During the initial three months, accredited exercise specialists directly supervised participants, ensuring the quality of the Active Support interventions. For example, the relevant skills of disability staff may relate to their ability to motivate clients to engage in MVPA and instill self-belief in them that they are capable of performing MVPA effectively. Since the disability staff lack these skills (Dixon-Ibarra et al., 2017; Westrop et al., 2024), the exercise specialists may have been better at this. Therefore, there was a decline in psychosocial outcomes when exercise specialists were no longer involved in the follow-up phase. Furthermore, the staff turnover rate is high in the Australian disability sector (Behavioural Economics Team of the Australian Government, 2023). New disability staff who did not participate in the training of this study had less ability to support PA participation, which in turn may have detrimentally affected specific psychosocial outcomes, such as self-efficacy, especially during the follow-up phase. However, this study did not gather relevant data on factors such as staff turnover. As a result, this study cannot provide detailed information on the possible causes of the diminishing effects of interventions at nine months post-baseline. Further research is necessary to establish an approach that ensures interventions are delivered with the intended quality so that improvements are maintained in the long term.

Furthermore, while participants remained in the trial, some did not have valid assessment data due to inadequate ability to complete outcome assessments, especially those involving self-reports. This resulted in a loss of observations and reduced statistical power. However, the aforementioned studies (Jo et al., 2018; Ringenbach et al., 2023) utilised smaller sample sizes to detect significant results, and this issue may not unduly affect the current study's findings. Nevertheless, future studies should emphasise developing assessment methods suitable for as many adults with ID as possible. Additionally, this study focused on adults with ID who could perform MVPA. Therefore, the findings may not be generalisable to the entire population with ID, including those with co-occurring physical impairments. Further research should investigate the effects of LSPA and STEX on a larger population with intellectual disabilities.

The results of this study confirm previous research findings that participation in PA has positive psychosocial impacts on adults with ID. The findings also indicate that LSPA programs provide a range of sustainable improvements across multiple psychosocial domains, suggesting they are better suited for adults with ID than STEX programs. In particular, the long-term compliance rates of LSPA programs demonstrate strong sustainability.

Additionally, the pragmatic experience gained from this study can be directly applied in community settings. Therefore, policymakers should establish relevant policies to ensure that adults with ID can access these interventions daily, and to empower caregivers to deliver these interventions competently by providing them with necessary training and support, as demonstrated in the current study.

Acknowledgements

The author of this thesis analysed the data from a randomised controlled trial (Lante et al., 2014). The views expressed are those of the current author and not necessarily those of the trial researchers.

Declaration of interests

The authors declare no competing interests.

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CHAPTER SEVEN

Discussion and Conclusions

7 Discussion and Conclusions

7.1 Overview

The overarching goal of this thesis was to develop pragmatic programs to increase the physical activity (PA) levels of adults with intellectual disability (ID) and integrate them into their everyday lives in the longer term. By combining exercise specialists and caregiver training into the interventions, lifestyle physical activity (LSPA) and structured exercise (STEX) programs were compared to a usual care (Control) group to determine whether they could achieve this goal. This thesis had three specific objectives: (1) to systematically review the literature on the effect of PA in improving aerobic fitness (VO_2peak) among populations with ID; (2) to investigate the effectiveness, feasibility, and sustainability of the two interventions for increasing moderate-to-vigorous physical activity (MVPA) levels, physical fitness, and PA-related psychosocial characteristics of adults with ID; and (3) to explore whether the two interventions differed in these outcomes.

7.2 Summary of Findings

Chapter 1 outlined the main research questions. This summary links each question to its relevant chapter findings. Chapter 2 was a standalone study corresponding to research question 1. Chapters 3 to 6 present the results from the same trial corresponding to research questions 2 to 5.

Some key information from Chapters 4 to 6 has been summarised in tables to highlight the potential differences between the LSPA and STEX interventions. Table 7.1 presents the notable differences within the trial groups over time, while Table 7.2 illustrates the significant differences between the trial groups. The effect sizes for significant differences were interpreted using the category descriptors of Sawilowsky (2009) and Funder and Ozer (2019), which were based on the descriptors of Cohen (1988).

Table 7.1. Significant improvements (Cohen's *d*) within the LSPA and STEX groups compared to baseline [a]

Outcomes	LSPA		STEX	
	3 months	9 months	3 months	9 months
PA level (Chapter 4)				
MVPA volume	*** (*d* = 0.5)	* (*d* = 0.5)	** (*d* = 0.6)	
Physical fitness (Chapter 5)				
VO_2peak				* (*d* = 0.4)
6MWT distance	* (*d* = 0.2)	* (*d* = 0.2)	** (*d* = 0.3)	* (*d* = 0.3)
Hand grip strength				
Triceps extension strength				
Biceps flexion strength	** (*d* = 0.3)	*** (*d* = 0.7)		** (*d* = 0.5)
Knee extension strength			* (*d* = 0.3)	
Body fat percentage			** (*d* = 0.6)	
BMI				
Psychosocial outcomes (Chapter 6)				
Self-efficacy	*** (*d* = 1.4)	* (*d* = 0.7)		
Social support	* (*d* = 0.6)		*** (*d* = 1.2)	* (*d* = 0.7)
Participation in domestic activities	* (*d* = 0.3)	* (*d* = 0.4)	* (*d* = 0.3)	
Exercise outcome expectations	* (*d* = 0.5)			

Note. PA = physical activity. MVPA = moderate-to-vigorous PA. LSPA = lifestyle PA group. STEX = structured exercise group. VO_2peak = maximum oxygen consumption. 6MWT = 6-Minute Walk Test. BMI = body mass index.
* $p < .05$, ** $p < .01$, *** $p < .001$
[a] The comparisons (9 months vs 3 months) are not shown in this table for simplicity and clarity.

Table 7.2. Significant improvements (Cohen's *d*) in the LSPA and STEX groups compared to the Control group [a]

Outcomes	LSPA		STEX	
	3 months	9 months	3 months	9 months
PA level (Chapter 4)				
MVPA volume	** (*d* = 0.8)		* (*d* = 0.7)	
Physical fitness (Chapter 5)				
VO_2peak				
6MWT distance		** (*d* = 0.8)		
Hand grip strength				
Triceps extension strength				
Biceps flexion strength		* (*d* = 0.8)		* (*d* = 0.7)
Knee extension strength				
Body fat percentage				
BMI				
Psychosocial outcomes (Chapter 6)				
Self-efficacy	* (*d* = 1.0)			
Social support			** (*d* = 1.0)	
Participation in domestic activities				
Exercise outcome expectations				

Note. PA = physical activity. MVPA = moderate-to-vigorous PA. LSPA = lifestyle PA group. STEX = structured exercise group. Control = usual care group. VO_2peak = maximum oxygen consumption. 6MWT = 6-Minute Walk Test. BMI = body mass index.
* $p < .05$, ** $p < .01$, *** $p < .001$
[a] The comparisons (STEX vs LSPA) are not shown in this table for simplicity and clarity.

As shown in Table 7.2, the comparisons between the interventions and the Control groups yielded significant findings, particularly regarding the primary outcome—MVPA volume. Notably, the effect sizes and their category descriptors (Cohen 1988; Funder & Ozer 2019; Sawilowsky 2009) were large for MVPA and some physical fitness outcomes and very large for self-efficacy and social support. However, there were relatively few significant between-group improvements in relation to the Control group. Some issues contributing to this have been discussed in previous chapters. For example, another primary outcome, aerobic fitness, did not reveal a significant difference from the Control group, as the VO_2peak was significantly lower in the LSPA group at baseline compared to the Control group (see Chapter 5, Table 5.3). Although a higher VO_2peak was noted in the intervention groups compared to the Control group after the intervention ceased, the differences were not statistically significant. In contrast, the within-group comparisons (Table 7.1) demonstrated more meaningful findings across many outcomes. This thesis reported both within-group and between-group findings. Given that this research project was conducted in an applied disability service environment, the primary concern for stakeholders is whether the intervention effectively improves outcomes over time (i.e., within-group comparisons) for adults with ID. Therefore, this thesis used both results to interpret its findings.

Question 1: What is the relationship between PA and aerobic fitness among individuals with ID? If there is any significant difference, is it clinically meaningful?

Chapter 2 was a systematic review and meta-analysis that demonstrated a positive relationship between PA and aerobic fitness among individuals with ID. The VO_2peak was substantially higher by 4.2 ml/kg/min (95% CI [2.2, 6.1], $p < .0001$, $d = 0.8$) for individuals with ID who participated in MVPA compared to those who did not. Publication bias was not detected, suggesting that additional studies would not distort the findings. The effect size was large, pointing to strong clinical significance. According to the scientific statement from the American Heart Association for the general population (Ross et al., 2016), adverse event rates for cardiovascular diseases (e.g., mortality rate) can be reduced between 10% and 30% when VO_2peak is increased by 3.5 ml/kg/min,

highlighting a clinically important finding. Chapter 2's findings emphasise the necessity of improving the PA levels of individuals with ID and thus significantly bolsters the rationale for experimental components in this thesis.

Question 2: What are the current baseline levels of PA, aerobic fitness, functional capacity, muscle strength, body mass index, and body fat in a physically capable sample of Australian adults with ID who have led sedentary lifestyles? Is there a need for them to increase their PA levels?

Chapter 3 presented the baseline data of adults with ID in the randomised controlled trial (Appendix 1-A) (Lante et al., 2014). The PA level was low (see Chapter 3, Tables 3.1 and 3.2), as the average weekly time spent performing MVPA was 126 minutes (Physical Activity Guidelines Advisory Committee, 2018). Nearly 70% of participants engaged in less than the recommended 150 min/week of MVPA. Moreover, most participants did not engage in *any vigorous* PA. On a typical day, participants spent an average of 18 minutes engaged in MVPA, nearly four hours in light PA, and 6.5 hours in sedentary behaviours. A positive association was found between MVPA levels and knee extension strength, indicating a large effect size ($r = 0.3$).

Table 3.2 in Chapter 3 revealed that the fitness levels were generally poor according to the ACSM's classification standards (American College of Sports Medicine & Pescatello, 2014). However, most participants were able to complete the physical assessments satisfactorily. In previous studies, adults with ID who exhibited physical fitness levels similar to those in the current study could undertake MVPA as intended (Boer & Moss, 2016; Calders et al., 2011). This suggests that the participants in the current study possessed sufficient physical capacity to increase their MVPA. For example, the 6MWT distance was comparable to that of healthy adults (Casanova et al., 2011). However, most participants had insufficient MVPA, did not engage in vigorous PA, and spent most of their waking time in sedentary behaviours. Given that participating in sufficient MVPA improves physical fitness (Physical Activity Guidelines Advisory Committee, 2018), this study cohort required an effective intervention to increase their PA levels substantially.

Chapter 3 provides essential information: Most participants could complete the physical assessments satisfactorily with training and support, such as detailed familiarisation procedures used before conducting the outcome assessments. However, some outcome values were missing. A primary reason for this was the presence of invalid data in some outcome assessments. In research involving adults with ID, incomplete assessments and data can be a common issue, stemming from problems related to participants' ability, motivation, and logistical factors. (van Schijndel‐Speet et al., 2017). Despite the detailed familiarisation, practice, and teaching procedures, some participants found the physical requirements of specific assessments too challenging to understand and comply with, which resulted in them not completing those assessments as intended. For example, some individuals were unable to undertake the required exercise intensity for the aerobic fitness assessment (cycle ergometer) that was strenuous enough to reach the requisite steady-state heart rate or could not complete a minimum 3-minute duration, both of which resulted in invalid data for predicting their VO_2peak. Another reason for missing data was that some individuals were just unwilling to undertake a physical assessment. There were 94 participants with valid outcome data in 6MWT, 82 to 87 in muscle strength tests, and 74 in the aerobic fitness assessment. Given that almost 23% of participants could not sufficiently comply with the assessment's requirements to generate valid data, the maximal exercise aerobic fitness test (VO_2peak) using a cycle ergometer may need to be modified in future research to suit this population better, or they may need more practice and verbal guidance to complete this assessment successfully.

