Resistance Training on an Outdoor Exercise Structure Improves Lower Body Relative Strength in Older Adults

by

Brianna Leadbetter

Bachelor of Kinesiology, Acadia University 2020

A Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of

Master of Science in Kinesiology

in the Graduate Academic Unit of Kinesiology

Supervisor:	Danielle R. Bouchard, Ph.D., Faculty of Kinesiology
Examining Board:	Jonathan Edwards, Ph.D., Faculty of Kinesiology, Chair
	Ken Seaman, Ph.D., Faculty of Kinesiology
	Jennifer Copeland, Ph.D., Kinesiology and Physical Education, University of Lethbridge

This thesis is accepted by the Dean of Graduate Studies.

THE UNIVERSITY OF NEW BRUNSWICK

April 2023

Abstract

Improving relative strength is important for maintaining functionality with age, and outdoor exercise structures could be useful to facilitate this. 29 adults aged 65+ participated in a crossover study with a six-week control followed by a six-week resistance training intervention on an outdoor exercise structure (3x/week). Relative strength (predicted maximal leg press/lower body lean mass (Dual-energy X-ray Absorptiometry)) and physical function variables were measured at baseline, post-control, and post-intervention. Represented as median (25^{th}-75^{th}), lower body relative strength improved from 7.91 (7.01-9.35) post-control to 8.50 (7.99-9.72) post-intervention ($p=.002$) in study completers ($n=17$). Maximum leg press ($p=.002$), 30-second chair stand ($p<.001$), one-leg stance ($p=.011$), and maximum chest press ($p=.009$) also improved significantly during the intervention. There were no significant changes in aerobic activity, grip strength, lean mass, or muscle power. This study demonstrates that there could be potential relative strength benefits associated with the use of outdoor exercise structures in older adults.

Acknowledgements

I would first like to acknowledge the participants who volunteered their time and effort to be a part of my study; this project could not have gone ahead without them and their dedication. I would like to thank my colleagues in the Cardiometabolic Exercise & Lifestyle Laboratory for their continued support, and I would specifically like to acknowledge Paige Grenier for her help during data collection, and Jake Mason for volunteering his time during the intervention. I would also like to thank my supervisory committee for their high-quality feedback and support throughout my project. Finally, I would like to dedicate a special acknowledgement to my supervisor, Dr. Danielle Bouchard, for her unwavering support throughout my degree. I have yet to meet somebody who is as invested and dedicated to the success of their students as Dr. Bouchard, and she has undoubtedly been my main source of inspiration and support throughout the past two years.

Table of Contents

1.0 Introduction

After the age of 50, older adults lose ~10% of lean mass per decade and 12-14% of muscle strength per decade (Doherty, 2001; Goodpaster et al., 2006). This can translate into a decline in functional capacity (Misic et al., 2007) and lead to a loss of independence and institutionalization (Luppa et al., 2010). Resistance training is an effective strategy for slowing this decline and even improving muscle strength and mass while aging (Izquierdo et al., 2021). However, 67.5% of older adults report not taking part in any resistance training activities (Copeland et al., 2019).

Significant barriers to performing regular resistance training include cost, location, lack of equipment, and lack of knowledge both in the breadth of benefits of resistance training and how to properly perform resistance training (Burton et al., 2017). Outdoor exercise structures could be a possible solution to address these barriers, especially if supervised. The literature shows that older adults are the demographic that uses these outdoor exercise structures the least (Cohen et al., 2012; Mora, 2012). Even if older adults were using these structures, it is unclear whether there are any benefits to this type of activity (Izquierdo et al., 2021).

The main objective of this study was to assess the impact of a 6-week resistance training program using outdoor exercise structures on lower body relative strength (strength/lean mass). The secondary objective was to explore whether a 6-week resistance training program using outdoor exercise structures can lead to a significant improvement in physical function.

A total of 29 participants who were over the age of 65 years old, community-dwelling, not currently taking part in any structured resistance training activities, able to grip objects in day-to-day life (self-reported), and had been cleared to exercise took part in this study. Using a crossover design, participants first took part in a 6-week control period followed by a 6-week intervention. Assessments were performed at baseline, after six weeks of the control condition, and after the 6-week intervention.

During the intervention, participants took part in a supervised resistance training program three times per week for six weeks on an outdoor exercise structure for 45 minutes per session. The exercise program focused on progressive overload by gradually increasing sets, reps, and difficulty of the exercises. The main outcome, lower body relative strength, was measured using lower body maximum strength divided by total lean leg mass (measured via Dual X-ray Absorptiometry). Physical function was assessed using a battery of validated tests to assess muscle power, strength, and balance.

Out of 29 participants, 17 completed the study protocol (70.6% female). During the intervention, median lower body relative strength improved from 7.91 (7.01-9.35) at post-control to 8.50 (7.99-9.72) at post-intervention ($p=.002$). There were also significant improvements in maximal leg press ($p=.002$), 30-second chair stand ($p<.001$), one leg stance ($p=.003$), and maximal chest press ($p=.028$) following the intervention. This short-term resistance training program using an outdoor exercise structure was associated with improvements in lower body relative strength and physical function in community-dwelling older adults. Nevertheless, more research is needed to understand and improve adherence to using these outdoor structures.

2.0 Literature Review

2.1 Aging

Over seven million people in Canada are over the age of 65, making up about 18.5% of the total Canadian population (Statistics Canada, 2021a). The World Health Organization (2021b) reports that the worldwide population of people over the age of 60 years old consists of about 1 billion, and that number is expected to double to 2.1 billion by the year 2050. The oldest old, those over the age of 80 years old, are expected to triple in numbers by 2050 to a total of 426 million (World Health Organization, 2021b).

This rapid population aging is due to multiple factors including continuously increasing life expectancy, healthcare advancements, and declining fertility trends (World Health Organization, 2021b). Over the past 50 years, the average fertility rate in Canada has dropped 29.9% from 2.14 to 1.5 children per woman, and life expectancy in Canada has increased by 13.18% from 73.03 to 82.66 years (MacroTrends, 2022; World Bank Group, 2022). This dramatic increase in older adults will have unprecedented effects on healthcare systems worldwide such as increased demands in expenditure and services, but especially in countries such as Canada with universal healthcare models in place (Prince et al., 2015).

Physiological aging is defined as the gradual decline of the body's biological processes that ultimately reduces its adaption capabilities such as metabolic processing and physical function (Flint & Tadi, 2022). Throughout the human lifespan, cell turnover is constantly occurring via cellular apoptosis and proliferation (Flint & Tadi, 2022). In the first few decades of life, cell turnover is remarkably efficient and relatively consistent. However, around the age of 30 years old, cell proliferation slows and apoptosis occurs at a faster rate than regeneration, which is one of the primary reasons that aging of the human body occurs (Flint & Tadi, 2022). While aging is inevitable, there are several epigenetic factors (such as lifestyle choices) that influence the rate at which cellular apoptosis and regeneration may occur (Neufer et al., 2015).

Specific changes that occur along the aging process include body composition changes such as loss of bone mass via decreases in bone density, increases in fat mass, and decreases in lean mass, all resulting in a decline in mobility and physical functioning (Jingzhong et al., 2007; Keller & Engelhardt, 2014). Lean mass is sometimes referred to as 'muscle mass' or 'fat-free mass' in the literature (Müller et al., 2014). After the age of 50, lean mass decreases at a rate of about 10% per decade, with muscle strength declining even faster at a rate of about 14% per decade (Doherty, 2001; Goodpaster et al., 2006).

One of the biggest contributors to the change in body composition observed with age is the lack of physical activity (Cunningham et al., 2020). While reports of physical activity levels vary greatly in older adults, most studies find that less than 25% of older adults meet the recommended physical activity guidelines of 150 minutes per week of moderate-to-vigorous physical activity (MVPA) (Sun et al., 2013). However, when the outcome is objectively measured, the prevalence of older adults meeting MVPA guidelines is much lower, with some studies reporting numbers as low as 2.5% (Jefferis et al., 2014; Sun et al., 2013).

2.1.1 Chronic Conditions

The risk of developing chronic conditions and multimorbidity increases with age, with a dramatic increase in that risk occurring after the age of 65 years old (Kirchberger et al., 2012). The Public Health Agency of Canada (2021) reports that of the seven million people over the age of 65 in Canada, about 6.3 million live with at least one chronic condition, making the prevalence of chronic conditions in Canada's senior population a staggering 89%. The most common chronic condition among Canadian seniors is hypertension with a prevalence of 65.5%, followed by osteoarthritis at 37.9%, and then ischemic heart disease at 26.9% (Public Health Agency of Canada, 2021).

The total burden of disease is often assessed by calculating the disability-adjusted life years (DALY), which is a measure that takes into account the number of years an individual has lost due to premature mortality or being in an unhealthy state (Rushby, 2001). The most recent estimation of the global burden of disease was done in 2010, which stated that people over the age of 60 years old account for 23.1% of the total global burden of disease, contributing 574 million to the 2490 million annual DALYs worldwide, and this number was projected to rise even more as the worldwide population ages. Years lost to cardiovascular disease, cancer, and chronic respiratory diseases are the leading contributors and add up to more than half of the annual DALYs in the aging population (Prince et al., 2015).

Chronic conditions are a major strain on healthcare systems all over the world. While exact statistics on the current cost of chronic conditions to Canada's healthcare system are not available, it has been estimated that chronic disease costs the Canadian healthcare system about $190 billion per year in direct and associated costs, making up 67% of Canada's annual healthcare spending (Elmslie, 2016). Physical inactivity is a major modifiable risk factor and is often assessed as a precursor for developing chronic conditions (Anderson & Durstine, 2019). Globally, physical inactivity is estimated to cost healthcare systems $145 billion in international currency (Anderson & Durstine, 2019). In the United

States, physical inactivity accounts for 27% of healthcare spending (Anderson et al., 2005). As our population ages and physical inactivity levels remain high, the prevalence of chronic disease will rise and the economic burden on our healthcare systems will continue to increase (Koné Pefoyo et al., 2015).

Physical activity is an important variable in preventing, managing, and treating numerous chronic conditions (Booth et al., 2012; Pedersen & Saltin, 2015). Older adults who engage in physical activity have a later onset of chronic conditions by 7 years compared to those who do not engage in physical activity, and they experience less severe symptoms and better outcomes (Zhou et al., 2018). In fact, older adults who exercise have a lower prevalence of chronic conditions altogether compared to those who don’t (Gopinath et al., 2018). Research shows that older adults who exercise live longer lives in better health than those who don’t exercise (Gopinath et al., 2018). These beneficial effects of physical activity and exercise on chronic conditions are also associated with improved body composition (Izquierdo et al., 2021).

2.2 Body Composition

As aging occurs, body composition tends to shift. After the age of 50 years old, adults lose lean mass and gain fat mass faster than any other age group (Gill et al., 2015). Body composition and how it changes can be influenced by several variables including genetics, age, sex, ethnicity, socioeconomic status, and environmental factors (Thibault et al., 2012). While some impacting factors of body composition such as genetics, sex, and ethnicity are fixed to a degree, others such as environmental factors (namely nutrition and physical activity habits) can be altered to improve body composition changes over the lifespan (Schoufour et al., 2021).

One of the most notable changes in body composition through aging is the loss of bone mass. This is due to a decrease in bone density that often occurs with aging. The excessive loss of bone density, known as osteoporosis, affects one in four Canadians over the age of 65 and disproportionately affects women more so than men with rates of 38.6% and 9.1%, respectively (Public Health Agency of Canada, 2021). Decreased bone density presents as a risk factor for decreased physical functioning, hip fractures, hospitalizations, and premature mortality (Bouvard et al., 2021).

As humans get older, body fat percentage often increases and they may eventually develop a chronic condition called obesity (He et al., 2018). Obesity is a complex chronic condition where an individual has an excessive amount of body fat, which could be detrimental to their health. Fat mass may increase or remain stable in old age, but there is often a redistribution from subcutaneous to visceral fat (Izquierdo et al., 2021). An obesity paradox has been presented and explored in aging literature which suggests some potentially protective effects of a higher body mass index (BMI) in older adults and chronic disease populations, however, this is often seen in individuals with more subcutaneous fat and less visceral fat (Bosello & Vanzo, 2021).

Research shows that the accumulation of subcutaneous fat below obesity thresholds may actually have protective effects on the human body, while the accumulation of visceral fat almost always has adverse health effects (Ibrahim, 2010). Despite the obesity paradox observed in older adults, excess amounts of body fat have generally been found to be harmful to health and increase an individual's risk of a plethora of chronic conditions (Bosello & Vanzo, 2021; Kivimäki et al., 2022). Additionally, the accumulation of visceral body fat in the abdominal region has been associated with an even greater risk of mortality

(Ibrahim, 2010). It has been well established that obesity is a worldwide epidemic, and rates of obesity are not predicted to decrease in the future (Malenfant & Batsis, 2019).

In 2016, the World Health Organization reported that the worldwide prevalence of obesity in individuals over the age of 18 years old was about 13% and that an additional 39% of the population was overweight (sometimes considered as pre-obese) (World Health Organization, 2021a). In Canada, approximately 25% of the adult population was classified as obese in 2015, and the prevalence of adult obesity in Canada is expected to double over the next 20 years (Bancej et al., 2015). Statistics Canada (2021b) has reported that these rates are even slightly higher in the senior population with 28.3% of seniors having a BMI classified as obese, and an additional 38.8% being classified as overweight (Statistics Canada, 2021b). It is worth noting that the aforementioned rates of obesity may be even higher than initially suggested since the use of BMI for diagnosis of obesity has a high specificity and low sensitivity, which increases the risk of a false negative and often leads to underdiagnosing obesity (Javed et al., 2015).

One of the best forms of treatment to avoid age-related body composition changes is physical activity, and more specifically, resistance training (Izquierdo et al., 2021). Resistance training is an effective treatment for fat loss and conservation of lean mass, and also leads to more efficient metabolic processes, resulting in a higher resting metabolic rate which will help to maintain an optimal body weight (Izquierdo et al., 2021). Evidence shows that after the age of 50 years old, lean mass decreases at a rate of about 10% per decade if proper interventions are not implemented (Goodpaster et al., 2006). Although it is normal to observe a decrease in lean mass associated with aging, a reduction above two standard deviations of the average of young adults is problematic and considered to be a chronic condition called sarcopenia (McLean & Kiel, 2015). It is currently estimated that about 10% of the world's population of seniors over the age of 60 years old suffers from sarcopenia, and prevalence is rising as the world's population ages and life expectancy increases (Shafiee et al., 2017). Sarcopenia is progressive and can be a debilitating condition, as it has been associated with decreased quality of life, frailty, hip fractures, disability, and mortality (Morley, 2016).

Treatment options for sarcopenia include lifestyle modifications such as physical activity, resistance training, and nutritional supplementation, as well as pharmacological interventions (Keller, 2019). However, pharmacological interventions are limited for sarcopenia and often have several undesirable side effects (Morley, 2016), and nutritional supplementation alone has only been shown to have a limited effect on sarcopenia which doesn't often translate into an improvement in physical function (Beaudart et al., 2017). Therefore, resistance training is a crucial front-line treatment for sarcopenia (Beaudart et al., 2017).

Sarcopenic obesity is a condition in which there are low levels of lean mass and high levels of fat mass, where an individual presents with both obesity and sarcopenia (Bouchard et al., 2009). Sarcopenic obesity is a risk factor in developing functional disabilities: a systematic review and meta-analysis by Schaap et al. (2013) showed that individuals with sarcopenic obesity were 2.5 times more likely to experience disability in instrumental activities of daily living when compared to those without sarcopenic obesity. In this same meta-analysis, there was no association found between disability onset and sarcopenia or obesity alone, which highlights the importance of diagnosing both conditions simultaneously.

It is abundantly clear that body composition changes occur with aging and that these changes negatively influence the ability to perform activities of daily living. This association is often mediated by a loss of muscular strength (Schaap et al., 2013).

2.3 Muscle Strength

Aging is associated with changes in the quality of the muscles in the human body (Schaap et al., 2013). Absolute strength refers to the sheer amount of load that a muscle can successfully contract against and is often measured using a 1-repetition maximum test as a field test, or maximum voluntary contraction via dynamometry as a laboratory test (Verdijk et al., 2009). Absolute strength has been an important variable in aging literature over the years; research has shown that skeletal muscle strength starts to decline in the fourth decade of life and that this decline significantly accelerates after the sixth decade (Keller & Engelhardt, 2014). After the age of 50 years, absolute muscle strength has been shown to decline by anywhere from 1.5% to as much as 5% per year (Keller & Engelhardt, 2014).

This age-related decline in skeletal muscle strength is the outcome of several complex interactions of physiological factors including progressive muscular atrophy, intrinsic changes to muscle composition (i.e., increased fat infiltration), alterations in muscle metabolism, a slowing of excitation-contraction coupling, and prolonged oxidative stress (Ryall et al., 2008). However, there are also behavioural factors that contribute as well such as reduced physical activity levels, increased sedentary behaviour, and severely reduced recruitment of upper-level motor units due to a lack of high-intensity activities (Hunter et al., 2016). It is unclear whether the various physiological changes occur due to aging and thus impact the behavioural, or whether a gradual reduction in moderate-to-vigorous physical activity drives these physiological changes, but it is clear that there is a distinct association between them (Hunter et al., 2016). A systematic review and meta-analysis performed by Schaap et al. (2013) also demonstrated that this age-related decline in absolute strength is associated with functional decline: the more muscle strength an individual loses, the higher their risk is for developing physical disability (Schaap et al., 2013). A large body of research has demonstrated that habitual physical activity and exercise can mediate these deteriorations in strength and physical function, and even lead to improvements in these measures (Izquierdo et al., 2021).

Relative strength represents the amount of force that a muscle can produce per unit of lean mass. Relative strength may also be referred to as 'specific strength', 'neuromuscular muscle quality', or 'muscle mass index' in the literature (Petrella et al., 2007; Radaelli et al., 2021). Recent research shows that relative strength may be more indicative of changes in overall muscle quality in older adults, and may be a better predictor of functional disability and loss of independence than absolute strength (De Lira et al., 2019; Francis et al., 2017). In fact, relative strength has been shown to be the strongest predictor of functional capacity when compared with absolute strength, body fat mass, and aerobic endurance, with relative strength accounting for 29-42% of the variability in physical function (Misic et al., 2007). This highlights the fact that the age-associated loss of muscle strength can be problematic and detrimental for older adults.

Dynapenia is defined as the progressive loss of skeletal muscle strength and power (Clark & Manini, 2012). While a decline in skeletal lean mass (sarcopenia) is cause for concern, it has been hypothesized that the loss of muscle strength may be even more detrimental to physical function and independence in older adults (Hairi et al., 2010). Due to dynapenia research lagging decades behind sarcopenia research, the worldwide prevalence of dynapenia is unclear. However, regional studies across the world have estimated rates of dynapenia in people over the age of 65 years old to be between 21.5% and 38.2% (Borges et al., 2020; Neves et al., 2018; Rodríguez-García et al., 2018; Tessier et al., 2019). This data suggests that rates of dynapenia are much higher than sarcopenia in older adults, and it seems to occur at a faster rate as well (Clark & Manini, 2012). Dynapenia seems to affect women more so than men and has a higher association with hospitalization rates than sarcopenia (Neves et al., 2018).

For a short time, scientists attempted to group dynapenia into the definition of sarcopenia but quickly realized that the age-related loss of lean mass and the age-related loss of muscle strength were only loosely associated and both merited their own definitions and categories (Manini & Clark, 2012). It was previously thought that sarcopenia may be the cause of dynapenia, but current research shows that is not the case, and that sarcopenia is only one of several factors that contribute to dynapenia (Manini & Clark, 2012). Other variables that significantly influence dynapenia include neural factors such as motor recruitment and discharge rate, and muscular factors such as muscle contractile quality, all of which are significantly influenced by physical activity and resistance training (Manini & Clark, 2012).

Dynapenic obesity is a condition in which high levels of adiposity occur with low levels of muscular strength and power. While obesity and dynapenia are both associated with functional decline, dynapenic obesity has been shown to be associated with more significant functional decline than obesity or dynapenia alone (Bouchard & Janssen, 2010). Obesity, sarcopenia, and dynapenia are all serious health conditions that independently contribute to an increased risk of developing other comorbidities. However, the presence of two or more of these body composition conditions together, such as sarcopenic and dynapenic obesity, produce a much higher risk of physical disability and disease manifestation (Malenfant & Batsis, 2019).

When it comes to assessments, relative strength is often expressed as a ratio where absolute strength is the numerator and lean mass is the denominator, resulting in a ratio referred to as the muscle quality index. Both parts of this ratio can be assessed in numerous ways. The numerator, muscle strength, can be assessed with 1-RM methods, grip strength tests, or through isometric or isokinetic dynamometry. The denominator, lean mass, can be assessed using dual-energy X-ray absorptiometry (DXA), computed tomography (CT), magnetic resonance imaging (MRI), muscle ultrasound (US), and bioelectrical impedance analysis (BIA) (Correa-de-Araujo et al., 2017; Radaelli et al., 2021). Since muscle quality is a relatively recent topic in research, there is a lack of consensus on what the best method is for assessing relative strength (Correa-de-Araujo et al., 2017).

In the current muscle quality research, DXA seems to be the most common imaging technique used to assess lean mass by far, followed by CT scans, MRI and US, and lastly, BIA (Radaelli et al., 2021). While US and BIA prove to be low-cost and easily implemented options for assessing fat-free mass, they may not be reliable enough to distinguish rates of change in lean mass. BIA has been found to be unreliable in measuring changes in lean mass when compared with US and CT scans (Nakanishi et al., 2019), and US techniques are subject to an operator dependency, meaning that the quality of the results has a high level of variability depending on the medical technologist completing the techniques, which are not present with DXA and CT scans. (Correa-de-Araujo et al., 2017).

As for the measurement of muscle strength within the relative strength ratio, the knee extensor muscles seem to be the most commonly assessed. A few studies have explored using grip strength or strength of the plantar flexors, but these methods come with limitations in assessing lean mass (Correa-de-Araujo et al., 2017). In a 2021 systematic review and meta-analysis by Radaelli et al., 15 out of 17 studies used knee extensor strength in their relative strength assessment methods and the remaining two used plantar flexor strength. Of the 15 studies that assessed knee extensor strength, five of them used a 1-repetition maximum test to measure it, seven used isokinetic dynamometry, and three used isometric strength. It is worth noting that both studies using planter flexor strength did not have sufficient data for inclusion in the meta-analysis.

2.4 Physical Function

Physical function is a multifaceted concept that involves several systems including the musculoskeletal, cardiorespiratory, neuromuscular, and nervous systems (Patrizio et al., 2020). Physical function is defined as the ability to complete basic activities of daily living which include ambulating, feeding, dressing, personal hygiene, continence, and toileting, as well as instrumental activities of daily living such as transportation and shopping, managing finances, meal preparation, home maintenance, communication, and managing medications (Edemekong et al., 2021). When physical function starts to decline, instrumental activities of daily living are often the first activities that people tend to seek assistance with. When people lose the ability to perform instrumental activities of daily living, they begin to lose their independence and ability to live alone in a community setting (Mlinac & Feng, 2016). They may be able to maintain independence while getting assistance with instrumental activities of daily living, but once they need assistance with activities of daily living, they are no longer able to live alone and must be moved to an institution or designated to a caretaker who will live with and care for them (Edemekong et al., 2021).

Peak physical functioning occurs between the age of 20 and 30 years old and then begins to gradually decline as the human body ages (Keller & Engelhardt, 2014). The most significant physical disabilities usually occur after the age of 50 years old, which is when significant declines in muscle strength and lean mass are observed (Doherty, 2001; Goodpaster et al., 2006). This decline in physical function is a major risk factor for institutionalization in older adults (Luppa et al., 2010). Physical function may decline gradually as a result of a lack of physical activity, or it may happen quickly and suddenly as a result of a fall, injury, or condition. While the latter may not be able to be directly impacted through proactive measures, functional decline in both scenarios can be delayed through physical activity and exercise (Izquierdo et al., 2021).

2.4.1 Assessment

Since physical function is a multidimensional concept, its assessment often includes self-reported abilities to complete day-to-day activities, or is measured via clinical tests as a proxy measure (Patrizio et al., 2020). A systematic review by Soubra et al. (2019) reported that a minimum of 31 different functional capacity tests and batteries have been developed over the years to capture the multiple factors that influence physical function. This systematic review highlights the lack of consensus on a gold standard when it comes to assessing physical function, and the need for clarity on which assessments are best suited for specific populations (Soubra et al., 2019). Two of the most popular physical function test batteries are the Senior Fitness Test and the Short Physical Performance Battery

(Patrizio et al., 2020). The Senior Fitness Test is especially intriguing as it has excellent reliability and validity, and even presents established sex-specific norms in 5-year age brackets from 60-94 years for reference (Hesseberg et al., 2015; Rikli & Jones, 1999a, 1999b).

The Senior Fitness Test battery consists of a 6-minute walk test to assess aerobic endurance, the 30-second chair stand to assess lower body strength, a biceps arm curl test to assess upper body strength, the timed-up-and-go test to assess agility and dynamic balance, the back scratch test to assess upper body flexibility, and the chair sit and reach test to assess lower body flexibility (Langhammer & Stanghelle, 2015). All six of the tests within the Senior Fitness Test battery have an intraclass correlation between 0.8 and 0.98 (with most being above 0.9), deeming the Senior Fitness Test a reliable battery of tests (Rikli & Jones, 1999a).

The 30-second chair stand, 6-minute walk, and chair sit and reach tests have all been compared to gold standard assessment practices to assess their criterion validity: the correlations were calculated as 0.77, 0.78, and 0.83, respectively, all demonstrating strong validity (Rikli & Jones, 1999a). The arm curl test was also compared to the gold-standard assessment of upper body strength but was calculated independently for males and females due to the differing protocols. The arm curl test demonstrated high validity for both males and females with correlations of 0.81 and 0.78, respectively (Rikli & Jones, 1999a). Due to the lack of consensus on gold-standard assessments for upper body flexibility and dynamic balance, the criterion validity for the chair sit and reach and timed-up-and-go tests could not be calculated. Instead, experts concur that these tests are considered to be the best measure of their respective criteria (Rikli & Jones, 1999a). Another benefit to this test battery is that the normative values for these tests are presented in 5-year age brackets, therefore allowing individuals to compare their scores more accurately to others of their respective age and sex.