Question 3: Can the two interventions enhance the PA levels of adults with ID? If so, are the effects clinically meaningful? Are the two interventions feasible and sustainable in the long term? Do the impacts of the two interventions differ?

In Chapter 4, PA was measured using the International Physical Activity Questionnaire for people with ID (IPAQ-ID) (Lante, 2007). It assigns a metabolic equivalent (MET) value to each activity, resulting in a single number in MET-min/week, which exercise specialists or medical doctors can use to assess treatment doses. A minimum of 500 MET-min/week of MVPA is sufficient to achieve long-

term health benefits (Physical Activity Guidelines Advisory Committee, 2018). Chapter 4 established that the two interventions could substantially increase the MVPA levels of adults with ID by more than 500 MET-min/week in both between-group and within-group comparisons (see Chapter 4, Tables 4.3 and 4.4). The effect sizes (d = 0.5 to 0.8) were medium to large, indicating clinically meaningful outcomes (Tables 7.1 and 7.2). Therefore, these improvements revealed that intervention benefits were clinically meaningful and indicated notable importance in community practice.

Although consistent evidence regarding interventions to increase MVPA levels in adults with ID is lacking (Hassan et al., 2019), available evidence partially supports the findings of Chapter 4. van Schijndel‐Speet et al. (2017) developed a PA program featuring an educational component designed to enhance knowledge about PA and its benefits for adults with ID. In the study by Shields et al. (2013), students with professional exercise knowledge were employed to assist young people with ID in engaging in MVPA at community gyms. The two strategies were combined into a community-based health promotion study (Bazzano et al., 2009). All these interventions involved individuals with ID in significantly more MVPA. The current study expanded upon the aforementioned features by incorporating caregiver training and accredited exercise specialists into the interventions. The LSPA and STEX interventions were developed using Active Support, which can engage adults with ID in participating in more daily activities (Flynn et al., 2018; Stancliffe et al., 2008).

Both interventions significantly increased MVPA levels at three months post-baseline compared to the Control group. However, these between-group comparisons were not statistically significant at nine months post-baseline. The MVPA levels remained comparable at the two post-baseline measurement time points (Chapter 4, Table 4.2 and Figure 4.2). However, the MVPA level in the Control group increased markedly at nine months post-baseline, likely contributing to non-significant comparison outcomes.

In the LSPA group, MVPA levels significantly increased from baseline to three months of intervention, and these considerable improvements were sustained at nine months post-baseline.

Furthermore, the intervention compliance rates were maintained above 100% for the LSPA group throughout the trial (see Chapter 4, Section 4.3). Since caregivers supported the interventions without the involvement of exercise specialists during the follow-up period, these findings suggested that the LSPA programs are feasible and sustainable in the longer term. The STEX group did not show statistically significant MVPA outcomes at nine months post-baseline and exhibited a compliance rate of only 52% between three- and nine-month periods. So, while the LSPA group met the MVPA "target" volume at three and nine months after the intervention started, the STEX group only achieved this at three months when exercise specialists conducted the group training programs.

As illustrated in the participant flow diagram (Chapter 4, Figure 4.1), missing outcome data were prevalent. Beyond the 14 withdrawals, the primary reason for the missing data was that some caregivers were unable to complete all the questions in the IPAQ-ID, resulting in invalid outcome assessments. For example, MVPA was the sum of vigorous PA and moderate PA. Therefore, when vigorous PA was absent, MVPA volume was also missing, although moderate PA was not.

Question 4: What are the relationships between the two PA interventions and physical fitness (i.e., aerobic fitness, muscle strength, and functional walking capacity) in adults with ID? If there is improvement, are the effects sustainable in the long term?

Chapter 5 revealed that the LSPA and STEX groups significantly improved the physical fitness levels in adults with ID except for BMI and hand grip strength (see Tables 5.3 and 5.4 in Chapter 5). These findings were consistent with previous studies that evaluated the effects of PA interventions on physical fitness among individuals with ID (Boer & Moss, 2016; Calders et al., 2011; Rimmer et al., 2004). The significant improvements were remarkably consistent in those studies involving exercise professionals in their interventions (see the forest plot in Chapter 2, Appendix 2-D, Figure 2-D.4).

Tables 7.1 and 7.2 present some significant findings along with effect sizes. The VO_2peak in the STEX group increased substantially by 3.7 ml/kg/min over time with a medium effect size (d = 0.4). A greater than 3.5 ml/kg/min increase is considered a clinically meaningful finding (Ross et al.,

2016). However, the VO_2peak at baseline was higher in the Control group than in the two intervention groups, which somewhat confounded between-group comparisons (see Chapter 5, Table 5.3). For example, it was higher by 4.1 ml/kg/min in the Control group than in the LSPA group, which is an important difference (> 3.5) (Ross et al., 2016). Consequently, even though both the LSPA and STEX groups improved over time, the comparisons with the Control group did not show statistically significant differences. This was unexpected because the meta-analysis in Chapter 2 demonstrated a significant improvement (d = 0.8) in VO_2peak in the PA intervention group compared to the non-PA control group (see Chapter 2, Figure 2.2).

The functional walking capacity at nine months post-baseline showed a significant improvement of 64 metres in the LSPA group compared to the Control group. The large effect size (d = 0.8) indicated both strong clinical and functional significance. This outcome also demonstrated significant improvements in both intervention groups at three and nine months compared to baseline. These effect sizes were small (d = 0.2 to 0.3), suggesting a greater potential for enhancing participants' opportunities and abilities to engage in relevant PA. For example, some light PA could be adapted into moderate-to-vigorous intensity efforts, such as brisk walking for transportation.

Three significant between-group comparisons were observed at nine months, while 10 out of the 13 significant within-group comparisons also occurred during this period. Notable improvements were detected nine months post-baseline, indicating that trained caregivers could continue supporting the interventions, even after the exercise specialists had stopped working with them. Therefore, the two interventions demonstrated their longer-term sustainability in improving physical fitness in adults with ID. Unfortunately, missing data were identified for all assessments, with reasons consistent with those outlined in research question two.

Question 5: What are the relationships between the two PA interventions and PA-related psychosocial changes (e.g., self-efficacy and social support for PA) in adults with ID? If there is improvement, are the effects sustainable in the longer term?

At three months post-baseline, the LSPA programs significantly improved self-efficacy, social support, participation in domestic activities, and exercise outcome expectations (see Chapter 6, Tables 6.3 and 6.4). Notably, on a scale with a maximum total of 12 scale points, self-efficacy in the LSPA group increased substantially from baseline by 3.4 scale points at three months post-baseline (d = 1.4). Compared to the Control group, the LSPA group demonstrated a significant increase in self-efficacy at three months post-baseline (d = 1.0). The two effect sizes were very large, indicating that these improvements were clinically meaningful in disability practice. Both interventions significantly increased social support at three months post-baseline.

Chapter 6 confirmed the positive relationships between the LSPA and STEX interventions and PA-related psychosocial factors in adults with ID (Tables 7.1 and 7.2), consistent with previous studies. In their study, Marks et al. (2013) deployed caregiver training and individualised PA programs for adults with ID that were more comparable to the LSPA programs. These approaches demonstrated significant improvements in self-efficacy and social support. In addition to these approaches, the current study deployed accredited exercise specialists to directly assist adults with ID in engaging in MVPA. Since exercise specialists ensured the quality of the interventions, it was not surprising that the LSPA programs significantly improved self-efficacy and social support. Although several studies have reported that PA interventions significantly improve psychosocial outcomes in adults with ID, they have not provided information on long-term sustainability (Heller et al., 2004; Jo et al., 2018; Marks et al., 2013; Ringenbach et al., 2023). The current study investigated the longer-term effects, raising some concerns about the sustainability of the interventions. Participants consistently participated in more activities throughout the trial. However, all other significant improvements declined at nine months post-baseline (i.e., self-efficacy in the LSPA group and social support in the STEX group). This drop in improvement might be attributed to the withdrawal of exercise specialists during the follow-up phase. Given the higher caregiver turnover rates (Behavioural Economics Team of the Australian Government, 2023), it may also result from the loss of trained caregivers.

Missing outcome data were identified for all psychosocial assessments. The primary reason was that some scale questions were challenging for participants or caregivers to complete, leading to incomplete assessments. Particularly for the Self-efficacy Scale for Activity for Persons with ID, participants with ID could not answer all six questions, resulting in invalid assessments.

Synthesis of the thesis's findings

In summary, this thesis has achieved its research goal. PA programs can significantly increase aerobic fitness in individuals with ID (Chapter 2). With a large effect size (d = 0.8), this finding indicates substantial clinical significance for disability service practices. The study participants exhibited low levels of MVPA and aerobic fitness while spending most of their time engaging in sedentary behaviours (Chapter 3), suggesting that they required an intervention to enhance their MVPA levels and, in turn, improve their aerobic fitness.

Although few between-group comparisons were statistically significant, they covered three major domains, particularly MVPA levels (Table 7.2). Compared to the Control group, MVPA levels significantly increased in both intervention groups at three months post-baseline, functional walking capacity improved notably in the LSPA group at nine months post-baseline, biceps flexion strength was enhanced significantly in both intervention groups at nine months post-baseline, self-efficacy observed significant improvement in the LSPA group at three months post-baseline, and social support was notably enhanced in the STEX group at three months post-baseline. No other between-group comparisons showed significant improvements. In contrast, significant within-group comparisons were exhibited in most of the study outcomes (Table 7.1). Although between-group comparisons investigate the effectiveness of interventions (e.g., LSPA and STEX) against controls (e.g., usual care), within-group comparisons assess changes in an individual's outcomes over time, indicating longer-term sustainability across repeated measurement points. The improvements in MVPA and physical fitness were maintained over the longer term, while the gains in psychosocial outcomes declined from three months to nine months post-baseline. Since self-efficacy and social

support facilitate PA participation in adults with ID (Dixon-Ibarra et al., 2017), further research is needed to address this issue. Interestingly, participants increasingly engaged in domestic activities in both the short and longer term, indicating an improved ability to live more independently.

In addition to the above, a crucial finding is that the comparisons between the two interventions (Tables 7.1 and 7.2) revealed how they influenced outcomes differently: the LSPA programs showed greater effectiveness in enhancing PA levels and psychosocial factors, while the STEX programs were more effective for improving attributes of physical fitness. In disability service practice, the LSPA programs might prove to be more feasible and sustainable in the longer term, as evidenced by the excellent follow-up compliance rate. Combining the best features of the two interventions may provide the optimal solution to obtain all the benefits (see further discussion in Section 7.5).