The Short Physical Performance Battery testing battery focuses on lower extremity functionality and was developed for older adults with lower self-reported functional capacity (Guralnik et al., 1994). It consists of a gait speed test, a 5-repetition sit-to-stand test, and three balance tests (feet side by side, tandem, semi-tandem) (Guralnik et al., 1994). Each test has a scoring system in which certain criteria are associated with a point value (i.e., semi-tandem stance >10 seconds=1 point; <10 seconds=0 points). The sum of the points is tallied up for a total out of 12 points, with 0 being the worst possible score.

The Short Physical Performance Battery has been shown to have excellent validity and reliability in both general and specific populations (Gómez et al., 2013; Guralnik et al., 2000). Reliability of the Short Physical Performance Battery has been reported as having an ICC between 0.83 and 0.92, deeming the Short Physical Performance Battery a reliable test battery (Gómez et al., 2013). It has been found to be a valid measure of physical function in older adults, and predictive of future disability (Guralnik et al., 2000). Low scores on the Short Physical Performance Battery (<8) have been associated with higher incident disability (Pahor et al., 2014), a greater risk of falls (Lauretani et al., 2019), and an increased chance of institutionalization (Gawel et al., 2012). A systematic review and meta-analysis by Pavasini et al. (2016) reported that scoring less than 10 points on the Short Physical Performance Battery is predictive of all-cause mortality.

Individual tests are also used by clinicians to assess physical function in a shorter timeframe including chair stand tests, timed-up-and-go tests, and gait speed tests (Patrizio et al., 2020). Physical function is a multifaceted concept and should be assessed as such. The main dimensions that are often assessed to reflect physical function are upper body strength, lower body strength, aerobic endurance, balance, and flexibility. Upper body strength is important for daily activities such as dressing oneself, preparing meals, carrying groceries, and performing house maintenance tasks such as cleaning and renovations (Edemekong et al., 2021).

The three most commonly used assessments for upper body strength include a 1-repetition maximum bench press or chest press, a biceps/arm curl test, and a grip strength dynamometer test. Grip strength measured via dynamometry is the most widely used measure of upper body grip strength as well as overall body strength (Bohannon, 2019). However, evidence suggests that grip strength is not always indicative of overall body strength when used alone, and it is therefore suggested that it be administered in conjunction with a lower body strength assessment (Sanderson et al., 2016).

Lower body strength is strongly correlated with physical function as it translates to walking, going up and down stairs, getting in and out of chairs, as well as being able to stand for extended periods to perform house maintenance tasks such as cleaning and renovations (Bårdstu et al., 2022). Common lower body strength assessments for older adults include maximum voluntary contraction via isokinetic dynamometry, one-repetition maximum leg press, one-repetition maximum leg extension, and a variation of chair stand tests (often the 5-repetition sit-to-stand test or 30-second chair stand test) (Verdijk et al., 2009). When equipment is available, the isokinetic dynamometric measure of maximum voluntary contraction of the leg extensor muscles is considered the gold standard for assessing lower body strength, however, research has shown that one-repetition maximum measures of leg extension and leg press are both strongly correlated with dynamometric measures of lower body strength (Verdijk et al., 2009).

One-repetition maximum testing has also been shown to have good to excellent test-retest reliability regardless of age, sex, resistance training experience, familiarization testing sessions, and exercise selection (Grgic et al., 2020). Additionally, given the importance of specificity in both strength training and assessments in older adults (Liu et al., 2014), it has been argued that one-repetition maximum strength testing may be more relevant than dynamometry when used to assess changes in muscle strength following an exercise intervention in older adults (Verdijk et al., 2009). This is also partially due to the fact that isokinetic dynamometry can only test muscle strength with one degree of freedom as it can only be conducted on single-joint movements such as leg extension, which is not the case with 1-repetition maximum testing (Grgic et al., 2020).

2.5 Physical Activity

Physical activity is defined as: "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen et al., 1985). Context-specific types of physical activity include leisure-time physical activity which is often done for enjoyment, occupational physical activity which is any job-related physical activity, transportation to get to and from destinations, and domestic which includes housework and renovations (Caspersen et al., 1985).

Current 24-hour movement guidelines recommend that adults over the age of 18 years old accumulate at least 150 minutes of MVPA per week (Ross et al., 2020). The guidelines also state that adults should strive to be active every day by incorporating several hours of light-intensity physical activity, reduce sedentary time to less than 8 hours per day, and perform muscle-strengthening activities focusing on major muscle groups at least twice per week. The Canadian Society of Exercise Physiology has recently been promoting a “healthy 24 hours” construct which focuses on incorporating several different types and intensities of physical activity throughout the entire day (Ross et al., 2020). Even though the emphasis has shifted to highlight the importance of maintaining movement throughout the whole day, reallocating time into MVPA from other movement behaviours is associated with more favourable improvements in several health outcomes (Janssen et al., 2020).

While multi-modal exercise routines are highly encouraged for those who are able, sedentary individuals should start with one mode of exercise (i.e., resistance, aerobic, or balance) and gradually progress to include other modes as they are able (Izquierdo et al., 2021). More specifically, it is recommended that physically inactive older adults perform resistance training activities before aerobic training in order to strengthen and condition the muscles needed to perform aerobic training (Izquierdo et al., 2021). Resistance training can also have cardiovascular and cardiorespiratory benefits, whereas aerobic training does not seem to produce musculoskeletal benefits (Izquierdo et al., 2021).

2.5.1 Resistance Training

Resistance training is defined as any type of muscle-strengthening activity that uses an external load for a muscle to resist against. It has been well-established in the literature that resistance training is highly beneficial for older adults (Izquierdo et al., 2021). The most notable benefits of resistance training include prophylactic effects through improved body composition, specifically improvements in muscle strength and mass, bone mass, and reduction in fat mass (Izquierdo et al., 2021). Resistance training has been identified as a key variable in preventing over 35 chronic conditions and has been shown to be an extremely effective front-line treatment for over 26 different chronic conditions including metabolic, neurological, cardiovascular, psychiatric, pulmonary, and musculoskeletal diseases and disorders, as well as cancer (Booth et al., 2012; Pedersen & Saltin, 2015). Resistance training has also been associated with a 21% reduction in risk of all-cause mortality (Saeidifard et al., 2019).

Bone mass in particular is very responsive to physical activity and resistance training, or lack thereof, as mechanical loading (such as lifting weights) both maintains bone mineral density and stimulates the growth of new bone (Bolam et al., 2013). However, in the absence of mechanical loading (physical inactivity), bone marrow can be resorbed, making the bone less dense and ultimately more frail, increasing the risk of fracture (Bolam et al., 2013). Progressive loading with resistance training is a highly effective strategy for increasing and maintaining a healthy bone mineral density in older adults, decreasing the risk of fractures and subsequent hospitalizations (Izquierdo et al., 2021).

Along with the significant effects that resistance training can have on bone mass and density, resistance training can also have tremendous effects on muscle strength, lean mass, and muscle quality in older adults (Radaelli et al., 2021). A systematic review and meta-analysis by Radaelli et al. (2021) that included 17 studies and almost 500 participants found resistance training exercise to be effective in improving muscle strength per unit of lean mass in older adults. This improvement in relative strength in older adults applies to both men and women, as well as obese and non-obese older adults (De Lira et al., 2019; Radaelli et al., 2021). This improvement in relative strength translates to an improvement in physical function and mobility, which in turn contributes to maintaining independence and improved quality of life in older adults (McGregor et al., 2014).

In terms of programming, multiple variables (i.e., frequency, duration, intensity) depend on the target outcome and the resistance training experience level of the individual (American College of Sports Medicine, 2009). Most physical activity guidelines for adults recommend performing at least two sessions of resistance training weekly targeting major muscle groups. For example, the National Strength and Conditioning Association (NSCA) recommends that for older adults, a strength training program should be performed 2-3 non-consecutive days each week, include 8-10 compound exercises targeting major muscle groups with 1-3 sets of 6 to 12 repetitions for each exercise to target improving muscular strength (Fragala et al., 2019). In Canada, the general recommendation for adults is simply to perform two sessions per week targeting major muscle groups, with no specific guidelines for older adults (Ross et al., 2020).

In order to elicit strength gains, progressive overload needs to be used to continually stimulate the muscle as it adapts to the previously applied stress (American College of Sports Medicine, 2009). Exercises can be progressed to be more challenging in a variety of different ways such as increasing sets, reps, load/resistance, time under tension, contraction speed, altering joint angles, or decreasing rest times between sets (American College of Sports Medicine, 2009). To allow for proper recovery, it's recommended that older adults take between 1-3 minutes of rest between exercises, depending on their readiness to continue exercising (Izquierdo et al., 2021). As exercise tolerance increases, older adults should be able to gradually reduce their rest times from three minutes down to one minute (Izquierdo et al., 2021).

In terms of duration, older adults who are new to resistance training often experience higher strength improvements in a shorter timeframe than intermediate and advanced lifters due to the primarily neural gains elicited when beginning resistance training (American College of Sports Medicine, 2009; Moritani & deVries, 1979). Significant increases in relative strength have been demonstrated in resistance training interventions as short as 6 weeks all the way up to 48 weeks, although a meta-analysis performed by Radaelli et al. (2021) showed no significant association between the length of intervention and relative strength. A systematic review performed by Lai et al. (2018) echoed these findings in physical function, reiterating that a minimum of 6 weeks of habitual resistance training is needed for improving both muscular strength and physical function in older adults (Lai et al., 2018).

In terms of all-cause mortality, Saeidifard et al. (2019) found that performing resistance training twice per week resulted in a significantly decreased risk in older adults, but that performing resistance training more than twice per week did not produce any additional benefit. A meta-analysis performed by Ralston et al. (2018) compared medium-frequency resistance training (2 days/week) and high-frequency resistance training (≥3 days/week) and found there were no significant differences in maximal strength gain between the two in elderly populations (Ralston et al., 2018).

The extensive benefits of resistance training for older adults have been very well documented and established over the last several decades (Izquierdo et al., 2021). The benefits greatly outweigh the risks, and it can be used to prevent, manage, and treat a plethora of chronic conditions in conjunction with, or in some cases, in lieu of pharmacological interventions (Pedersen & Saltin, 2015). Resistance training has barely any negative side effects, besides harmless muscle soreness (Izquierdo et al., 2021). Yet still, 67.5% of older adults report not taking part in any muscle-strengthening activities whatsoever (Copeland et al., 2019).

2.5.2 Barriers

While the research is abundantly clear on the fact that resistance training is extremely beneficial for all age groups and especially later in life, the large majority of older adults are not taking part in any type of resistance training (Copeland et al., 2019). It is well-known that behaviour change is complex and includes several variables that can make it difficult for older adults to take part in resistance training (Rhodes et al., 2019). Barriers to resistance training for older adults include individual-level barriers, social barriers, and environmental barriers (Burton et al., 2017). Individual-level barriers may include physical barriers such as pain, fatigue, and fear of injury, psychological barriers such as low self-efficacy, mental health issues, or fear of adverse events, or other individual-level barriers such as lack of time, lack of knowledge, and cost. Social barriers include a lack of social support and family or work obligations and responsibilities. Environmental barriers include lack of access to exercise facilities, geographical location, and lack of age-appropriate exercise options (Burton et al., 2017).

One of the most significant reported barriers to exercise is cost, especially for seniors who are often on a fixed income (Dismore et al., 2020). While the price of a gym membership varies significantly depending on the facility, it can cost anywhere from $20 to $180 per month. Even with a senior's discount, gym memberships can cost hundreds of dollars per year. On top of that, physical literacy is often lacking in senior populations and older adults may need to hire a personal trainer to ensure safety while taking part in resistance training which are very expensive. Cost can disguise itself as other barriers as well such as lack of accessibility to exercise facilities, geographical location, and lack of time (Burton et al., 2017). Appropriate interventions are needed that take the barrier of cost into account in order to increase resistance training participation in community-dwelling older adults. Outdoor exercise structures have been proposed as a potential solution to several of the aforementioned barriers to physical activity and resistance training (Cohen et al., 2012).

2.6 Outdoor Exercise Structures

An outdoor exercise structure is any kind of outdoor equipment or space that has been installed with the intention to promote structured physical activity (Jansson et al., 2019; Lee et al., 2018). Since the research on outdoor exercise structures is relatively new, there are several different terms used to describe these structures with a lack of consensus on which one should be properly used (Lee et al., 2018). Outdoor exercise structures may otherwise be referred to as “outdoor gyms” (Lee et al., 2018), “outdoor fitness equipment” (Chow, 2013), “active parks” (Copeland et al., 2017), “family fitness zones” (Cohen et al., 2012), “open gyms” (Mora, 2012), or “golden age gyms” (Salin et al., 2014). These outdoor exercise structures often resemble playground equipment and are simple, versatile pieces of equipment that can be creatively used to perform a variety of different exercises. Outdoor exercise structures are often installed to increase levels of habitual physical activity in community settings in order to appeal to a public health agenda (Scott et al., 2021).

Outdoor exercise structures have been proposed as a possible solution to several barriers to resistance training and have been installed in parks all over the globe (Cohen et al., 2012). Outdoor exercise structures are free to use, available at any time of day, and often provide instruction on proper usage (Lee et al., 2018). They may provide exercise infrastructure in rural communities where people may not have access to formal exercise facilities, or the transportation needed to get to exercise facilities. Outdoor exercise structures also allow you to perform types of physical activity (such as resistance training) that are often performed indoors, outdoors. This is beneficial because the majority of adults don't get enough sunlight in the run of a day, and regular sunlight exposure can be beneficial to both mental and physical health (Razzaque, 2018).

Outdoor exercise structures have only recently been researched in the past decade or so, with the first studies on the topic being published in 2012 (Jansson et al., 2019; Lee et al., 2018). Early studies focused on observing outdoor exercise structures to assess usage trends and conducting surveys with equipment users in order to gain perspective on how and why the structures are used (Cohen et al., 2012; Mora, 2012). A natural experiment performed by Cohen et al. in 2012 found that installing exercise infrastructure in parks resulted in increased park usage, increased levels of moderate-to-vigorous physical activity, and encouraged more new park users. Cohen et al. also found the installation of these structures to be very cost-effective.

The cost-effectiveness of physical activity interventions has been evaluated by the cost required to increase physical activity by one metabolic equivalent (MET), which is typically the energy expenditure of 20 minutes of walking (Wu et al., 2011). According to Cohen et al., outdoor exercise structures have an impressive cost-effectiveness ratio of 10.5 cents/MET. Cost-effectiveness is an important aspect when considering the installment of outdoor exercise structures (Cohen et al., 2012). In an era when increasing physical activity levels can have significant implications for healthcare spending by reducing chronic condition prevalence and facilitating healthy aging, low-cost interventions are essential (Anderson & Durstine, 2019; Elmslie, 2016).

Outdoor exercise structures are often meant to be geared toward senior populations, however, older adults seem to be the age demographic that uses these resources the least (Cohen et al., 2012; Mora, 2012). A study conducted by Mora (2012) found that adults over the age of 60 years old accounted for 14% of outdoor exercise structure users on weekends, and only 3% of gym users during the weekdays. Cohen et al. (2012) found similar results with seniors accounting for only 3.8% and 5.5% of users on two separate observation occasions. Young adults seemed to make up the bulk of outdoor exercise structure users in these early studies with people between the ages of 15 and 29 accounting for 46% of users on the weekend and 59% of users on weekdays (Mora, 2012). Cohen et al. did not differentiate between young adults and middle-aged adults but did report that adults between the ages of 18-59 years old accounted for 64.4% of users at their most recent follow-up.

In order to understand why these patterns in demographics occur in outdoor exercise structure users, multiple studies have been conducted to explore the perceptions of gym users and community members (Chow, 2013; Copeland et al., 2017). A study conducted by Chow (2013) used semi-structured interviews with 55 outdoor exercise structure users (27 males and 28 females) who were over the age of 50 years old and found that older adults were generally satisfied with the outdoor exercise structures in their communities. However, the outdoor exercise equipment was perceived as supplementary features to the walking trails and surrounding parks; not many older adults went to the parks specifically to use the exercise equipment (Chow, 2013). The main reasons that people did use the outdoor exercise structures were to improve their health, to socialize with others, and for enjoyment (Chow, 2013).

Copeland et al. (2017) found similar results when interviewing outdoor exercise structure users and local residents near the identified sites to gain perspective on how the infrastructure is perceived in the community. Health benefits was the top theme that emerged in both studies as a reason for using the exercise equipment (Chow, 2013; Copeland et al., 2017), with the additional benefits of improved accessibility and being family-friendly reported by Copeland et al. 70% of residents reported that they believed the exercise structures promoted a sense of community, and 82% reported that they believed the outdoor exercise structures increased physical activity levels within the community (Copeland et al., 2017). When residents were asked what would be the best strategies to encourage increased usage of the outdoor exercise structures, 60% responded that there needed to be more advertisement outside of the park, and 44% responded that there needed to be more marketing within the park itself (Copeland et al., 2017).

So far, there have been three systematic reviews performed on outdoor exercise structures (Jansson et al., 2019; Lee et al., 2018; Ng et al., 2021). The first systematic review conducted on outdoor exercise structures was performed by Lee et al. (2018) and aimed to assess the current quantitative and qualitative literature available on outdoor exercise structures. This review assessed nine studies that were published between 2012 and 2017, including four mixed-methods, three qualitative, and three quantitative studies (Lee et al., 2018). Lee et al. found that outdoor exercise structures vary greatly between locations and have no consistent unifying standards. While 'health' seems to be the central theme regarding outdoor exercise structures, Lee et al. also found that 'social connectedness', 'affordable', 'support', and 'designed and promotion' emerged as major themes within the reviewed studies.

A systematic review by Jansson et al. (2019) analyzed quantitative and mixed-methods studies that assessed physical activity levels and health-related outcomes in relation to outdoor exercise structures. 18 studies which were published between 2012 and 2018 were included in the review by Jansson et al., but due to the lack of congruency in the outcomes of the included studies, Jansson et al. could not come to a consensus on whether the use of outdoor exercise structures improved physical activity levels or health-related outcomes. Studies varied extensively in primary and secondary outcome measures, length of interventions, types of exercise interventions (i.e., resistance training vs. aerobic training vs. combined), number of participants, and age of participants (Jansson et al., 2019). Half of the studies included demonstrated significant increases in MVPA levels in areas where outdoor exercise structures were implemented, while half did not (Jansson et al., 2019). Regarding health- and fitness-related outcomes, the three included studies in the Jansson et al. review had too wide of a range of outcomes to make a definitive decision on whether or not the use of outdoor exercise structures can facilitate health benefits.

All studies that measured health- and fitness-related outcomes demonstrated a significant improvement in at least one (but not all) outcomes (Jansson et al., 2019). For example, a randomized control trial conducted by Kim et al. (2018) found that a 6-week exercise intervention performed on an outdoor exercise structure resulted in significant improvements in upper body strength and endurance (push-up test), physical function (6-minute walk test), and fasting insulin levels in older adults, but did not see any changes in body composition measures. However, a study conducted by Nguyen et al. (2014)

demonstrated a significant decrease in body weight, body fat mass, and waist circumference and a significant increase in upper and lower body muscular endurance in a similar 6-week intervention performed on outdoor exercise structures. The Kim et al. (2018) study was conducted on participants over the age of 65 years old, while the Nguyen et al. study had a mean age of 35 years old, which may explain the discrepancy in body composition results. Similarly, Sales et al. (2017) did not find any significant improvements in their primary outcome (balance as measured by the BOOMER test battery) but did demonstrate significant improvements in unipedal balance, knee extensor strength, and the timed sit-to-stand test in older adults after an 18-week exercise intervention using outdoor exercise structures.

A recent systematic review performed by Ng et al. (2021) took Jansson et al.'s review one step further and aimed to assess the current literature on the effect of outdoor exercise structure use on health-related outcomes in older adults. A total of nine studies were included in this systematic review including three randomized control trials, three cross-sectional studies, and three qualitative studies, and it was also reported by Ng et al., that like the Jansson et al. (2019) review, all the studies differed significantly in terms of participants, outcomes, and interventions. Due to the lack of literature regarding outdoor exercise structures and the close proximity in the publication of all three systematic reviews, a large majority of the studies were included in all three reviews.

Two meta-analyses were performed in the review by Ng et al., each consisting of only two studies. The first meta-analysis was performed on the Sales et al. (2017) and Kim et al. (2018) articles for the outcome measures of the 30-second chair stand and single-leg balance test, which showed no significant difference in either measure between the control and intervention groups. The second meta-analysis was performed for the outcome measure of the timed-up-and-go (TUG) test which included the Sales et al. study and a study conducted by Leiros-Rodriguez & Garcia-Soidan (2014), however, heterogeneity was too high (I^2=98%) for this analysis and thus was not included in the review. In conclusion, Ng et al. found that there is insufficient evidence available to conclude whether outdoor exercise structures are sufficient in facilitating health-related outcomes in older adults, and that more studies are needed in order to successfully complete this analysis.

Outdoor exercise structures vary significantly in terms of size, number of structures, type of machines available, and intended use (Lee et al., 2018). While some are built to resemble conventional exercise machines, others may resemble playground equipment, and some may consist solely of an array of vertical and horizontal metal beams. There is currently no consensus or information available on what an outdoor exercise structure should consist of, or how much it should cost to build. With an initial price tag of anywhere between $10,000 and $70,000, and averaging around $45,000, outdoor exercise structures are a significant community investment (Cohen et al., 2012). The estimated cost of maintenance for these structures per year is approximately $2000, although that value can vary significantly based on the size of the outdoor exercise structure and the pieces of equipment installed (Cohen et al., 2012).

The type of physical activity and resistance training that are intended to be performed on these outdoor exercise structures have been shown to result in improvements in health-related outcomes such as body composition, strength, and cardiovascular fitness (Izquierdo et al., 2021; Radaelli et al., 2021). These improvements can result in significant healthcare savings through reduced risk of falls, reduced chances of hospitalization, and reduced risk of developing chronic conditions that are especially burdensome to the healthcare system (Koné Pefoyo et al., 2015; Prince et al., 2015). However, it is currently unknown whether outdoor exercise structures are sufficient in providing the means to achieve the numerous health benefits of resistance training.

2.7 Gap in the Literature

While outdoor exercise structures seem like a viable option to address several barriers and increase accessibility to physical activity and resistance training, little is known about their implications on health-related outcomes (Jansson et al., 2019; Lee et al., 2018). Preliminary research shows promise that outdoor exercise structures can be used to increase physical activity levels in community settings, but there is limited research regarding the effect of outdoor exercise structures on health-related outcomes such as strength, balance, aerobic endurance, mobility, and physical function (Jansson et al., 2019).

Given the dire importance of maintaining relative strength while aging to maintain or improve other health outcomes, functional capacity, maintain independence, and decrease the chances of hospitalization and institutionalization, it is crucial to explore whether outdoor exercise structures can be used to facilitate improvements in relative strength. As a result, the present study will assess whether performing a progressive resistance training program on an outdoor exercise structure will result in significant improvements in relative strength in community-dwelling older adults.

3.0 References

American College of Sports Medicine. (2009). Progression Models in Resistance Training for Healthy Adults. *Medicine & Science in Sports & Exercise*, *41*(3), 687–708. https://doi.org/10.1249/MSS.0b013e3181915670

Anderson, E., & Durstine, J. L. (2019). Physical activity, exercise, and chronic diseases: A brief review. *Sports Medicine and Health Science*, *1*(1), 3–10. https://doi.org/10.1016/j.smhs.2019.08.006

Anderson, L. H., Martinson, B. C., Crain, A. L., Pronk, N. P., Whitebird, R. R., O'Connor, P. J., & Fine, L. J. (2005). Health Care Charges Associated With Physical Inactivity, Overweight, and Obesity. *Preventing Chronic Disease*, *2*(4), A09.

Bancej, C., Jayabalasingham, B., Wall, R. W., Rao, D. P., Do, M. T., de Groh, M., & Jayaraman, G. C. (2015). Trends and projections of obesity among Canadians. *Health Promotion and Chronic Disease Prevention in Canada : Research, Policy and Practice*, *35*(7), 109–112.

Bårdstu, H. B., Andersen, V., Fimland, M. S., Raastad, T., & Saeterbakken, A. H. (2022). Muscle strength is associated with physical function in community-dwelling older adults receiving home care. A cross-sectional study. *Frontiers in Public Health*, *10*, 856632. https://doi.org/10.3389/fpubh.2022.856632

Beaudart, C., Dawson, A., Shaw, S. C., Harvey, N. C., Kanis, J. A., Binkley, N., Reginster, J. Y., Chapurlat, R., Chan, D. C., Bruyère, O., Rizzoli, R., Cooper, C., & Dennison, E. M. (2017). Nutrition and physical activity in the prevention and treatment of sarcopenia: Systematic review. *Osteoporosis International*, *28*(6), 1817–1833. https://doi.org/10.1007/s00198-017-3980-9

Bolam, K. A., van Uffelen, J. G. Z., & Taaffe, D. R. (2013). The effect of physical exercise on bone density in middle-aged and older men: A systematic review. *Osteoporosis International*, *24*(11), 2749–2762. https://doi.org/10.1007/s00198-013-2346-1

Booth, F. W., Roberts, C. K., & Laye, M. J. (2012). Lack of exercise is a major cause of chronic diseases. *Comprehensive Physiology*, *2*(2), 1143–1211. https://doi.org/10.1002/cphy.c110025

Borges, V. S., Lima-Costa, M. F. F., & Andrade, F. B. de. (2020). A nationwide study on prevalence and factors associated with dynapenia in older adults: ELSI-Brazil. *Cadernos de Saúde Pública*, *36*(4), e00107319. https://doi.org/10.1590/0102-311x00107319

Bosello, O., & Vanzo, A. (2021). Obesity paradox and aging. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*, *26*(1), 27–35. https://doi.org/10.1007/s40519-019-00815-4

Bouchard, D. R., Dionne, I. J., & Brochu, M. (2009). Sarcopenic/Obesity and physical capacity in older men and women: data from the nutrition as a determinant of successful aging (NuAge)—the Quebec longitudinal study. *Obesity*, *17*(11), 2082–2088. https://doi.org/10.1038/oby.2009.109

Bouchard, D. R., & Janssen, I. (2010). Dynapenic-obesity and physical function in older adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *65A*(1), 71–77. https://doi.org/10.1093/gerona/glp159

Bouvard, B., Annweiler, C., & Legrand, E. (2021). Osteoporosis in older adults. *Joint Bone Spine*, *88*(3), 105135. https://doi.org/10.1016/j.jbspin.2021.105135

Burton, E., Farrier, K., Lewin, G., Pettigrew, S., Hill, A.-M., Airey, P., Bainbridge, L., & Hill, K. D. (2017). Motivators and barriers for older people participating in resistance training: A systematic review. *Journal of Aging and Physical Activity*, *25*(2), 311–324. https://doi.org/10.1123/japa.2015-0289

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports*, *100*(2), 126–131.