7.3 Key Features of The Interventions

This was the first study, to the author's knowledge, using Active Support to increase PA participation in adults with ID living in group homes. Active Support is a practical approach that enables individuals with ID to participate in more daily activities in group home settings (Flynn et al., 2018; Stancliffe et al., 2008). In Australia, two studies implemented Active Support in group homes for individuals with ID (Clement & Bigby, 2008; Stancliffe et al., 2007). Stancliffe et al. (2007) investigated the Active Support application in five Australian group homes. They demonstrated a positive relationship between caregiver support and participants' activity engagement, reporting significant improvement in support and activity engagement. Clement and Bigby (2008) focused on caregiver training in 16 Australian group homes and successfully enabled caregivers to apply Active Support to supporting individuals with ID in their workplaces. In other words, caregivers can utilise Active Support to increase daily activity participation in individuals with ID living in group homes. These research findings are consistent with this thesis's outcomes, including improvements in PA participation, social support from caregivers, and engagement in domestic activities.

In an insightful review, Stancliffe et al. (2008) presented several essential elements of Active Support that must be considered when designing interventions to increase participation in activities by adults with ID living in group homes or similar facilities (see Chapter 1, Tables 1.1 and 1.2). The two tables illustrated the alignment between the Active Support requirements and the LSPA and STEX interventions. More specifically, the two interventions (1) focused on assisted participation in PA; (2) provided support through verbal requests, step-by-step verbal instructions, gestures, physical guidance, and other features; (3) focused on engagement by incorporating the interests, enjoyment, and other issues raised by relevant stakeholders; and, (4) provided onsite caregiver training when exercise specialists were implementing the interventions. There was no team training for group homes because only specific individual staff members took part in the trial, rather than the entire group home staff. Therefore, the LSPA and STEX programs clearly demonstrated the key features of Active Support. Nevertheless, LSPA aligns more closely with Active Support because its more individualised programs correspond with person-centred Active Support (Jones & Lowe, 2008). As the name implies, LSPA programs integrate more seamlessly with the individual's existing lifestyle and daily routine activities (Flynn et al., 2018; Stancliffe et al., 2008), which represents another key feature of person-centred Active Support and likely contributed to the much higher compliance rate of the LSPA group during the follow-up period. Furthermore, participants may feel more comfortable and capable of performing LSPA activities due to their familiarity with their routines and appropriate support (Dixon-Ibarra et al., 2017). This likely contributed to significant improvements in PA self-efficacy. Therefore, LSPA programs appear feasible in everyday disability service practice.

On-site caregiver training is crucial to the implementation of Active Support (Clement & Bigby, 2008; Stancliffe et al., 2008). Clement and Bigby (2008) reported that caregivers initially opposed applying the Active Support approach until they observed positive changes in participant engagement. Moreover, the LSPA and STEX interventions increased PA intensity to moderate-to-vigorous levels (Appendix 1-A) (Lante et al., 2014) and must focus on engagement using authentic materials and activities and involving interactive coaching and feedback (Stancliffe et al., 2008). To achieve the above, professional knowledge and skills are required (Kreinbucher-Bekerle et al., 2022). However,

participants and their caregivers likely lacked these skills and experiences and therefore engaged in less PA (Dixon-Ibarra et al., 2017). In this thesis, Australian accredited exercise specialists instructed participants and trained caregivers on-site (Appendix 1-A) (Lante et al., 2014). By involving caregivers in planning PA programs, exercise specialists determine the type, intensity, and duration of these programs and gradually increase them to a suitable level for participants. For example, PA intensity increased over 12 weeks from light-to-moderate intensity for LSPA programs and from moderate-to-vigorous intensity for STEX programs. These strategies enhanced the quality of interventions and on-site caregiver training. Michalsen et al. (2023) employed a similar strategy to increase PA participation in individuals with ID.

This thesis presented a broad range of outcomes, facilitating comparisons between the two intervention groups, which benefited in diverse ways. In addition to the previously mentioned key features of the LSPA, several factors may influence the effects of the interventions differently. In the LSPA group, exercise specialists provided 60 minutes of direct support for participants. By contrast, exercise specialists conducted the entire 150-minute STEX intervention. Previous studies involving individuals with ID have shown that PA interventions featuring exercise professionals in the implementation process consistently led to improvements in physical fitness (Boer & Moss, 2016; Calders et al., 2011; Naczk et al., 2021), while those without the involvement of exercise professionals did not (Cowley et al., 2011; Millar et al., 1993). Further evidence can be found in the forest plot within Chapter 2 (Appendix 2-D, Figure 2-D.4). Moreover, the intensity of STEX activities was moderate-to-vigorous, higher than that for LSPA. So, participants in the STEX group exercised more vigorously than those in the LSPA group, resulting in better benefits to aerobic fitness (VO_2peak) (Physical Activity Guidelines Advisory Committee, 2018) and for a broader range of physical fitness attributes (see Table 7.1).

As previously noted, the LSPA intervention demonstrated greater benefits to psychosocial outcomes. Given the reciprocal relationship between PA participation and psychosocial factors (e.g., social support) (Brooker, 2018), the findings reveal a mutual benefit between these two outcomes.

Furthermore, according to theories of behavioural changes (U.S. Department of Health and Human Services, 2018), improved exercise outcome expectations and self-efficacy promote the transition from sedentary to physically active behaviour. These findings suggest the potential for enhanced sustainability of LSPA programs in the long term.

7.4 Limitations of the Thesis

Some inherent limitations and problems that arose during the trial constrained this study's findings. Given that the study participants were physically capable and lived in group homes or other supported facilities, one obvious limitation is that the findings of this thesis may not apply to those with concomitant physical impairments or those living with their families.

During the trial, some caregivers were already too busy at work and thus unable to support their clients' participation. This situation affected 10 of the 14 withdrawals from the trial prior to the intervention's commencement. Other reasons for withdrawals included medical issues (2 participants) and personal reasons (2 participants). Of all withdrawals, 11 were from the same organisation. This outcome suggests that any organisation's staffing situation may not be sufficient to enable a caregiver-supported intervention. Future research and practice should investigate the specific circumstances needed (e.g., ratio of caregivers to clients; caregiver characteristics) to ensure the effective implementation of such interventions. Despite the number of participant withdrawals, the trial sample size allowed for 23% attritions (Appendix 1-A) (Lante et al., 2014), suggesting an acceptable withdrawal rate. As the number of withdrawals was nearly equal for each group (see Chapter 4, Figure 4.1), the withdrawals were unlikely to have a differential influence between groups.

A shortage of caregivers may result in their absence from intervention sessions, leading to lower intervention compliance rates, especially in the follow-up phase, where caregivers are solely responsible for intervention implementation. Due to randomisation, STEX participants were usually drawn from several different group homes and transported by caregivers to an intervention site. This process added extra time and cost and required additional caregivers. Thus, the caregiver shortage and

the logistical issues in the STEX group may have significantly contributed to a decline in compliance rates from 95% to 52%, indicating less feasibility and sustainability for STEX programs. By contrast, LSPA participants undertook activities in their living and everyday disability service settings, maintaining a satisfactory compliance rate of over 100%. Because of the individual nature of the LSPA intervention, in practice, the randomisation procedure would be irrelevant, thus circumventing any logistical issues. Combining the key features of the two interventions may be a viable approach in everyday disability service practice.

Missing assessment data were identified for most study outcomes, which resulted in weaknesses in the statistical analyses. The reasons have been outlined in the summary of research questions (see Section 7.2), including participants' insufficient ability and willingness to respond to questionnaire items and comply with the requirements of physical assessments. This highlights the drawbacks regarding the usefulness of several outcome assessments for adults with ID (e.g., cycle ergometer), which should be addressed in future research to identify assessment types that a larger percentage of participants with ID can comply with.

The caregivers' performance was not evaluated and supervised during the follow-up, so there is no information on the nature and quality of implementation beyond basic compliance. Drawing on the Active Support literature, an evaluation system must be established to monitor the ongoing implementation of Active Support (Clement & Bigby, 2008; Stancliffe et al., 2007). Clement and Bigby (2008) tracked their project for 12 months to gather information on the implementation of Active Support. They highlighted that the absence of an evaluation and monitoring system posed a threat to the sustainability of successful Active Support implementation. Key features of such a system may include a set of written records for individual participants: 1) individualised activity and support plans; 2) records of activity goals and criteria for performing activities each time; 3) step-by-step protocols for completing activities; 4) ongoing caregiver training; 5) observation and written assessment instruments for evaluating the implementation of Active Support; 6) documented maintenance and adjustment records of the routine work activities of caregivers (Clement & Bigby,

2008; Stancliffe et al., 2007). This approach could also be applied to monitor the sustainability of caregiver-supported interventions to increase PA.

In this trial, cluster effects might exist. The potential cluster was the group home (or the STEX group). Participants from the same cluster may have similar outcomes and differ from those in other clusters. For example, some group home staff may have been more diligent or better at implementing the intervention, leading to participants from that group home performing better. Alternatively, a trained staff member may have been replaced by an untrained one due to job changes, causing participants from that group home to experience worse outcomes. However, this trial was not designed to gather relevant evidence on clustering. The existence and extent of cluster effects are unknown and should be evaluated in future research.

Table 7.2 shows limited effects on outcomes when comparing the intervention and control groups. For example, the IPAQ-ID outcomes did not differ at nine months. The main issue was the significant increase in MVPA of the control group at nine months (as discussed in Section 4.4). Another concern was the wide range of IPAQ-ID data (zero to 6030 MET-min/week) (see Section 4.3). Future research should address these issues, such as keeping the control participants out of PA interventions or recruiting participants based on different PA levels. Overall, these limitations mentioned above mean that the study findings should be interpreted cautiously.

7.5 Implications for Practice and Future Research

This trial, reported in the current thesis, was an authentic project that presented practical and feasible interventions for promoting PA among adults with ID in group homes and everyday disability service environments. It involved screening and, if necessary, clearance from a medical practitioner for participation in PA, with accredited exercise specialists delivering the intervention activities. These strategies significantly reduced participants' and caregivers' concerns about participating in PA, such as those (e.g., safety, skills, etc.) found in a previous study (Dixon-Ibarra et al., 2017). Combining the pragmatic and valuable experience and knowledge from the two Active Support projects (Clement &

Bigby, 2008; Stancliffe et al., 2007) for adults with ID in the same type of settings (Australian group homes), the current thesis's findings can be directly applied to everyday disability service practice. However, these findings for group homes and disability staff may not apply to individuals living with their families. One option for future research is to work specifically with adults with ID and train family members to support the person with ID in engaging in increased MVPA.

Another key point for everyday practice is access to accredited exercise specialists. Fortunately, one-on-one specialist services provided by an accredited exercise specialist have been included in the Australian Disability Insurance Scheme (Australian National Disability Insurance Agency, 2023), which is accessible to adults with ID. These services, comprising personal training and physical well-being activities, can be delivered to individuals or small groups. Although caregiver training is not currently part of these services, exercise specialists working collaboratively with caregivers in the long term may help increase PA participation. In the trial, the involvement of exercise specialists during the 3-month intervention phase is an example of how this might work. Future studies should explore whether these exercise specialists can effectively work with disability services to facilitate wide-scale implementation of Active Support in promoting PA among adults with ID.

Further work is needed to establish an evaluation system for long-term operation, as Clement and Bigby (2008) and Stancliffe et al. (2007) recommended. Clement and Bigby (2008) reported that caregivers felt stressed about implementing Active Support in their workplaces, which can hinder operations. An evaluation system enables caregivers and managers to clearly understand their practice. However, gathering implementation data (see the recommendations in Section 7.4) is carried out by caregivers, which increases their stress and workload. Additional research is necessary to identify ongoing data collection methods that yield enough information without overburdening caregivers.

As previously mentioned, a combination of LSPA and STEX may be workable to support PA participation among adults with ID. During the trial, the STEX group encountered logistic problems

due to randomisation. In everyday practice, because randomisation is inappropriate, these problems can be minimised or overlooked unless they pertain to research purposes. In contrast, LSPA programs continued routine activities. Given that the two interventions have different benefits, integrating the features of LSPA and STEX into a single approach in real-world practice may be a viable option to harness all advantages. The primary distinction between LSPA and STEX was the delivery methods of PA programs, not the types of PA. Therefore, these authentic programs could be combined and customised more effectively to suit an individual's circumstances, physical abilities, routines and available supports.

7.6 Conclusions

This thesis was the first to employ the Active Support approach to increase PA participation among adults with ID. It involved accredited exercise specialists and included caregiver training as an integral component of the LSPA and STEX interventions. The findings indicate significant improvements in MVPA participation, physical fitness, and PA-related psychosocial characteristics. In keeping with the principles of Active Support, this project was delivered within a typical disability community service setting by disability staff. It became part of the daily lives of adult disability service users with ID. Policymakers should consider embedding these approaches into routine disability support services.

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Appendices

Appendix 1-A. Study Protocol for the Randomised Controlled Trial

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BMC Public Health

STUDY PROTOCOL Open Access

Embedding sustainable physical activities into the everyday lives of adults with intellectual disabilities: a randomised controlled trial

Kerrie Lante[1], Roger J Stancliffe[2*], Adrian Bauman[3], Hidde P van der Ploeg[3,4], Stephen Jan[5] and Glen M Davis[6]

Abstract

Background: Adults with intellectual disability (ID) are physically very inactive. This study will compare two approaches to increasing physical activity in adults with ID: a lifestyle physical activity (light-moderate intensity) approach and a structured exercise (moderate-vigorous intensity) approach. The trial will compare the short-term (3-month) and long-term (9-month) outcomes and sustainability of each approach with a usual-care control group.

Methods/Design: A three-arm randomised controlled trial (RCT) will be conducted. Ninety adults with ID aged 18-55 will be randomly assigned to one of three groups: 1) a lifestyle physical activity group ($n = 30$), 2) a structured exercise group ($n = 30$), or 3) a usual care control group ($n = 30$). Participants in both groups will receive a 12-week intervention delivered by exercise specialists in the community with disability service staff, after which intervention will continue for 6 months, delivered by disability service staff only. Primary outcomes are aerobic fitness, 12-hour energy expenditure, and proxy-reported everyday physical activity. Secondary outcomes include objectively assessed physical activity and sedentary behaviour, intervention compliance, functional walking capacity, participation in domestic activities, muscle strength, body composition, psychosocial outcomes, quality of life and health care costs.

Discussion: The trial results will determine the effectiveness and sustainability of two approaches to increasing physical activity and exercise among adults with ID.

Trial registration: ISRCTN77889248 (18 April 2012).

Keywords: Intellectual disability, Community living, Physical activity, Exercise

Background

Adults with intellectual disability (ID) are substantially less physically active than the general community [1-3] which may contribute to preventable physical and mental health problems [4,5]. In Australia, the proportion of adults with ID who meet national guidelines for physical activity [6] is only around half that of the general community [7]. People with ID have a right to good health and a healthy lifestyle, yet without adequate exercise and physical activity they are more likely to experience a lower quality of life and a higher level of physical and mental ill health. Failing to address these issues places an increased burden on families and carers, as well as on disability services and health systems. Such preventable health problems can increase dependency (requiring higher disability service staffing levels), add to absenteeism from disability employment, and result in premature withdrawal from the workforce and greater health care utilisation [5].

The majority of adults with ID have the potential to meet the physical activity guidelines [8-10], but people with ID need direct personal support to plan, organise, travel to and participate in physical activities. There is a ready source of such support: disability service staff who already provide daily (usually 24-hour) support to their clients. However, these staff do not usually have the skills to support physical activity and exercise of appropriate intensity and duration. Crucially, research on 'Active Support' from staff has shown (a) that appropriate personal support strongly increases participation in functional everyday

* Correspondence: roger.stancliffe@sydney.edu.au
[2]Centre for Disability Research and Policy, The University of Sydney, PO Box 170, Lidcombe NSW 1825, Australia
Full list of author information is available at the end of the article

activities by adults with ID and (b) that disability staff can be trained to provide it [11,12].

Physical activity is an important national policy issue in Australia [13]. The objective of this project is to improve the physical activity, aerobic fitness, strength and well-being of adults with ID by increasing their everyday physical activity and exercise levels in a manner that is sustainable in the long-term. This will involve comparing two approaches to disability staff support of physical activity by adults with ID: (I) a lifestyle physical activity (light-moderate intensity [LMI] lifestyle) approach and (II) a structured exercise (moderate-vigorous intensity [MVI] exercise) approach. The effectiveness of the two strategies for increasing physical activity and exercise in adults with ID will be evaluated and compared to a usual-care control group. By contrasting two different approaches to increased physical activity we will compare the short-term (3-month) and long-term (9-month) effectiveness and sustainability of both strategies. In addition, the project will evaluate the cost-effectiveness of both strategies.

Methods

The trial has been registered on International Standard Randomised Controlled Trial Number Register (ISRC TN77889248).

Funding

The study is being funded by National Health and Medical Research Council (Australia) Partnership Grant APP 1012692, and two disability industry partners, Lorna Hodgkinson Sunshine Home, and House With No Steps.

Design

A three arm randomised controlled clinical trial (RCT) will be conducted. Exercise specialists will deliver either a 3-month LMI-Lifestyle physical activity program or a structured MVI-Exercise program. During program delivery, exercise specialists will train disability service provider staff so that they can continue the program post intervention. The trial will be conducted with the two partner organisations, which provide services to adults with ID across Sydney, New South Wales, Australia. These services include (a) staff supported accommodation in small group homes or other community-based settings and (b) sheltered employment.

Ethics approval has been obtained from Sydney University Human Research Ethics Committee (HREC 05-2011/13821). Participants and where relevant their caregiver or guardian will be provided with information sheets, and written informed consent will be obtained prior to inclusion in the study and baseline assessment. Any adverse events related to the trial will be recorded and reported to the Human Research Ethics Committee.

Participants

Ninety adults with ID will be recruited through the disability partner organisations on a rolling schedule. Those interested in participating will be asked to complete a Physical Activity Readiness Questionnaire (PAR-Q) [14] and where concerns are identified by the PAR-Q, medical clearance will need to be obtained in order to participate in the study.

Inclusion criteria

Participants will be included if:

1. they have intellectual disability
2. they are aged between 18-55 years
3. it is reported they have been physically inactive for the past 12 months or longer
4. they reside within a 1.5-hour commute to the testing site
5. they are able to participate in assessments such as the 6-minute walk test
6. there is a signed informed consent in accordance with the ethics requirements.

Exclusion criteria

Participants will be excluded if:

1. they have contraindications to participating in exercise programs or outcome assessments, as advised by the primary care physician and/or ineligibility according to American College of Sports Medicine (ACSM) criteria [15].
2. they are judged at risk of self-harm by the disability service provider care staff.

Randomization

Participants will be randomly assigned to one of three groups: 1) a LMI-Lifestyle intervention physical activity group 2) a structured MVI-Exercise group or 3) a usual care control group.

Intervention

Intervention group 1; lifestyle (LMI) physical activity

Exercise specialists from the University of Sydney will use the 'Active Support' approach [12] to promote the LMI-Lifestyle intervention. 'Active Support' is an evidence-based approach for the long-term support of activities of daily living (e.g., cooking), with training of disability service provider staff to provide tailored support as a central feature. Using the principles underlying active support participants in the LMI-Lifestyle group will be encouraged to engage in a total of 150 minutes per week of LMI physical activity. Participants will be supported for 1 hour (60 minutes) a week by the exercise specialist to engage in individually tailored LMI-Lifestyle activities that are enjoyable

(e.g., X-Box Kinnect, swimming, television advertisement exercises) or serve a functional purpose (e.g., walking for transport, hanging out washing). The remaining 90 minutes of weekly physical activity will be supervised by disability staff, who will be encouraged to follow an activity program set out by the university exercise specialist. During the weekly session with the exercise specialist, participants will wear a multi-sensor armband, Sensewear [16] to assess exercise intensity and compliance. Disability service provider staff will participate in the planning, and where appropriate the activity during and beyond the 12-week intervention period.

Intervention group 2; structured MVI-exercise Moderate-vigorous intensity exercise classes led by the university exercise specialists will take place over 12 weeks. Three to six participants will be recruited for each cohort. A MVI-Exercise session will comprise 30 to 45 minutes of cardiovascular exercise and 15 to 20 minutes of muscular strength. Sessions will be conducted three times per week. Exercise intensity will be gradually increased over the 12 week intervention period from 40%-50% of heart rate reserve to 50%-70% of heart rate reserve [17]. Exercise modes will be conducted indoors or outdoors in local community settings (partner organisation's facilities, parks, community gyms) using a small group approach involving activities like brisk walking, jogging and calisthenics with emphasis upon enjoyable body movements. To assess exercise intensity and compliance participants will wear a multi-sensor armband, Sensewear [16], for estimation of energy expenditure, throughout the initial 12-week intervention. Participants will also wear heart rate monitors (Polar, Port Washington, NY, USA) to ensure that they are exercising in the appropriate target heart rate zone. Partner Organisation staff will participate in the exercise sessions alongside the exercise specialists and will be trained to continue these classes beyond the 12-week intervention period.

Intervention group 3; control participants Participants in the control group will continue with their everyday activities. They will not be involved in any physical activity interventions led by the exercise specialists.

Outcome assessments

All outcomes will be assessed at baseline, 3-months post-baseline and at 9-months post-baseline. Participants and assessors will be un-blinded. The primary outcome measures are aerobic fitness, energy expenditure and physical activity. Secondary outcomes include intervention compliance, participation in domestic activity, objectively assessed physical activity and sedentary time, muscle strength, functional walking capacity, health care utilisation and cost, quality of life, body composition and psychosocial measures.

Primary outcome measures

Aerobic fitness

To assess aerobic fitness a submaximal exercise aerobic fitness test will be performed. Participants will undertake up to 4 × 5-min leg cycling using an isokinetic cycle ergometer, with resistance adjusted to elicit target heart rates equivalent to 45%, 55%, 65% and 75% of age-adjusted peak heart rate. Using ACSM metabolic equations [18], power output (W) and measured heart rate at each submaximal stage will be used to estimate submaximal oxygen consumption and VO_2peak ($ml \cdot kg \cdot min^{-1}$).

Energy expenditure

To quantify possible change of energy expenditure after the two exercise interventions, 12-hour energy expenditure will be assessed. At baseline, 3-month and 9-month post assessment participants will, on two days, wear a multi-sensor armband, Sensewear [16]. This small, lightweight self-contained device accurately measures and stores energy expenditure and physical activity data in the field.

Physical activity

The long, telephone version of the *International Physical Activity Questionnaire* (IPAQ) was adapted to measure the physical activity of adults with ID using proxy respondents [19]. To quantify possible change of physical activity via a simple recall questionnaire, the adapted version of the IPAQ, the IPAQ-ID, will be administered to carers of the adult with ID.