Chow, H. (2013). Outdoor fitness equipment in parks: A qualitative study from older adults' perceptions. *BMC Public Health*, *13*(1), 1–9.

Clark, B. C., & Manini, T. M. (2012). What is dynapenia? *Nutrition (Burbank, Los Angeles County, Calif.)*, *28*(5), 495–503. https://doi.org/10.1016/j.nut.2011.12.002

Cohen, D. A., Marsh, T., Williamson, S., Golinelli, D., & McKenzie, T. L. (2012). Impact and cost-effectiveness of family Fitness Zones: A natural experiment in urban public parks. *Health & Place*, *18*(1), 39–45. https://doi.org/10.1016/j.healthplace.2011.09.008

Copeland, J., Currie, C., Walker, A., Mason, E., Truba, T., & Amson, A. (2017). Fitness equipment in public parks: frequency of use and community perceptions in a small urban centre. *Journal of Physical Activity and Health, 14*, 1–29. https://doi.org/10.1123/jpah.2016-0277

Copeland, J., Good, J., & Dogra, S. (2019). Strength training is associated with better functional fitness and perceived healthy aging among physically active older adults: A cross-sectional analysis of the Canadian Longitudinal Study on Aging. *Aging Clinical and Experimental Research*, *31*(9), 1257–1263. https://doi.org/10.1007/s40520-018-1079-6

Correa-de-Araujo, R., Harris-Love, M. O., Miljkovic, I., Fragala, M. S., Anthony, B. W., & Manini, T. M. (2017). The need for standardized assessment of muscle quality in skeletal muscle function deficit and other aging-related muscle dysfunctions: A symposium report. *Frontiers in Physiology, 8*. https://www.frontiersin.org/article/10.3389/fphys.2017.00087

Cunningham, C., O' Sullivan, R., Caserotti, P., & Tully, M. A. (2020). Consequences of physical inactivity in older adults: A systematic review of reviews and meta-analyses. *Scandinavian Journal of Medicine & Science in Sports*, *30*(5), 816–827. https://doi.org/10.1111/sms.13616

De Lira, C., Vargas, V., Silva, W., Bachi, A., Vancini, R., & Andrade, M. (2019). Relative strength, but not absolute muscle strength, is higher in exercising compared to non-exercising older women. *Sports*, *7*(1), Article 1. https://doi.org/10.3390/sports7010019

Dismore, L., Hurst, C., Sayer, A. A., Stevenson, E., Aspray, T., & Granic, A. (2020). Study of the older adults' motivators and barriers engaging in a nutrition and resistance exercise intervention for sarcopenia: An embedded qualitative project in the MIlkMAN pilot study. *Gerontology and Geriatric Medicine*, *6*, 2333721420920398. https://doi.org/10.1177/2333721420920398

Doherty, T. J. (2001). The influence of aging and sex on skeletal muscle mass and strength. *Current Opinion in Clinical Nutrition & Metabolic Care*, *4*(6), 503–508.

Edemekong, P. F., Bomgaars, D. L., Sukumaran, S., & Levy, S. B. (2021). *Activities of Daily Living*. https://www.ncbi.nlm.nih.gov/books/NBK470404

Elmslie, K. (2016). *Against the Growing Burden of Disease* [PowerPoint Slides]. https://cagh-acsm.org/sites/default/files/resources/2016/10/elmslie.pdf

Flint, B., & Tadi, P. (2022). Physiology, Aging. *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK556106/

Fragala, M. S., Cadore, E. L., Dorgo, S., Izquierdo, M., Kraemer, W. J., Peterson, M. D., & Ryan, E. D. (2019). Resistance training for older adults: position statement from the national strength and conditioning association. *The Journal of Strength and Conditioning Research,* 33(8).

Francis, P., Toomey, C., Mc Cormack, W., Lyons, M., & Jakeman, P. (2017). Measurement of maximal isometric torque and muscle quality of the knee extensors and flexors in healthy 50- to 70-year-old women. *Clinical Physiology and Functional Imaging, 37*(4), 448–455. https://doi.org/10.1111/cpf.12332

Gawel, J., Vengrow, D., Collins, J., Brown, S., Buchanan, A., & Cook, C. (2012). The short physical performance battery as a predictor for long term disability or institutionalization in the community dwelling population aged 65 years old or older. *Physical Therapy Reviews*, *17*(1), 37–44. https://doi.org/10.1179/1743288X11Y.0000000050

Gill, L. E., Bartels, S. J., & Batsis, J. A. (2015). Weight management in older adults. *Current Obesity Reports*, *4*(3), 379–388. https://doi.org/10.1007/s13679-015-0161-z

Gómez, J. F., Curcio, C.-L., Alvarado, B., Zunzunegui, M. V., & Guralnik, J. (2013). Validity and reliability of the Short Physical Performance Battery (SPPB). *Colombia Médica : CM*, *44*(3), 165–171.

Goodpaster, B. H., Park, S. W., Harris, T. B., Kritchevsky, S. B., Nevitt, M., Schwartz, A. V., Simonsick, E. M., Tylavsky, F. A., Visser, M., Newman, A. B., & for the Health ABC Study. (2006). The loss of skeletal muscle strength, mass, and quality in older adults: The health, aging and body composition study. *The Journals of Gerontology: Series A*, *61*(10), 1059–1064. https://doi.org/10.1093/gerona/61.10.1059

Gopinath, B., Kifley, A., Flood, V. M., & Mitchell, P. (2018). Physical activity as a determinant of successful aging over ten years. *Scientific Reports*, *8*(1), 10522. https://doi.org/10.1038/s41598-018-28526-3

Grgic, J., Lazinica, B., Schoenfeld, B. J., & Pedisic, Z. (2020). Test–retest reliability of the one-repetition maximum (1RM) strength assessment: A systematic review. *Sports Medicine - Open*, *6*(1). https://doi.org/10.1186/s40798-020-00260-z

Guralnik, J. M., Ferrucci, L., Pieper, C. F., Leveille, S. G., Markides, K. S., Ostir, G. V., Studenski, S., Berkman, L. F., & Wallace, R. B. (2000). Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the Short Physical Performance Battery. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *55*(4), M221–M231. https://doi.org/10.1093/gerona/55.4.M221

Guralnik, J. M., Simonsick, E. M., Ferrucci, L., Glynn, R. J., Berkman, L. F., Blazer, D. G., Scherr, P. A., & Wallace, R. B. (1994). A short physical performance battery assessing lower extremity function: Association with self-reported disability and prediction of mortality and nursing home admission. *Journal of Gerontology*, *49*(2), M85–M94.

Hairi, N. N., Cumming, R. G., Naganathan, V., Handelsman, D. J., Le Couteur, D. G., Creasey, H., Waite, L. M., Seibel, M. J., & Sambrook, P. N. (2010). Loss of muscle strength, mass (sarcopenia), and quality (specific force) and its relationship with functional limitation and physical disability: the Concord health and ageing in men project. *Journal of the American Geriatrics Society*, *58*(11), 2055–2062. https://doi.org/10.1111/j.1532-5415.2010.03145.x

He, X., Li, Z., Tang, X., Zhang, L., Wang, L., He, Y., Jin, T., & Yuan, D. (2018). Age- and sex-related differences in body composition in healthy subjects aged 18 to 82 years. *Medicine*, *97*(25), e11152. https://doi.org/10.1097/MD.0000000000011152

Hesseberg, K., Bentzen, H., & Bergland, A. (2015). Reliability of the senior fitness test in community-dwelling older people with cognitive impairment. *Physiotherapy Research International: The Journal for Researchers and Clinicians in Physical Therapy*, *20*(1), 37–44. https://doi.org/10.1002/pri.1594

Hunter, S. K., Pereira, H. M., & Keenan, K. G. (2016). The aging neuromuscular system and motor performance. *Journal of Applied Physiology*, *121*(4), 982–995. https://doi.org/10.1152/japplphysiol.00475.2016

Ibrahim, M. M. (2010). Subcutaneous and visceral adipose tissue: Structural and functional differences. *Obesity Reviews*, *11*(1), 11–18. https://doi.org/10.1111/j.1467-789X.2009.00623.x

Izquierdo, M., Merchant, R. A., Morley, J. E., Anker, S. D., Aprahamian, I., Arai, H., Aubertin-Leheudre, M., Bernabei, R., Cadore, E. L., Cesari, M., Chen, L.-K., de Souto Barreto, P., Duque, G., Ferrucci, L., Fielding, R. A., García-Hermoso, A., Gutiérrez-Robledo, L. M., Harridge, S. D. R., Kirk, B., … Singh, M. F. (2021). International exercise recommendations in older adults (ICFSR): expert consensus guidelines. *The Journal of Nutrition, Health & Aging*, *25*(7), 824–853. https://doi.org/10.1007/s12603-021-1665-8

Janssen, I., Clarke, A. E., Carson, V., Chaput, J.-P., Giangregorio, L. M., Kho, M. E., Poitras, V. J., Ross, R., Saunders, T. J., Ross-White, A., & Chastin, S. F. M. (2020). A systematic review of compositional data analysis studies examining associations between sleep, sedentary behaviour, and physical activity with health outcomes in adults. *Applied Physiology, Nutrition, and Metabolism*, *45*(10 (Suppl. 2)), S248–S257. https://doi.org/10.1139/apnm-2020-0160

Jansson, A. K., Lubans, D. R., Smith, J. J., Duncan, M. J., Haslam, R., & Plotnikoff, R. C. (2019). A systematic review of outdoor gym use: Current evidence and future directions. *Journal of Science and Medicine in Sport*, *22*(12), 1335–1343. https://doi.org/10.1016/j.jsams.2019.08.003

Javed, A., Jumean, M., Murad, M. H., Okorodudu, D., Kumar, S., Somers, V. K., Sochor, O., & Lopez-Jimenez, F. (2015). Diagnostic performance of body mass index to identify obesity as defined by body adiposity in children and adolescents: A systematic review and meta-analysis. *Pediatric Obesity*, *10*(3), 234–244. https://doi.org/10.1111/ijpo.242

Jefferis, B. J., Sartini, C., Lee, I. M., Choi, M., Amuzu, A., Gutierrez, C., Casas, J. P., Ash, S., Lennnon, L. T., Wannamethee, S. G., & Whincup, P. H. (2014). Adherence to physical activity guidelines in older adults, using objectively measured physical activity in a population-based study. *BMC Public Health*, *14*(1), 382. https://doi.org/10.1186/1471-2458-14-382

Jingzhong, D., Kritchevsky, S. B., Newman, A. B., Taaffe, D. R., Nicklas, B. J., Visser, M., Lee, J. S., Nevitt, M., Tylavsky, F. A., Rubin, S. M., Pahor, M., & Harris, T. B. (2007). Effects of birth cohort and age on body composition in a sample of community-based elderly for the Health ABC Study. *The American Journal of Clinical Nutrition*, *85*(2), 405–410. https://doi.org/10.1093/ajcn/85.2.405

Keller, K. (2019). Sarcopenia. *Wiener Medizinische Wochenschrift*, *169*(7–8), 157–172. https://doi.org/10.1007/s10354-018-0618-2

Keller, K., & Engelhardt, M. (2014). Strength and muscle mass loss with aging process. Age and strength loss. *Muscles, Ligaments and Tendons Journal*, *3*(4), 346–350.