Secondary outcome measures

Objectively assessed physical activity and sedentary time

Participants will wear an Actigraph GT1M/GT3X accelerometer (Actigraph, Pensacola, FL, US) on the right hip attached to an elastic belt, for 7 consecutive days. The Actigraph is a non-invasive device the size and weight of a matchbox that records activity counts and steps taken. Participants wear the accelerometer during waking hours except during water activities. The accelerometer data allows for checks of wearing compliance and can be used to estimate time spent in sedentary, light, moderate, and vigorous physical activities.

Intervention compliance

Compliance with physical activities in both intervention groups will be measured through a daily physical activity log. For participants in either intervention group the disability service provider staff will be asked to log each person's participation in physical activities (type and duration).

Functional walking capacity

Participant's functional walking capacity will be assessed through a 6-Minute Walk Test (6MWT). Participants will be asked to walk as fast as they can for 6 minutes

and if required, the participant may briefly stop. The test will be performed indoors, along a flat, hard-surfaced passageway. The total distance walked will be measured and heart rate will be recorded using a heart rate monitor (Polar, Port Washington, NY, USA). This is a well validated test for a range of populations [20].

Participation in domestic activity

The 13-item Index of Participation in Domestic Life (IPDL) [21] scale will be administered to carers of the adult with ID. It measures participation in functional domestic activity, not physical activity.

Muscle strength

Isometric assessment of participants' muscle strength will be via dynamometry and include maximal handgrip strength, biceps flexion, triceps extension and knee extension strength [22].

Body composition and body fat

The Innerscan Body Composition Monitor (Tanita BC-541, Tsimshatsui East, Kowloon, Hong Kong) will be used by a trained research assistant to measure the participant's body mass and estimated percentage body fat. Height will also be measured. From the recorded information Body Mass Index (BMI) will be calculated.

Psychosocial measures

We will examine the effects of the interventions on attitudes and psychosocial outcomes through self-report and/or proxy interview data. Attitudes towards physical activity (self-efficacy, social support and exercise expectations) will be assessed using the following scales:

Self-Efficacy for Activity for persons with Intellectual Disabilities (SE-AID) This scale [10] is a 6-item self-report scale with internal consistency (alpha) = 0.73, and test-retest reliability intraclass correlation (ICC) = 0.49.

Social Support for Activity for persons with Intellectual Disabilities (SS-AID) This scale [10] has versions for closely related family and staff. The family version is a 7-item self-report scale with internal consistency (alpha) of 0.73, and test-retest reliability (ICC) of 0.79. The staff version has 6 items, with alpha = 0.74 and test-retest ICC = 0.78. The version of the scale administered will be dependent on the participants living circumstances.

The exercise perceptions scale This scale [23] measures expected outcomes of exercise. It is a 9-item self-report scale (alpha = 0.81), and test-retest r = 0.72 [24].

Psychosocial outcomes (depression and health-related quality of life) will be assessed using the following scales:

The Glasgow Depression Scale (GDS) The GDS [25] has self-report and proxy-report versions which correlate strongly ($r = 0.93$). It is specifically designed for people with ID and has excellent internal and test–retest reliability and criterion validity, with 96% specificity and 90% sensitivity. Both versions will be completed, with the proxy-report version being administered to the carers of the adult with ID.

Quality of life

The Health Utilities Index 2 (HUI 2) This scale [26] used for economic evaluation will assess quality of life.

Health care costs

An economic evaluation will determine the cost-effectiveness of the intervention. To assess the impact on health economics carers of the adult with ID will be given a prospective diary to complete about the person's use of health services. The diary will ask for information on the number of hospitalizations, any medical consultations (and other medical services) and any medications taken over the period.

The Health Utilities Index 2 (HUI 2) [26] is a widely used generic measure of health state utility used for economic evaluation. The scale will be administered to carers of the adult with ID.

Statistical analyses

Sample size

We will power the study based on the primary outcome of aerobic fitness (VO_2peak; ml•kg•min^{-1}). Our MVI-Exercise approach is similar to a previous study that used a 12-week gym-based intervention for people with ID [27]. They reported substantially better post-test aerobic fitness outcomes (assessed by VO_2peak) for the intervention group relative to controls (large effect size, Cohen's d = 0.91). Assuming an effect size of d = 0.80 (equivalent to f =0.40), and using a design with three groups and three repeated measures, power calculations with alpha = 0.05, power = 0.95, and a correlation among repeated measures of 0.5 show that this would require a total sample size of 69 (i.e., 23 per group), to analyse between-group differences using repeated measures ANOVA. Our assumptions are conservative so as to avoid under-powering the study. Therefore, we will recruit 30 participants per group for a total sample of 90, which allows for 23% attrition without compromising power.

Analyses

Repeated-measures ANOVA will be used to compare both the intervention and control group participants on primary and secondary outcome measures, at the 3-month and 9-month assessments. To identify personal characteristics of participants and features of their environment

that are associated with better outcomes multiple regression will be used. Significance will be set to $p < 0.05$. Analysis will be on the basis of intention to treat, with a secondary per-protocol analysis.

For the economic evaluation a trial based cost-effec tiveness analysis, taking a health system perspective, will compare the two exercise interventions with one another and, separately, with usual care (i.e., our control group). The economic evaluation will estimate the incremental cost-effectiveness of each of the interventions in terms of cost per quality adjusted life year gained. Participant level costs associated with use of health services and medications will be derived from proxy-reported utilisation at each follow-up and costed on the basis of standard published costs (e.g., Australian Refined Diagnosis Related Groups cost weights for hospitalisation and Medicare Benefits Schedule and Pharmaceutical Benefits Scheme [PBS] rates for medical services and prescribed medications respectively). Quality of life will be assessed by the HUI 2 via proxy and converted into health state utilities via the UK scoring system [28].

Discussion

This trial will enable evaluation of the effectiveness of two forms of exercise intervention for adults with ID, an under-researched group in preventive health research. The project has potentially important outcomes for both people with ID and the disability industry.

Through support for increased physical activity and exercise, we will determine if people with ID experience changes in primary outcomes of fitness, energy expenditure and physical activity, as well as a range of important secondary outcomes. We will evaluate outcomes after three months of intervention delivered by exercise specialists and disability service provider staff, and again six months later following continued intervention supported by disability service provider staff alone.

If successful, the project will form the basis for increased disability industry capacity to support healthy behaviours by training disability service provider staff to support physically active lifestyles. For widespread clinical implementation of our approach in the ID sector to be successful, it is necessary (in addition to staff training) to use a simple, low cost method to monitor the effectiveness of the physical activity interventions. One of our primary outcomes, the IPAQ-ID [19], is a low-cost, low-tech tool that disability service staff can be trained to use in everyday clinical practice. Therefore, an additional important outcome of this project will be further evidence to complement initial validation studies [29] of the IPAQ-ID's capacity to detect important changes in physical activity in this population. This will enable easier future uptake and evaluation of physical activity interventions by the disability industry.

It is expected that this trial will require three years to complete.

Trial status

Recruitment and intervention will be conducted in four overlapping waves.

Abbreviations

ID: Intellectual disability; RCT: Randomised controlled trial; LMI: Light-moderate intensity; MVI: Moderate-vigorous intensity; PAR-Q: Physical activity readiness questionnaire.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

RJS, GMD, AB, SJ, HVDP and KL were responsible for the design of the trial and secured funding. RJS is responsible for the coordination and management of the trial. SJ is responsible for the cost-effectiveness analyses. All authors have read and approved the final manuscript.

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Author details

[1]Faculty of Medicine, Nursing and Health Sciences, Flinders University, Adelaide SA 5001, Australia. [2]Centre for Disability Research and Policy, The University of Sydney, PO Box 170, Lidcombe NSW 1825, Australia. [3]Sydney School of Public Health, The University of Sydney, Sydney NSW 2006, Australia. [4]Department of Public and Occupational Health, VU University Medical Center Amsterdam, Amsterdam, The Netherlands. [5]The George Institute for Global Health, Camperdown NSW 2050, Australia. [6]Discipline of Exercise and Sports Science, The University of Sydney, Lidcombe NSW 1825, Australia.

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Cite this article as: Lante *et al.*: Embedding sustainable physical activities into the everyday lives of adults with intellectual disabilities: a randomised controlled trial. *BMC Public Health* 2014 **14:**1038.

Appendix 2-A. Literature search terms for MEDLINE via Ovid (1946 to present)

Date of first search: July 18, 2021
Search results returned: 590 records
Date of final search: September 1, 2021

Search strategies:

1. exp Exercise Therapy/ or exp Leisure Activities/ or "physical activit*".mp. or exp Exercise/
2. exp Simulation Training/ or exp Inservice Training/ or Training Support/ or exp High-Intensity Interval Training/ or training.mp. or exp High Fidelity Simulation Training/ or exp "Physical Education and Training"/ or exp Endurance Training/ or exp Resistance Training/
3. aerobic.mp. or exp Exercise Test/
4. cardiovascular.mp.
5. exp Oxygen Consumption/ or exp Cardiorespiratory Fitness/ or exp Physical Fitness/ or cardiorespiratory.mp.
6. metabolic.mp.
7. 1 or 2 or 3
8. 3 or 4 or 5 or 6
9. exp Intellectual Disability/ or exp Developmental Disabilities/ or intellectual disabilit*.mp. or exp Autism Spectrum Disorder/
10. mental retardation.mp.
11. Down syndrome.mp. or exp Down Syndrome/
12. 9 or 10 or 11
13. 7 and 8 and 12

Appendix 2-B. Data extraction form

Data extraction form

Title of our study:
Effects of physical activity on cardiorespiratory fitness in individuals with intellectual disability: a systematic review and meta-analysis

Abbreviations: BMI (body mass index). BAT (before- and after-intervention trial). CF (cardiorespiratory fitness). DS (Down syndrome). NR (not reported). NRCT (non-randomised controlled trial). PA (physical activity). PWID (people with intellectual disability). RCT (randomised controlled trial). TCL (total cholesterol level). VO_2peak (peak oxygen consumption).

This extraction form was created to answer the following key questions:

1. Is this study eligible for our review through screening its title and abstract?
2. What were the general information and study characteristics of available studies?
3. Which types of outcomes were examined in the study?
4. What is the mean VO_2peak before and after intervention?
5. Which factors, such as age, sex, country, socioeconomic status, are associated with the prevalence?
6. What is the quality of the available evidence?

Note: The checked box (☒) is the answer. Data are mean (standard deviation) unless otherwise specified.

Reviewers: 1st reviewer ☐ XL 2nd reviewer ☐ GD	***Number of the record*:**
Date of extraction:	
Reviewer's email: Email: xili9611@uni.sydney.edu.au	
Included ☐ Excluded ☐	

1. General information

Study citation		
Exclusion criteria Were study participants reported to have ID, DS, mental retardation, or developmental disability?	YES ☐ NO ☐	*Location in text* Title ☐ Abstract ☐ Results ☐
Did intervention involve components of any type of PA/exercise?	YES ☐ NO ☐	Title ☐ Abstract ☐ Results ☐
Were comparators non-intervention controls?	YES ☐ NO ☐	Title ☐ Abstract ☐ Results ☐
Was VO_2peak reported?	YES ☐ NO ☐	Title ☐ Abstract ☐ Results ☐
Do not proceed if NO for any of above conditions. The study will be excluded.		

General information (continued)

Aim/objectives of the study	
Country in which the study was conducted	*Source of data* Primary ☐ Secondary ☐
Type of publication Journal ☐ Conference ☐ Unpublished ☐ Book ☐ Organisation ☐ Thesis ☐ Other ☐	*Language used in the study* English ☐ Other ☐ :
Source of funding	*Conflicts of interest* None ☐ Not reported ☐ Conflicts ☐

2. Study methods

Study design RCT ☐ NRCT ☐ BAT ☐ Cluster ☐ Two groups ☐ Three groups ☐	*Comparator* Non-intervention controls ☐ Other ☐
Sampling & randomisation procedures Stratification ☐ Probability ☐ Proportional ☐ No details ☐	*Blinding and allocation* Allocation concealment ☐ Blinding to assessors ☐ Not reported ☐
Type of PA Aerobic ☐ Endurance ☐ Strength ☐ Balance ☐ Flexibility ☐ Leisure PA ☐ Structured exercise ☐ Other ☐ Details:	*Does of intervention* Duration: weeks Frequency: days per week Light PA: minutes per week Moderate PA: minutes per week Vigorous PA: minutes per week
Intensity of PAs Light ☐ Moderate ☐ Vigorous ☐	*Components of intervention* Walking ☐ Cycling ☐ Stepping ☐ Running ☐ Treadmill ☐ Bridging ☐ Sprint ☐ Brisk walking ☐ Swimming ☐ Jogging ☐ Trainer ☐ Diet ☐ Nutrition ☐ Education ☐ Fitness equipment ☐ Supervised ☐ Dancing ☐ Heavy lifting ☐ Muscular strength training ☐ Others ☐
Analytic methods Intention-to-treat ☐ Per protocol ☐ ANOVA ☐ ANCOVA ☐ Regression ☐ Subgroup analysis ☐	
Unit of analysis Individual participant ☐ Cluster ☐	*Effect measurements* Mean difference of changes from baseline ☐ Mean difference of final measures between groups ☐
Total number of participants analysed	*Drop-out rate*
Information of missing data	*VO2peak measurement* Treadmill test ☐ Cycle test ☐:
Study participant inclusion and exclusion criteria	

3. Participants

Age (years) Mean ☐ ( ) Range ☐ ( )	*Sample size (number)* Total ☐ ( ) Male ☐( ) Female ☐( )
Other health condition	*Residential condition (number of participants)* Group home ☐( ) Family ☐( ) Others ☐( )
IQ score Mean ☐ ( ) Range ☐ ( )	*Sample source* Primary ☐ Secondary ☐
Type of developmental disability (number of participants) ID ☐( ) DS ☐( ) Autism ☐( ) Others ☐( )	*Trial groups (number of participants)* Intervention ( ) 2nd intervention ( ) Controls ( )

4. Measurements

	Intervention group		Control group	
	Baseline	Final	Baseline	Final
Number of participants				
Age (years)				
Sex (number)				
IQ score				
Weight (kg)				
BMI (kg/m^2)				
Body fat (%)				
Fat mass (kg)				
TCL (mg/dl)				
VO_2peak (ml/kg/minute)				

5. Study bias

a. For RCTs:
Overall risk of bias: High ☐ Some concerns ☐ Low ☐

Table 1: Domain outcomes of critical appraisal for RCTs*

Items	Low	High	Some concerns
Bias arising from the randomisation process	☐	☐	☐
Bias due to deviations from intended interventions	☐	☐	☐
Bias due to missing outcome data	☐	☐	☐
Bias in measurement of the outcome	☐	☐	☐
Bias in selection of the reported result	☐	☐	☐

Low: lower risk of bias; High: higher risk of bias; Some concerns: some concerns of risk of bias
* This checklist was adapted from the Cochrane tool RoB 2 that was used to assess bias separately

Comments:
Optional: What is the overall predicted direction of bias for this outcome?

b. For non-randomised studies:
Overall risk of bias: Low☐ Moderate ☐ Serious ☐ Critical ☐ No information ☐

Table 2: Domain outcomes of critical appraisal for non-randomised studies

Items	Low	Moderate	Serious	Critical	No information
Bias due to confounding	☐	☐	☐	☐	☐
Bias in selection of participants into the study	☐	☐	☐	☐	☐
Bias in classification of interventions	☐	☐	☐	☐	☐
Bias due to deviations from intended interventions	☐	☐	☐	☐	☐
Bias due to missing data	☐	☐	☐	☐	☐
Bias in measurement of outcomes	☐	☐	☐	☐	☐
Bias in selection of the reported result	☐	☐	☐	☐	☐
Overall bias	☐	☐	☐	☐	☐

* This checklist was adapted from the Cochrane tool ROBINS-I that was used to assess bias separately

Comments:
Optional: What is the overall predicted direction of bias for this outcome?

6. Additional information
Yes ☐ No ☐
If yes, give details:

Participant sources	
Sampling methods	
Sample size calculation	
Participant allocation	
Blinding: not reported	
Confounding control	
Balance at baseline	
Drop-out	

7. Is further information required from the authors?
Yes ☐ No ☐
If yes, give details:

Appendix 2-C. List of excluded studies that might be eligible

Citation	Reason for exclusion	Study results
Boer, P. (2018). Effects of detraining on anthropometry, aerobic capacity and functional ability in adults with Down syndrome. *Journal of Applied Research in Intellectual Disabilities*, *31*(Suppl. 1), 144-150. https://doi.org/10.1111/jar.12327	The same source as Boer and Moss (2016)	
Millar, A. L. (1985). *Effects of endurance training on Down's syndrome adolescents and young adults* [Thesis, Arizona State University]. AZ.	The same source as Millar et al. (1993)	
Ordonez, F. J., Rosety, M. A., Camacho, A., Rosety, I., Diaz, A. J., Fornieles, G., Garcia, N., & Rosety-Rodriguez, M. (2014). Aerobic training improved low-grade inflammation in obese women with intellectual disability. *Journal of Intellectual Disability Research*, *58*(6), 583-590. https://doi.org/10.1111/jir.12056	The same source as Ordonez et al. (2013)	
Rosety-Rodriguez, M., Diaz, A. J., Rosety, I., Rosety, M. A., Camacho, A., Fornieles, G., Rosety, M., & Ordonez, F. J. (2014). Exercise reduced inflammation: but for how long after training? *Journal of Intellectual Disability Research*, *58*(9), 874-879. https://doi.org/https://doi.org/10.1111/jir.12096		
Lante, K., Davis, G., Stancliffe, R., Bauman, A., Jan, S., & van Der Ploeg, H. (2012). Aerobic fitness, functional exercise capacity and muscle strength of adults with intellectual disability. *Journal of Science and Medicine in Sport*, *15 (SUPPL.1)*, S78-S79.	The study is not yet completed.	
Varela, A. M., Sardinha, L. B., & Pitetti, K. H. (2001). Effects of an aerobic rowing training regimen in young adults with Down syndrome. *American Journal of Mental Retardation*, *106*(2), 135-144. https://doi.org/10.1352/0895-8017(2001)106<0135:EOAART>2.0.CO;2	The full paper was not obtained.	Data from another article: final VO_2peak values in $ml \cdot kg^{-1} \cdot min^{-1}$ for intervention group (M = 31.7, SD = 4, N = 8) and for control group (M = 31.1, SD = 4.1, N = 8). No significant difference between groups.