Kirchberger, I., Meisinger, C., Heier, M., Zimmermann, A.-K., Thorand, B., Autenrieth, C. S., Peters, A., Ladwig, K.-H., & Döring, A. (2012). Patterns of multimorbidity in the aged population. Results from the KORA-Age study. *PLoS ONE*, *7*(1), e30556. https://doi.org/10.1371/journal.pone.0030556

Kivimäki, M., Strandberg, T., Pentti, J., Nyberg, S. T., Frank, P., Jokela, M., Ervasti, J., Suominen, S. B., Vahtera, J., Sipilä, P. N., Lindbohm, J. V., & Ferrie, J. E. (2022). Body-mass index and risk of obesity-related complex multimorbidity: An observational multicohort study. *The Lancet Diabetes & Endocrinology*, *10*(4), 253–263. https://doi.org/10.1016/S2213-8587(22)00033-X

Koné Pefoyo, A. J., Bronskill, S. E., Gruneir, A., Calzavara, A., Thavorn, K., Petrosyan, Y., Maxwell, C. J., Bai, Y., & Wodchis, W. P. (2015). The increasing burden and complexity of multimorbidity. *BMC Public Health*, *15*(1), 415. https://doi.org/10.1186/s12889-015-1733-2

Lai, C.-C., Tu, Y.-K., Wang, T.-G., Huang, Y.-T., & Chien, K.-L. (2018). Effects of resistance training, endurance training and whole-body vibration on lean body mass, muscle strength and physical performance in older people: A systematic review and network meta-analysis. *Age and Ageing*, *47*(3), 367–373. https://doi.org/10.1093/ageing/afy009

Langhammer, B., & Stanghelle, J. K. (2015). The senior fitness test. *Journal of Physiotherapy*, *61*(3), 163. https://doi.org/10.1016/j.jphys.2015.04.001

Lauretani, F., Ticinesi, A., Gionti, L., Prati, B., Nouvenne, A., Tana, C., Meschi, T., & Maggio, M. (2019). Short-Physical Performance Battery (SPPB) score is associated with falls in older outpatients. *Aging Clinical and Experimental Research*, *31*(10), 1435–1442. https://doi.org/10.1007/s40520-018-1082-y

Lee, J. L. C., Lo, T. L. T., & Ho, R. T. H. (2018). Understanding outdoor gyms in public open spaces: a systematic review and integrative synthesis of qualitative and quantitative evidence. *International Journal of Environmental Research and Public Health*, *15*(4), Article 4. https://doi.org/10.3390/ijerph15040590

Liu, C., Shiroy, D. M., Jones, L. Y., & Clark, D. O. (2014). Systematic review of functional training on muscle strength, physical functioning, and activities of daily living in older adults. *European Review of Aging and Physical Activity*, *11*(2), Article 2. https://doi.org/10.1007/s11556-014-0144-1

Luppa, M., Luck, T., Weyerer, S., Konig, H.-H., Brahler, E., & Riedel-Heller, S. G. (2010). Prediction of institutionalization in the elderly. A systematic review. *Age and Ageing*, *39*(1), 31–38. https://doi.org/10.1093/ageing/afp202

MacroTrends. (2022). *Canada Fertility Rate 1950-2022*. https://www.macrotrends.net/countries/CAN/canada/fertility-rate

Malenfant, J. H., & Batsis, J. A. (2019). Obesity in the geriatric population – a global health perspective. *Journal of Global Health Reports*, *3*, e2019045. https://doi.org/10.29392/joghr.3.e2019045

Manini, T. M., & Clark, B. C. (2012). Dynapenia and aging: an update. *The Journals of Gerontology: Series A*, *67A*(1), 28–40. https://doi.org/10.1093/gerona/glr010

McGregor, R. A., Cameron-Smith, D., & Poppitt, S. D. (2014). It is not just muscle mass: A review of muscle quality, composition and metabolism during ageing as determinants of muscle function and mobility in later life. *Longevity & Healthspan*, *3*(1), 9. https://doi.org/10.1186/2046-2395-3-9

McLean, R. R., & Kiel, D. P. (2015). Developing consensus criteria for sarcopenia: an update. *Journal of Bone and Mineral Research*, *30*(4), 588–592. https://doi.org/10.1002/jbmr.2492

Misic, M. M., Rosengren, K. S., Woods, J. A., & Evans, E. M. (2007). Muscle quality, aerobic fitness and fat mass predict lower-extremity physical function in community-dwelling older adults. *Gerontology*, *53*(5), 260–266. https://doi.org/10.1159/000101826

Mlinac, M. E., & Feng, M. C. (2016). Assessment of activities of daily living, self-Care, and independence. *Archives of Clinical Neuropsychology*, *31*(6), 506–516. https://doi.org/10.1093/arclin/acw049

Mora, R. (2012). Moving bodies: open gyms and physical activity in Santiago. *Journal of Urban Design*, *17*(4), 485–497.

Moritani, T., & deVries, H. A. (1979). Neural factors versus hypertrophy in the time course of muscle strength gain. *American Journal of Physical Medicine*, *58*(3), 115–130.

Morley, J. E. (2016). Pharmacologic options for the treatment of sarcopenia. *Calcified Tissue International*, *98*(4), 319–333. https://doi.org/10.1007/s00223-015-0022-5

Nakanishi, N., Tsutsumi, R., Okayama, Y., Takashima, T., Ueno, Y., Itagaki, T., Tsutsumi, Y., Sakaue, H., & Oto, J. (2019). Monitoring of muscle mass in critically ill patients: comparison of ultrasound and two bioelectrical impedance analysis devices. *Journal of Intensive Care*, *7*(1), 61. https://doi.org/10.1186/s40560-019-0416-y

Neufer, P. D., Bamman, M. M., Muoio, D. M., Bouchard, C., Cooper, D. M., Goodpaster, B. H., Booth, F. W., Kohrt, W. M., Gerszten, R. E., Mattson, M. P., Hepple, R. T., Kraus, W. E., Reid, M. B., Bodine, S. C., Jakicic, J. M., Fleg, J. L., Williams, J. P., Joseph, L., Evans, M., … Laughlin, M. R. (2015). Understanding the Cellular and Molecular Mechanisms of Physical Activity-Induced Health Benefits. *Cell Metabolism*, *22*(1), 4–11. https://doi.org/10.1016/j.cmet.2015.05.011

Neves, T., Ferriolli, E., Lopes, M. B. M., Souza, M. G. C., Fett, C. A., & Fett, W. C. R. (2018). Prevalence and factors associated with sarcopenia and dynapenia in elderly people. *Journal of Frailty, Sarcopenia and Falls*, *3*(4), 194–202. https://doi.org/10.22540/JFSF-03-194

Ng, Y. L., Hill, K. D., Levinger, P., & Burton, E. (2021). Effectiveness of outdoor exercise parks on health outcomes in older adults—a mixed-methods systematic review and meta-analysis. *Journal of Aging and Physical Activity*, *29*(4), 695–707.

Pahor, M., Guralnik, J. M., Ambrosius, W. T., Blair, S., Bonds, D. E., Church, T. S., Espeland, M. A., Fielding, R. A., Gill, T. M., Groessl, E. J., King, A. C., Kritchevsky, S. B., Manini, T. M., McDermott, M. M., Miller, M. E., Newman, A. B., Rejeski, W. J., Sink, K. M., Williamson, J. D., & LIFE study investigators.

(2014). Effect of structured physical activity on prevention of major mobility disability in older adults: The LIFE study randomized clinical trial. *JAMA*, *311*(23), 2387–2396. https://doi.org/10.1001/jama.2014.5616

Patrizio, E., Calvani, R., Marzetti, E., & Cesari, M. (2020). Physical functional assessment in older adults. *The Journal of Frailty & Aging*, 1(9). https://doi.org/10.14283/jfa.2020.61

Pavasini, R., Guralnik, J., Brown, J. C., di Bari, M., Cesari, M., Landi, F., Vaes, B., Legrand, D., Verghese, J., Wang, C., Stenholm, S., Ferrucci, L., Lai, J. C., Bartes, A. A., Espaulella, J., Ferrer, M., Lim, J.-Y., Ensrud, K. E., Cawthon, P., … Campo, G. (2016). Short Physical Performance Battery and all-cause mortality: systematic review and meta-analysis. *BMC Medicine*, *14*(1), 215. https://doi.org/10.1186/s12916-016-0763-7

Pedersen, B. K., & Saltin, B. (2015). Exercise as medicine – evidence for prescribing exercise as therapy in 26 different chronic diseases. *Scandinavian Journal of Medicine & Science in Sports*, *25*(S3), 1–72. https://doi.org/10.1111/sms.12581

Petrella, J. K., Kim, J., Tuggle, S. C., & Bamman, M. M. (2007). Contributions of force and velocity to improved power with progressive resistance training in young and older adults. *European Journal of Applied Physiology*, *99*(4), 343–351. https://doi.org/10.1007/s00421-006-0353-z

Public Health Agency of Canada. (2021, July 14). *Aging and chronic diseases: A profile of Canadian seniors*. https://www.canada.ca/en/public-health/services/publications/diseases-conditions/aging-chronic-diseases-profile-canadian-seniors-report.html

Prince, M. J., Wu, F., Guo, Y., Gutierrez Robledo, L. M., O'Donnell, M., Sullivan, R., & Yusuf, S. (2015). The burden of disease in older people and implications for health policy and practice. *The Lancet*, *385*(9967), 549–562. https://doi.org/10.1016/S0140-6736(14)61347-7

Radaelli, R., Taaffe, D. R., Newton, R. U., Galvão, Daniel. A., & Lopez, P. (2021). Exercise effects on muscle quality in older adults: A systematic review and meta-analysis. *Scientific Reports*, *11*, 21085. https://doi.org/10.1038/s41598-021-00600-3

Ralston, G. W., Kilgore, L., Wyatt, F. B., Buchan, D., & Baker, J. S. (2018). Weekly training frequency effects on strength gain: a meta-analysis. *Sports Medicine - Open*, *4*(1), 36. https://doi.org/10.1186/s40798-018-0149-9

Razzaque, M. S. (2018). Sunlight exposure: Do health benefits outweigh harm? *The Journal of Steroid Biochemistry and Molecular Biology*, *175*, 44–48. https://doi.org/10.1016/j.jsbmb.2016.09.004

Rhodes, R. E., McEwan, D., & Rebar, A. L. (2019). Theories of physical activity behaviour change: a history and synthesis of approaches. *Psychology of Sport and Exercise*, *42*, 100–109. https://doi.org/10.1016/j.psychsport.2018.11.010

Rikli, R. E., & Jones, C. J. (1999a). Development and validation of a functional fitness test for community-residing older adults. *Journal of Aging and Physical Activity*, *7*(2), 129–161. https://doi.org/10.1123/japa.7.2.129

Rikli, R. E., & Jones, C. J. (1999b). Functional fitness normative scores for community-residing older adults, ages 60-94. *Journal of Aging and Physical Activity*, *7*(2), 162–181. https://doi.org/10.1123/japa.7.2.162

Rodríguez-García, W. D., García-Castañeda, L., Vaquero-Barbosa, N., Mendoza-Núñez, V. M., Orea-Tejeda, A., Perkisas, S., Vandewoude, M., & Castillo-Martínez, L. (2018). Prevalence of dynapenia and presarcopenia related to aging in adult community-dwelling Mexicans using two different cut-off points. *European Geriatric Medicine*, *9*(2), 219–225. https://doi.org/10.1007/s41999-018-0032-8

Ross, R., Chaput, J.-P., Giangregorio, L. M., Janssen, I., Saunders, T. J., Kho, M. E., Poitras, V. J., Tomasone, J. R., El-Kotob, R., McLaughlin, E. C., Duggan, M., Carrier, J., Carson, V., Chastin, S. F., Latimer-Cheung, A. E., Chulak-Bozzer, T., Faulkner, G., Flood, S. M., Gazendam, M. K., … Tremblay, M. S. (2020). Canadian 24-hour movement guidelines for adults aged 18–64 years and adults aged 65 years or older: an integration of physical activity, sedentary behaviour, and sleep. *Applied Physiology, Nutrition, and Metabolism*, *45*(10 (Suppl. 2)), S57–S102. https://doi.org/10.1139/apnm-2020-0467

Rushby, J. F. (2001). Calculating and presenting disability adjusted life years (DALYs) in cost-effectiveness analysis. *Health Policy and Planning*, *16*(3), 326–331. https://doi.org/10.1093/heapol/16.3.326

Ryall, J. G., Schertzer, J. D., & Lynch, G. S. (2008). Cellular and molecular mechanisms underlying age-related skeletal muscle wasting and weakness. *Biogerontology*, *9*(4), 213–228. https://doi.org/10.1007/s10522-008-9131-0

Saeidifard, F., Medina-Inojosa, J. R., West, C. P., Olson, T. P., Somers, V. K., Bonikowske, A. R., Prokop, L. J., Vinciguerra, M., & Lopez-Jimenez, F. (2019). The association of resistance training with mortality: A systematic review and meta-analysis. *European Journal of Preventive Cardiology*, *26*(15), 1647–1665. https://doi.org/10.1177/2047487319850718

Salin, M. da S., VIrtuoso, J. F., Alice Souza Noronha, N., Graciella Greice, W., & Giovana Zarpellon, M. (2014). Golden Age Gym: reasons for entry, permanence and satisfaction among participating older adults. *Revista Brasileira de Cineantropometria & Desempenho Humano*, *16*, 152–160.

Schaap, L. A., Koster, A., & Visser, M. (2013). Adiposity, muscle mass, and muscle strength in relation to functional decline in older persons. *Epidemiologic Reviews*, *35*(1), 51–65. https://doi.org/10.1093/epirev/mxs006

Schoufour, J. D., Tieland, M., Barazzoni, R., Ben Allouch, S., van der Bie, J., Boirie, Y., Cruz-Jentoft, A. J., Eglseer, D., Topinková, E., Visser, B., Voortman, T., Tsagari, A., & Weijs, P. J. M. (2021). The relevance of diet, physical activity, exercise, and persuasive technology in the prevention and treatment of sarcopenic obesity in older adults. *Frontiers in Nutrition*, *8*, 661449. https://doi.org/10.3389/fnut.2021.661449

Scott, T., Lole, L., Oorloff, A., & Aprile, K. (2021). "It's about getting the best bang for your buck": exploring local councils' perceptions about providing exercise infrastructure in public parks. *Health Promotion Journal of Australia*, *32*(3), 483–491. https://doi.org/10.1002/hpja.380

Shafiee, G., Keshtkar, A., Soltani, A., Ahadi, Z., Larijani, B., & Heshmat, R. (2017). Prevalence of sarcopenia in the world: a systematic review and meta- analysis of general population studies. *Journal of Diabetes & Metabolic Disorders*, *16*(1), 21. https://doi.org/10.1186/s40200-017-0302-x

Soubra, R., Chkeir, A., & Novella, J.-L. (2019). A systematic review of thirty-one assessment tests to evaluate mobility in older adults. *BioMed Research International*, *2019*, 1–17. https://doi.org/10.1155/2019/1354362

Statistics Canada. (2021a, July 1). *Older adults and population aging statistics*. https://www.statcan.gc.ca/en/subjects-start/older_adults_and_population_aging

Statistics Canada. (2021b, September 8). *Body mass index, overweight or obese, self-reported, adult, age groups (18 years and older)*. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310009620

Sun, F., Norman, I. J., & While, A. E. (2013). Physical activity in older people: A systematic review. *BMC Public Health*, *13*(1), 449. https://doi.org/10.1186/1471-2458-13-449

Tessier, A.-J., Wing, S. S., Rahme, E., Morais, J. A., & Chevalier, S. (2019). Physical function-derived cut-points for the diagnosis of sarcopenia and dynapenia from the Canadian longitudinal study on aging. *Journal of Cachexia, Sarcopenia and Muscle*, *10*(5), 985–999. https://doi.org/10.1002/jcsm.12462

Thibault, R., Genton, L., & Pichard, C. (2012). Body composition: Why, when and for who? *Clinical Nutrition*, *31*(4), 435–447. https://doi.org/10.1016/j.clnu.2011.12.011

Verdijk, L. B., van Loon, L., Meijer, K., & Savelberg, H. H. (2009). One-repetition maximum strength test represents a valid means to assess leg strength in vivo in humans. *Journal of Sports Sciences*, *27*(1), 59–68. https://doi.org/10.1080/02640410802428089

World Bank Group. (2022). *Life expectancy at birth, total (years)—Canada | Data*. https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=CA

World Health Organization. (2021a, June 9). *Obesity and overweight*. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

World Health Organization. (2021b, October 4). *Ageing and health*. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

Wu, S., Cohen, D., Shi, Y., Pearson, M., & Sturm, R. (2011). Economic analysis of physical activity interventions. *Am J Prev Med*, *40*(2), 149–158.

Zhou, P., Hughes, A. K., Grady, S. C., & Fang, L. (2018). Physical activity and chronic diseases among older people in a mid-size city in China: A longitudinal investigation of bipolar effects. *BMC Public Health*, *18*, 486. https://doi.org/10.1186/s12889-018-5408-7

4.0 Article

Resistance Training on an Outdoor Exercise Structure Improves Lower Body Relative Strength in Older Adults

Brianna Leadbetter[1,2], Danielle R Bouchard[1,2]

[1]Faculty of Kinesiology, University of New Brunswick, 90 MacKay Drive, Fredericton, NB E3B 5A3, Canada.
[2]Cardiometabolic Exercise & Lifestyle Laboratory (CELLab), 90 MacKay Drive (Room 105), Fredericton, NB E3B 5A3, Canada.

TO BE SUBMITTED AT: Journal of Physical Activity and Health

Manuscript Type: Original Research

Key Words (3-5): Aging; Outdoor gym; Physical function.

Abstract Word Count: 229 words

Manuscript Word Count: 3984 words

Role of the student in the project: conceptualization, formal analysis, investigation, methodology, writing – original draft, software

Author Affiliations
Brianna Leadbetter, BKin, CEP
Graduate student, Faculty of Kinesiology, University of New Brunswick
Email: bri.leadbetter@icloud.com

Danielle R. Bouchard, Ph.D, CEP
Associate Professor, Faculty of Kinesiology, University of New Brunswick
Co-Director: Cardiometabolic Exercise & Lifestyle Laboratory (CELLab)
Email: dboucha1@unb.ca

Abstract

Background: Improving muscle strength and muscle mass is important for maintaining physical function with age, but improving relative muscle strength (muscle strength/muscle mass) may be even more important. Outdoor exercise structures may be an option for increasing lower body relative strength and other functional outcomes while addressing barriers to regular exercise.

Methods: 29 adults aged 65+ participated in a crossover study with a six-week control period followed by a six-week resistance training intervention on an outdoor exercise structure. The intervention consisted of three 45-minute exercise sessions per week for six weeks including a warmup, strength exercises, and a cooldown. Physical activity levels (Axivity AX3 accelerometer), body composition (Dual-energy X-ray Absorptiometry), physical function (30-second chair stand), strength (leg press, chest press, grip strength), leg extension power (Humac Norm), and balance (one leg stance) were measured at baseline, six weeks, and 12 weeks.

Results: 17 participants completed the study protocol (58.6%). Lower body relative strength improved from 7.91 post-control to 8.50 at post-intervention ($p=.002$), as well as maximum leg press ($p=.002$), 30-second chair stand ($p<.001$), one leg stance ($p=.011$), and maximum chest press ($p=.009$). There were no significant changes in physical activity levels, grip strength, lower body lean mass, or leg extension power during the intervention.

Conclusions: Six weeks of resistance training on an outdoor exercise structure significantly improved lower-body relative strength, as well as physical functions in community-dwelling older adults.

Introduction

After the age of 50, muscle mass decreases at an average rate of 10% per decade, and muscle strength decreases at an average rate of 12-15% per decade (Doherty, 2001; Goodpaster et al., 2006). This marked loss of muscle mass and muscle strength in older adults is problematic as it can lead to a significant decline in physical function and eventually a loss of independence (Luppa et al., 2010). While both muscle mass and muscle strength have been shown to be significantly associated with physical function in older adults, it is unclear whether one is more important than the other (Schaap et al., 2013). However, an emerging area of research suggests that the relationship between muscle mass and muscle strength may be more important than either one independently (Radaelli et al., 2021). The amount of strength that a muscle can produce is often referred to as relative strength and is depicted as a ratio between the amount of force that an individual can produce per unit of muscle mass (Radaelli et al., 2021).

One of the most efficient interventions for slowing and reversing the decline in muscle mass and muscle strength with age is resistance training (Izquierdo et al., 2021). A minimum of two resistance training sessions per week is recommended to maintain and improve health-related outcomes such as strength, balance, and physical function (El-Kotob et al., 2020). However, 67.5% of older adults report not taking part in any resistance training activities (Copeland et al., 2019). In an attempt to address several barriers to resistance training for older adults including cost, location, and lack of equipment (Cavill & Foster, 2018), municipalities worldwide have been installing outdoor exercise structures.

Outdoor exercise structures are any kind of outdoor equipment or space that has been installed with the intention to promote structured physical activity (Jansson et al., 2019; Lee et al., 2018). Outdoor exercise structures often resemble playground equipment and are versatile pieces of equipment that can be creatively used to perform a variety of different exercises targeting strength, balance, and aerobic fitness. They are free to use, available anytime, often erected in residential areas, and provide instruction on proper use. Despite increased installations, usage uptake by older adults has remained low, making up only 3-14% of users (Cohen et al., 2012; Mora, 2012).

Previous research has shown that these outdoor exercise structures may be beneficial for increasing levels of physical activity within communities, but the potential to improve health or functional outcomes is not clear (Jansson et al., 2019). The main objective of this study was to contribute to this area of research by assessing whether performing resistance training on an outdoor exercise structure for six weeks can improve lower-body relative strength in adults aged 65 and above. The secondary objective was to explore any functional benefits of using an outdoor exercise structure for the same period.

Methods

Design

The present study used a cross-over design where participants took part in a six-week non-exposure control period, and then subsequently participated in a six-week resistance training intervention. Data collection was performed at baseline, six weeks (post-control), and 12 weeks (post-intervention).

Participants

Participants were recruited in a rural city with a population of ~70,000 people via virtual flyers, social media outlets such as Facebook, and physical flyers placed around the community. To be eligible for this study, participants had to be over the age of 65 years old, live in a community setting, not currently be engaged in any structured resistance training, be able to grip objects in day-to-day life (self-reported), and be cleared to exercise using the Get Active Questionnaire (Canadian Society of Exercise Physiology, 2017). Exclusion criteria included any uncontrolled medical conditions, any current musculoskeletal injuries, and any vacation lasting more than one week during the intervention.

To determine the appropriate sample size to test the main hypothesis, an expected effect size and variation on lower body relative strength (1.03 +/- 0.825) were calculated from Fragala et al. (2014). Based on these values and accounting for 25% attrition as reported by previous studies (Cyarto et al., 2006), using a power of 80% and an alpha of 0.05, the aim was to recruit 28 participants with an equal number of males and females.

Intervention

During the intervention, participants met at an outdoor exercise structure located centrally three times per week for six consecutive weeks. The outdoor exercise structure used in this study was comprised of mostly horizontal and vertical metal beams. All sessions were supervised by a certified exercise professional from 10:00 AM until 2:00 PM every Monday, Wednesday, and Friday, and participants were instructed to come within this time to complete their workout session. As a result, participants either exercised in small groups or on their own. Each session lasted approximately 45 minutes and consisted of a warm-up (~10mins), a resistance training regime (~30mins), and a cool-down (~5mins). Since the exercise program occurred three times per week for six weeks, the goal was to have each participant complete all 18 sessions before performing the post-intervention. Make-up sessions were offered for two weeks following the initial six-week program to allow participants to complete all sessions in case they missed any due to personal reasons or if sessions had to be cancelled due to inclement weather, which poses a unique challenge to studies that occur outdoors.

The resistance training program followed the American College of Sports Medicine's recommendations for resistance training in older adults (Izquierdo et al., 2021). Participants were given a resistance training program consisting of eight exercises focusing on all major muscle groups, but individual modifications were made to accommodate various abilities and conditions. Each prescribed exercise included four progressions ranging from least difficult to most difficult to guide participants as needed (Appendix A). A mandatory familiarization session was provided prior to the intervention to teach participants the exercises and allow them to try the appropriate progressions.

When the intervention began, participants were advised to start each exercise with one set of six to twelve repetitions and to gradually increase in sets and repetitions first before moving through exercise progressions. When participants could successfully complete one set of 12 repetitions, they were advised to progress to two sets of 6-12 repetitions, and then three sets of 6-12 repetitions. Once participants could successfully perform three sets of 12 repetitions on an exercise, they were advised to move to the next progression. Each session consisted of at least one exercise for each major muscle group including the chest, back, arms, and legs. Participants were encouraged to take a rest period between each set of 1-3 minutes as needed (Izquierdo et al., 2021). They were each provided with a personal booklet to record their exercises, sets, and repetitions performed in each session. Each booklet had a list of the exercises to complete, photo demonstrations of each exercise, and a copy of exercise progressions included for reference.

Outcomes

Descriptive variables were collected at baseline to describe the sample. These included age (years), sex (M/F), marital status (married; not married), education level (high school or less; college or above), employment status (full-time; part-time; retired), income (less than $50,000; more than $50,000), and self-reported health (Short-Form 36 Health Status Questionnaire (SF-36)) (Lyons et al., 1994). Finally, chronic conditions and medications were self-reported by presenting participants with a list of 51 chronic conditions (e.g., diabetes, hypertension, etc.) and asking participants if they have a history of any of them, and asking how many different medications they take per day. Participants were screened using the Get Active Questionnaire to assess eligibility for safety reasons (Canadian Society of Exercise Physiology, 2017). Height (cm), weight (kg), resting blood pressure (mmHg), and resting heart rate (bpm) were measured, and body mass index (kg/m^2) was calculated to describe the sample.

Physical activity level was measured via a wrist-mounted Axivity AX3 accelerometer (Newcastle, UK) (Clarke et al., 2017) to ensure any changes in the main outcome were not due to a change in aerobic activities. The device was worn on the non-dominant wrist for seven days at baseline, six weeks, and 12 weeks (Grimes et al., 2019). Autocalibration for the accelerometers was used (Van Hees et al., 2014). The raw accelerometer data were processed using the software *R* (R Core Team, 2022) version 4.2.2, the software *RStudio* (RStudio Team, 2022) version 2022.7.0.548, and the GGIR package (Migueles et al., 2019), which has been previously validated (Sabia et al., 2014;

Van Hees et al., 2013). Data were only included if the participant had at least four days of valid data with at least 16 hours of valid data per day (Chen et al., 2009). The raw accelerometry data is measured in milligravity (mg), and the cut-points for light, moderate, and vigorous physical activity were 40 mg, 100 mg, and 400 mg, respectively (Migueles et al., 2019).

Besides the baseline characteristics captured to describe the sample, all outcomes were captured at baseline, after the control condition (six weeks), and after the intervention (12 weeks). The main outcome was lower body relative strength (maximal leg strength/lean leg mass). Maximal leg strength was assessed by performing between a 1- and 10-repetition maximum on a Nautilus leg press apparatus and then the Brzycki prediction equation (Brzycki, 1993) was used to estimate a 1-repetition maximum (1-RM):

$$[\text{load in kilograms}/(1.0278-0.0278\times\text{repetitions})]$$

Lean leg mass was measured using Dual-Energy X-ray Absorptiometry (DXA) (Hologic Horizon, Massachusetts, US). Full body scans were performed following the standardized protocol to assess total body composition in terms of lean mass, adipose tissue mass, and bone mass (Bazzocchi et al., 2016). Lean leg mass was then assessed bilaterally using the 'region of interest' function on the DXA machine, and the lean leg mass of both legs was added together to get the value for the denominator of the lower body relative strength equation.