Appendix 2-D. Additional Forest Plots for Meta-Analyses

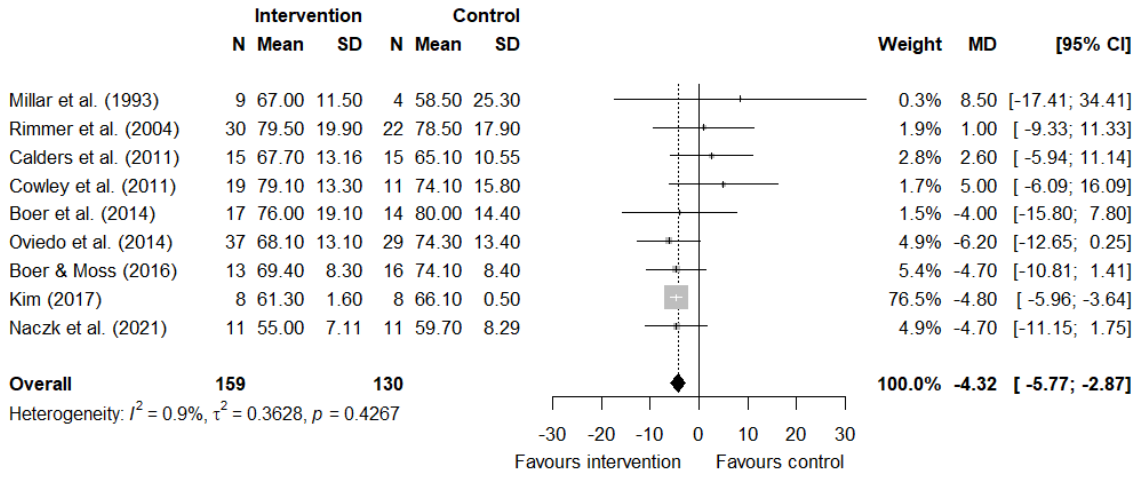

Figure 2-D.1. Forest plot for body mass in kilograms

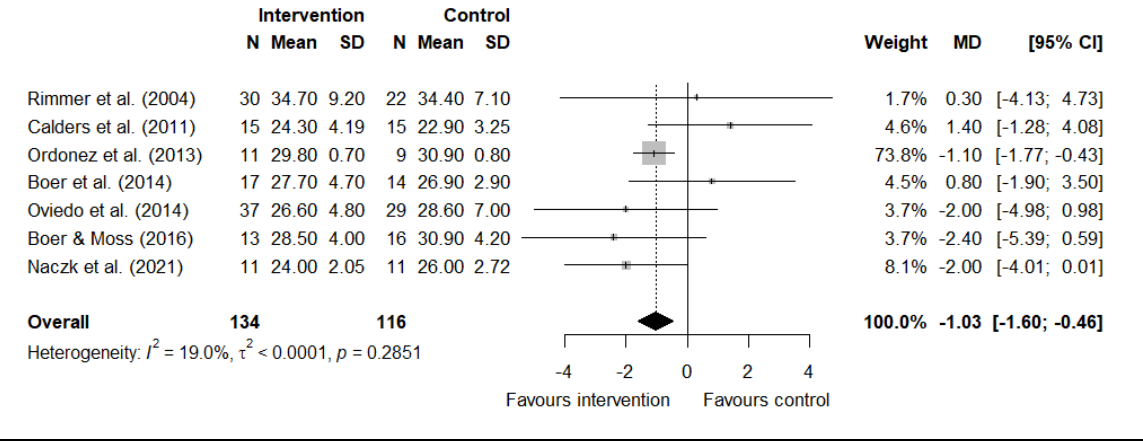

Figure 2-D.2. Forest plot for body mass index in kilograms per square meters

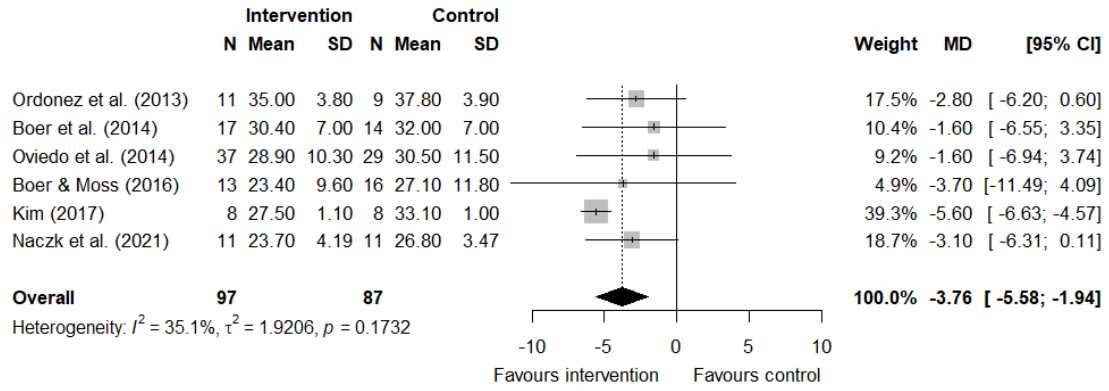

Figure 2-D.3. Forest plot for body fat percentage

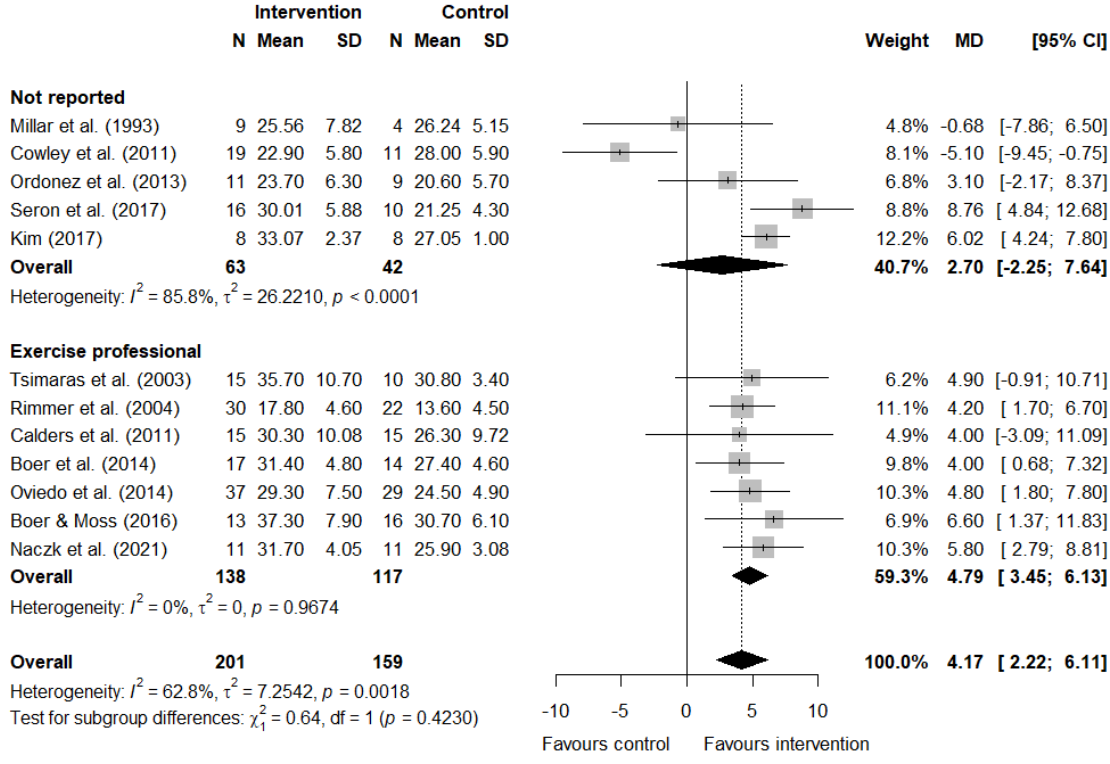

Figure 2-D.4. Forest plot for peak oxygen consumption (ml/kg/min) by exercise professional involvement

Appendix 2-E. Funnel plot for publication bias

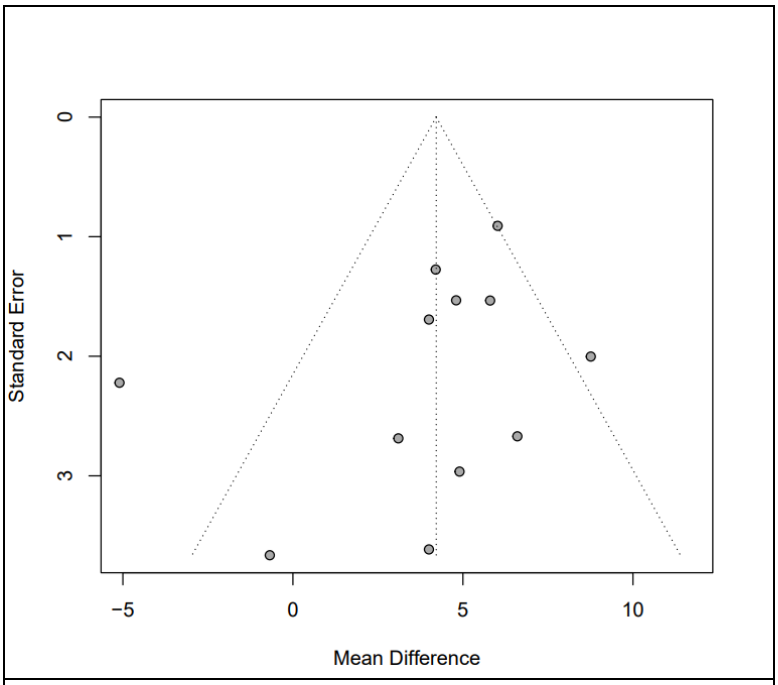

Figure 2-E.1. Funnel plot for publication bias

Appendix 3-A. Approval letter of Human Research Ethics Committee

THE UNIVERSITY OF SYDNEY

RESEARCH INTEGRITY
Human Research Ethics Committee
Web: http://sydney.edu.au/ethics/
Email: ro.humanethics@sydney.edu.au

Address for all correspondence:
Level 6, Jane Foss Russell Building - G02
The University of Sydney
NSW 2006 AUSTRALIA

Ref: [MF/KFG]

27 May 2011

Associate Professor Roger Stancliffe
Disability and Community Faculty Research Group
Faculty of Health Sciences
Cumberland Campus – C42
The University of Sydney
Email: roger.stancliffe@sydney.edu.au

Dear A/Prof Stancliffe

Thank you for your correspondence dated 25 May 2011 addressing comments made to you by the Human Research Ethics Committee (HREC).

I am pleased to inform you that with the matters now addressed your protocol entitled **"Embedding sustainable physical activities into the everyday lives of adults with intellectual disabilities"** has been approved.

Details of the approval are as follows:

Protocol No.:	**05-2011 / 13821**
Approval Period:	**May 2011 to May 2012**
Authorised Personnel:	**Associate Professor Roger Stancliffe** **Professor Glen Davis** **Professor Adrian Bauman** **Associate Professor Stephen Jan** **Dr Hidde van der Ploeg**

Documents Approved:

1. Participant Information Statement (version 2, 24 May 2011)
2. Guardian/Person Responsible Information Statement (version 2, 24 May 2011)
3. Participant Consent Form (version 2, 24 May 2011)
4. Guardian/Person Responsible Consent Form (version 2, 24 May 2011)

Questionnaires, Logs and Assessment Resources:

5. Physical Activities Readiness Questionnaire (PAR-Q)
6. International Physical Activity Questionnaire – Intellectual Disability (IPAQ-ID)
7. Physical activity participation log (activity compliance) – Lifestyle group
8. Physical activity participation log (activity compliance) – Structured exercise group
9. Health Diary
10. Health Utilities Index – 2 (HUI-2)
11. Glasgow Depression Scale for persons with Learning Disability (GDS-LD)
12. Self-Efficacy for Activity for persons with Intellectual Disabilities (SE-AID)
13. Social Support for Activity for persons with Intellectual Disabilities (SS-AID) – family scale and staff scale
14. Exercise Perceptions Scale (Attitudes and Beliefs about Exercise)
15. Inventory for Client and Agency Planning (ICAP)

Manager Human Ethics
Dr Margaret Faedo
T: +61 2 8627 8176
E: margaret.faedo@sydney.edu.au

Human Ethics Secretariat:
Ms Patricia Engelmann **T:** +61 2 8627 8172 **E:** patricia.engelmann@sydney.edu.au
Ms Karen Greer **T:** +61 2 8627 8171 **E:** karen.greer@sydney.edu.au
Ms Kala Retnam **T:** +61 2 8627 8173 **E:** kala.retnam@sydney.edu.au

ABN 15 211 513 464
CRICOS 00026A

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The HREC is a fully constituted Ethics Committee in accordance with the National Statement on Ethical Conduct in Research Involving Humans-March 2007 under Section 5.1.29.

The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Research Involving Humans. A report on this research must be submitted every 12 months from the date of the approval or on completion of the project, whichever occurs first. Failure to submit reports will result in withdrawal of consent for the project to proceed. Your report is due by **31 May 2012**.

Chief Investigator / Supervisor's responsibilities to ensure that:

1. All serious and unexpected adverse events should be reported to the HREC within 72 hours for clinical trials/interventional research.

2. All unforeseen events that might affect continued ethical acceptability of the project should be reported to the HREC as soon as possible.

3. Any changes to the protocol must be approved by the HREC before the research project can proceed.

4. All research participants are to be provided with a Participant Information Statement and Consent Form, unless otherwise agreed by the Committee. The following statement must appear on the bottom of the Participant Information Statement: *Any person with concerns or complaints about the conduct of a research study can contact the Manager, Human Ethics, University of Sydney on +61 2 8627 8176 (Telephone); + 61 2 8627 8177 (Facsimile) or ro.humanethics@sydney.edu.au (Email).*

5. You must retain copies of all signed Consent Forms and provide these to the HREC on request.

6. It is your responsibility to provide a copy of this letter to any internal/external granting agencies if requested.

7. The HREC approval is valid for four (4) years from the Approval Period stated in this letter. Investigators are requested to submit a progress report annually.

8. A report and a copy of any published material should be provided at the completion of the Project.

Please do not hesitate to contact Research Integrity (Human Ethics) should you require further information or clarification.

Yours sincerely

Dr Margaret Faedo
Manager, Human Ethics
On behalf of the HREC

Appendix 3-B. Calculation example of maximal oxygen consumption (VO_2peak)

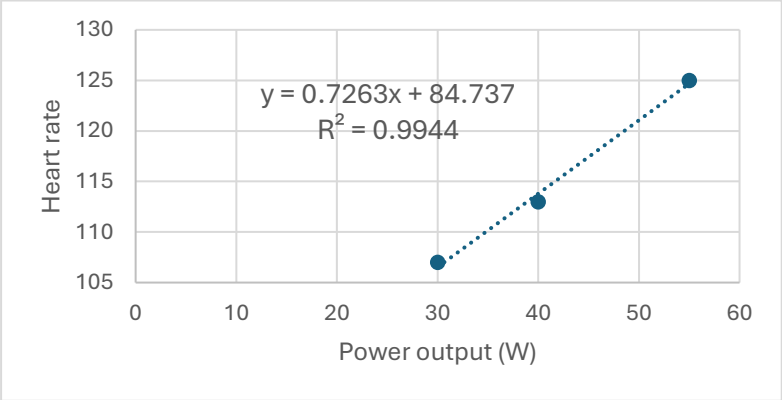
1. Formula adapted from American College of Sports Medicine, & Pescatello, L. S. (2014). *ACSM's guidelines for exercise testing and prescription* (9th ed.). Wolters Kluwer/Lippincott Williams & Wilkins Health. (p. 173)

   VO_2peak in ml/kg/min = 7.0 + (1.8 × 6.12 × W_{max})/body mass

2. Data from the submaximal exercise test:

Power output (W)	Heart rate
30	107
40	113
55	125

3. Linear association between power output and heart rate in Excel



4. Age-adjusted maximum heart rate

   Age = 38 years
   Heart $Rate_{max}$ = 220 – age = 182

5. Predicted maximum power output (W_{max})

   W_{max} = (182 – 84.737)/0.7263 = 133.92

6. Calculation

   Weight = 73.8 kg
   VO_2peak = 7.0 + (1.8 × 6.12 × 133.92)/73.8 = 26.99 ml/kg/min

Appendix 4-A. Metabolic equivalent (MET) values for physical activities and calculation methods

Adapted from: Lante, K. (2007). *Development of a proxy response instrument to measure the physical activity behaviours of adults with an intellectual disability* [PhD thesis, RMIT University]. Australia.

1) Day Agency Domain

- Walking MET-minutes/week at work = 3.3 * walking minutes * walking days at day agency
- Moderate MET-minutes/week at work= 4.0 * moderate-intensity activity minutes * moderate-intensity days at day agency
- Vigorous MET-minutes/week at work= 8.0 * vigorous-intensity activity minutes * vigorous-intensity days at day agency
- Total Work MET-minutes/week =sum of Walking + Moderate + Vigorous MET-minutes/week scores at day agency

2) Transportation Domain

- Walking MET-minutes/week for transport = 3.3 * walking minutes * walking days for transportation
- Cycle MET-minutes/week for transport= 6.0 * cycling minutes * cycle days for transportation
- Total Transport MET-minutes/week = sum of Walking + Cycling MET-minutes/week scores for transportation

3) Housework and Garden Domain

- Vigorous MET-minutes/week garden chores = 5.5 * vigorous-intensity activity minutes * vigorous-intensity days doing garden work (Note: the MET value of 5.5 indicates that vigorous garden work should be considered a moderate-intensity activity for scoring and computing total moderate intensity activities)
- Moderate MET-minutes/week garden chores= 4.0 * moderate-intensity activity minutes * moderate intensity days doing yard work
- Moderate MET-minutes/week housework chores= 3.0 * moderate-intensity activity minutes * moderate intensity days doing housework
- Total Housework and Garden MET-minutes/week =sum of Vigorous garden + Moderate garden + Moderate housework MET-minutes/week scores

4) Leisure Domain

- Leisure walking MET-minutes/week leisure = 3.3 * walking minutes * walking days in leisure
- Moderate MET-minutes/week leisure = 4.0 * moderate-intensity activity minutes * moderate-intensity days in leisure

- Vigorous MET-minutes/week leisure = 8.0 * vigorous-intensity activity minutes * vigorous-intensity days in leisure
- Total Leisure-Time MET-minutes/week = sum of Walking + Moderate + Vigorous MET-minutes/week scores in leisure

5) Total Scores for all Walking, Moderate and Vigorous Physical Activities

- Total Walking MET-minutes/week = Walking MET-minutes/week (at Day agency + for Transport + in Leisure)
- Total Moderate MET-minutes/week total = Moderate MET-minutes/week (at Day agency + Garden chores + housework chores + in Leisure time) + Cycling Met-minutes/week for Transport + Vigorous Garden chores MET-minutes/week
- Total Vigorous MET-minutes/week = Vigorous MET-minutes/week (at Day agency + in Leisure)
- Note: Cycling MET value and Vigorous garden work MET value fall within the coding range of moderate-intensity activities

6) Total Physical Activity Scores

- Total physical activity MET-minutes/week = sum of Total Day Agency + Total Transport + Total Housework and Garden + Total Leisure-Time MET-minutes/week scores

Appendix 4-B. Data examination at baseline

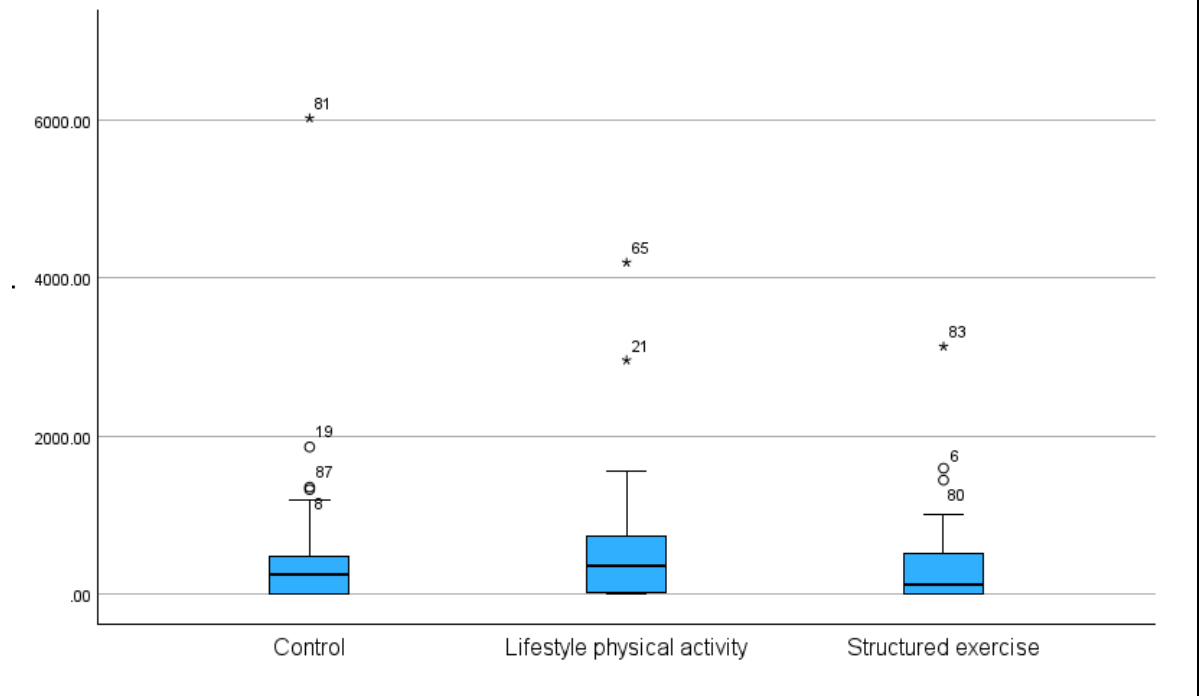


Figure Appendix 4-B.1. Boxplot for MVPA levels (MET-min/week) at baseline
Note. MVPA = moderate and vigorous physical activity. LSPA = lifestyle physical activity group. STEX = structured exercise group. Control = usual care group.

Appendix 5-A. Self-Efficacy for Activity for Person with Intellectual Disabilities Scale

NHMRC Partenership Project: Embedding sustainable physical activities into the everyday lives of adults with intellectual disabilities

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Self-efficacy for activity for persons with intellectual disabilities (SE-AID) scale

Response options are no (0), maybe (1), and yes (2) for each item

Question		Response
1	Do you think that you can make time for physical activities almost everyday?	
2	Do you think that you can do physical activities even when you are very busy?	
3	Do you think that you can do physical activities even when you are feeling sad or depressed?	
4	Do you think that you can do physical activities even after a long, hard day at work?	
5	Do you think that you can do physical activities on days when you are tired or don't have much energy?	
6	Do you think you can do physical activities when you feel lazy?	

Assessment resource sourced from: Peterson, J J., Peterson, N A., Lowe, J B., & Nothwehr, F K. (2009). Promoting leisure physical activity participation among adults with intellectual disabilities: Validation of self-efficacy and social support scales. Journal of Applied Research in Intellectual Disabilities, 22, p. 487-497.

Appendix 5-B. Social Support for Persons with Intellectual Disabilities Scale

NHMRC Partenership Project: Embedding sustainable physical activities into the everyday lives of adults with intellectual disabilities

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HOUSE WITH NO STEPS

sunshine

Social support for activity for persons with intellectual disabilities (SS-AID): Staff scale

Response options are no (0), yes-sometimes (1), and yes-a lot (2) for each item

Question		Response
1	Does your staff remind you to do physical activities?	
2	Does your staff do physical activities with you?	
3	Does your staff plan physical activities when you spend time with them?	
4	Does your staff show you how to do physical activities?	
5	Does your staff tell you that you are good at physical activities?	
6	Does your staff drive you somewhere to do physical activities when you need them to?	

Assessment resource sourced from: Peterson, J J., Peterson, N A., Lowe, J B., & Nothwehr, F K. (2009). Promoting leisure physical activity participation among adults with intellectual disabilities: Validation of self-efficacy and social support scales. Journal of Applied Research in Intellectual Disabilities, 22, p. 487-497.

Appendix 5-C. Exercise Perception Scale

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Attitudes and Beliefs about Exercise

"I am going to read you some possible reasons why you might want to exercise. Do you think that exercise would: ..."

Question		Response		
		1	*2*	*3*
1	Help you lose/control your weight or not help you lose/control your weight?	*Help*	*Not Help*	*Neither or Both*
2	Make you feel less tired or make you feel more tired?	*Less Tired*	*More Tired*	*Neither or Both*
3	Make your body feel good or not make your body feel good?	*Feel Good*	*Not Feel Good*	*Neither or Both*
4	Make you feel happier or not make you feel happier?	*Feel Happier*	*Not Feel Happier*	*Neither or Both*
5	Make you hurt less or not make you hurt less?	*Hurt Less*	*Not Hurt Less*	*Neither or Both*
6	Help you meet new people or not help you meet new people?	*Help*	*Not Help*	*Neither or Both*
7	Help you get in shape or not help you get in shape?	*Help*	*Not Help*	*Neither or Both*
8	Make you look better or not make you look better?	*Look Better*	*Not Look Better*	*Neither or Both*
9	Improve your health or not improve your health?	*Improve*	*Not Improve*	*Neither or Both*

Assessment resource sourced from: Marks, B., Sisirak, J., Heller, T., and Riley, B. (November 6, 2006). Efficacy of a Train-the-Trainer Program to Improve Health Status for People with Intellectual and Developmental Disabilities, American Public Health Association, 134th Annual Meeting and Exposition, Boston, MA.

Appendix 5-D. Index of Participation in Domestic Life

Raynes, N. V., Sumpton, R. C., and Pettipher, C. (1989). *Index of Participation in Domestic Life*. Manchester, U.K.: The University Department of Social Policy and Social Work.
Raynes, N., Wright, K., Shiell, A., & Pettipher, C. (1994). *The cost and quality of community residential care*. London: Fulton

INDEX OF PARTICIPATION IN DOMESTIC LIFE

Client:_____ **Date:**_____ **House:**_____

DOES THE CLIENT DO OR HELP TO DO ANY OF THE FOLLOWING JOBS.
(PUT A TICK IN THE APPROPRIATE BOX)

	(2)	(1)	(0)
JOB	Does alone or with other residents. No staff help.	Helps staff with	Does not do
Shopping for food			
Preparing meals			
Setting table			
Serving meals			
Washing up			
Cleaning kitchen			
Cleaning living and dining rooms			
Cleaning own bedroom			
Cleaning bathroom and toilet			
Shopping for supplies			
Doing own washing			
Doing own ironing			
Looking after the garden			
TOTAL SCORE - ____			

Scoring procedure
1. Add all the ticks in each column – 2,1,0.
2. Multiply number of ticks by number of columns (i.e., the score for that column).
3. Add score for each column and record in total score box in left hand column.