Secondary outcomes

Secondary outcomes included measures of physical function, muscle power, and muscle strength. Physical function was measured using the 30-second chair stand test

(Jones et al., 1999) and the one-leg stance test with eyes open (Hurvitz et al., 2000) as per their established protocols. For muscle power, leg extension power was measured using isokinetic dynamometry testing on a HUMAC NORM (Computer Sports Medicine Inc., Stoughton, MA.) (Habets et al., 2018). Participants started with their knees bent at 90 degrees and had a fixed range of motion at the knee between 90 and 0 degrees, with a fixed speed of 90°/second (Callahan et al., 2007). Upper body strength was assessed by estimating a chest press 1-RM using the same protocol as the leg extension and inputting it into the Brzycki equation. Additionally, grip strength was measured with a JAMAR hand dynamometer (Bolingbrook, IL) using a standardized protocol (Canadian Society of Exercise Physiology, 2021).

Statistical Analysis

Due to the small sample size, non-parametric tests were used to evaluate the results. The descriptive data are presented as the median (25^{th}-75^{th} percentile) for each variable. Friedman's ANOVA was used to assess the changes in the main variable and secondary outcomes between baseline, post-control, and post-intervention. If a significant difference was detected, Bonferroni posthoc analyses were performed to determine where the effect occurred. To assess any differences between completers and non-completers, a Mann-Whitney U test was conducted on the baseline characteristics of both groups. A participant was identified as a completer if they completed the entire study protocol, including all 18 exercise sessions and the post-intervention.

Results

Twenty-nine participants initially agreed to take part in this study, and 17 successfully completed the study protocol (Figure 1). During the control period, one participant dropped out due to an unrelated injury. During the intervention, 11 more participants were lost to follow-up due to a change in health condition (n=5), unforeseen circumstances (n=2), unrelated injury (n=1), inability to cope with the time commitment (n=1), and two participants did not provide their reasoning for not completing the program.

The baseline characteristics of the sample (n=29) are presented in Table 1, and a comparison between participants who completed the program and those who did not are presented in Table 2. The median (25^{th}-75^{th}) age of the participants was 72 years (66.5-75.5) and was mainly composed of overweight, highly educated, married females who perceive themselves to be relatively healthy. Compared to those who did not complete the study protocol, completers at baseline weighed significantly less [68.6 kg (54.1-80.2) vs. 88.1 kg (72.2-92.2); $p=.013$], had significantly less lean mass [39.7 kg (33.6-43.8) vs. 48.4 kg (40.0-54.5); $p=.034$], performed a greater number of chair stands in 30 seconds [15.0 repetitions (12.5-20.0) vs. 12.5 repetitions (10.0-14.0); $p=.029$], and had a lower 1-RM leg press [96.4 kg (82.2-104.7) vs. 124.8 kg (91.9-164.6); $p=.037$]. Additionally, only 50% of non-completers were meeting aerobic physical activity guidelines at baseline, while 100% of completers were meeting the guidelines ($p=.003$).

A significant improvement was observed over time in lower body relative strength when analyzed by Friedman's ANOVA ($p=.002$) (Figure 2). A Bonferroni-corrected post-hoc analysis revealed that there were no significant differences between lower body relative strength at baseline and post-control [7.82 (6.48-9.11) vs. 7.91 (7.01-9.35); $p=.075$], but there was a significant improvement in lower body relative strength between post-control and post-intervention [7.91 (7.01-9.35) vs. 8.50 (7.99-9.72); $p=.002$]. Maximal leg press, the numerator of the lower body relative strength ratio, improved significantly from post-control to post-intervention [102.4 kg (87.5-115.5) vs 116.14 kg (87.01-134.9); *p=.002*)]. Inversely, lower body lean mass, the denominator of the relative strength ratio, did not show a significant effect between post-control and post-intervention after a Bonferroni correction [12.3 kg (10.8-14.6) vs. 12.7 kg (10.8-15.0); *p=.035*).

Between post-control and post-intervention, significant improvements were also observed in the 30-second chair (*p<.001*), one-leg stance (*p=.011*), and 1-RM chest press (*p=.009*). While a significant effect over time was observed in leg extension peak power (*p=.039*), Bonferroni-corrected post-hoc analyses showed no significant differences between baseline and post-control (*p=.492*), or post-control and post-intervention (*p=.022*). No significant changes were noted in grip strength at any point (*p=.138*).

Discussion

The purpose of this study was to investigate the potential changes in lower body relative strength after performing resistance training on an outdoor exercise structure for six weeks in adults aged 65+. Despite a drop-out of 41% of participants, a significant improvement was observed in lower body relative strength for those who completed the intervention, which was driven by an increase in maximal leg strength. Physical function and upper body strength also improved significantly. This study confirms the hypothesis that performing resistance training using an outdoor exercise structure for six weeks significantly improves lower body relative strength in adults aged 65+.

The fact that only six weeks of resistance training is associated with a significant increase in relative muscle strength is important considering relative strength has been shown to be the strongest predictor of functional capacity, accounting for up to 42% of the variability in physical function (Misic et al., 2007). Also, since lean mass has been shown to decrease with age (Goodpaster et al., 2006), performing resistance training activities could delay the loss of muscle mass and contribute to a greater lower body relative strength. The lack of change in lower body lean mass observed in this study is consistent with a randomized control trial by Kim et al. (2018) who also observed an improvement in muscle strength, but not muscle mass. One could argue that this observation is in part due to the short duration of the intervention, however, Radaelli et al. (2021) found no association between intervention length (ranging from six to 48 weeks) and changes in lower body relative strength in older adults, therefore a longer intervention may not have had any additional effect.

Despite the observation of an improvement in lower body relative strength for participants completing the program, one of the most intriguing observations was a very high attrition rate (41%) in such a short period compared with previously reported attrition rates in the same demographic when performing strength training (Cyarto et al., 2006). However, when looking at studies conducted by Leiros-Rodriguez & García-Soidan (2014) and Kim et al. (2018) with older adults using outdoor exercise structures, the attrition rates were 33.3% and 25.4%, respectively; therefore, it could be argued that attrition rates when using outdoor exercise structures are greater than when performing traditional and indoor strength activities. In the present study, we found that non-completers were heavier than completers, but also had greater absolute lean mass. Non-completers also had a lower 30-second chair stand score, further supporting the importance of relative muscle strength as opposed to muscle mass or absolute muscle strength independently in terms of maintaining functional capacity. Our results and those from the literature suggest that outdoor exercise structures might not be well-suited for all people living in the community.

Interestingly, most participants in the present study (65%) met the aerobic components of the physical activity guidelines of a minimum of 150 minutes of moderate-to-vigorous intensity weekly (Ross et al., 2020) at baseline, suggesting that generally active older adults may be more interested in taking part in a program using outdoor exercise structures. This proportion is much higher than what is reported in the literature (2.5-17%) (Sun et al., 2013). In addition, nearly two times more completers (n=15) met these guidelines compared with non-completers (n=8). This could suggest that those who are already active can add to their healthy behaviour more easily; a phenomenon called “habit-stacking” (Fiorella, 2020). Nonetheless, the inclusion of resistance training in addition to aerobic activity is extremely important for all adults, especially older adults (Bennie et al., 2018).

Following the intervention, a significant increase in the 30-second chair stand was also observed, which is important to note given that older adults perform this movement at least 45 times per day on average (Bohannon, 2015). In addition, an improvement of three repetitions was observed during the intervention, surpassing the minimal clinically important difference of two repetitions (Wright et al., 2011). Whether or not the use of an outdoor exercise structure can result in improvements in the 30-second chair stand is inconclusive in the literature, as the two existing randomized control trials which measured this variable have had conflicting results (Kim et al., 2018; Sales et al., 2017). Our findings are consistent with one of these randomized control trials which assessed the functional benefits of an 18-week exercise program using an outdoor exercise structure with adults aged 60+ (Sales et al., 2017), but not consistent with the other randomized control trial which also assessed the functional benefits of using one of these structures over six weeks with adults aged 65+ (Kim et al., 2018). This could be due to the fact that in the Kim et al. (2018) study, only three exercises were included in the program and only one of those was a lower body exercise, which was non-weight-bearing, therefore it was lacking in specificity for the 30-second chair stand assessment.

The potential for older adults to improve their balance following an exercise intervention using outdoor exercise structures is also disputed in the literature (Ng et al., 2021). Three randomized control trials which have assessed balance in older adults following the use of an outdoor exercise structure have found conflicting results (Kim et al., 2018; Leiros-Rodríguez & García-Soidan, 2014; Sales et al., 2017). Our findings are consistent in terms of balance improvements with the results of the Leiros-Rodriguez & García-Soidan (2014) study. However, it is worth noting that all three previous studies used different measures of balance and only one specifically targetted balance exercises during the intervention (Leiros-Rodríguez & García-Soidan, 2014), making it difficult to compare the findings and conclude if outdoor exercise structure could lead to balance improvements.

It is important to emphasize that, as was noted in the 2018 systematic review by Lee et al., outdoor exercise structures vary immensely from site to site, making it difficult to replicate studies and findings at different locations. While some outdoor exercise structures consist of equipment that resembles conventional exercise machines such as a leg press, rowing machine, or stationary bicycle, others consist solely of an array of vertical and horizontal metal beams. While it is unclear which style of equipment is most beneficial, some perceived benefits and drawbacks should be noted for each. While those that consist primarily of metal beams (such as the one used in the present study) would likely be cheaper to install, require less maintenance due to the lack of moving parts, and be more versatile in terms of which exercises can be performed, they may not be very beneficial to individuals who have little to no prior knowledge of exercise. As for the machine-based designs, they may be more costly to install and maintain, but would likely be easier to use for novice exercisers and may present less of a risk of injury due to clearer usage instruction and less stability required. More research should be done regarding the types of outdoor exercise equipment available, and what the benefits and drawbacks are of each design in order to guide future installations.

As there are with all studies, there are some limitations that need to be noted. First, this study had a small sample size and a high attrition rate, therefore the results observed in this sample may not be generalizable to the greater population. Secondly, a total of three sessions were cancelled due to rain. However, because there were make-up sessions offered after the initial six weeks, participants did not miss out on the total number of sessions. It is possible that limiting the study period to six weeks would not lead to a significant change in lower body relative strength. There was also no protection from either the sun or the rain at the outdoor exercise structure used in this study, which could be especially problematic for older adults during physical exertion. The use of a ratio as the main outcome could be considered a limitation as a reduction in lean mass with the maintenance or even a loss in strength at a lower rate could result in an improvement in the relative strength ratio, even though the loss of lean mass or strength would theoretically be an unfavourable outcome. Finally, the baseline information of the sample does not seem to represent the greater population of adults aged 65+ in terms of aerobic physical activity levels.

In conclusion, the current study demonstrates that performing resistance training on an outdoor exercise structure for 18 sessions has the potential to result in significant improvements in lower body relative strength, as well as other functional outcomes. However, the attrition rate observed in this study suggests that outdoor exercise structures may not be entirely suitable for all seniors living in the community.

References

Bazzocchi, A., Ponti, F., Albisinni, U., Battista, G., & Guglielmi, G. (2016). DXA: technical aspects and application. *European Journal of Radiology*, *85*(8), 1481–1492. https://doi.org/10.1016/j.ejrad.2016.04.004

Bennie, J. A., Lee, D., Khan, A., Wiesner, G. H., Bauman, A. E., Stamatakis, E., & Biddle, S. J. H. (2018). Muscle-strengthening exercise among 397,423 U.S. adults: prevalence, correlates, and associations with health conditions. *American Journal of Preventive Medicine*, *55*(6), 864–874. https://doi.org/10.1016/j.amepre.2018.07.022

Bohannon, R. W. (2015). Daily sit-to-stands performed by adults: a systematic review. *Journal of Physical Therapy Science*, *27*(3), 939. https://doi.org/10.1589/jpts.27.939

Brzycki, M. (1993). Strength testing—predicting a one-rep max from reps-to-fatigue. *Journal of Physical Education, Recreation & Dance*, *64*(1), 88–90. https://doi.org/10.1080/07303084.1993.10606684

Callahan, D., Phillips, E., Carabello, R., Frontera, W. R., & Fielding, R. A. (2007). Assessment of lower extremity muscle power in functionally-limited elders. *Aging Clinical and Experimental Research*, *19*(3), 194–199. https://doi.org/10.1007/BF03324689

Canadian Society of Exercise Physiology. (2017). *Get Active Questionnaire* [Medical clearance tool]. Canadian Society of Exercise Physiology. https://csep.ca/2021/01/20/pre-screening-for-physical-activity/#:~:text=The%20Get%20Active%20Questionnaire%20is,testing%20using%20the%20latest%20research.

Canadian Society of Exercise Physiology. (2021). *CSEP Physical Activity Training for Health® (CSEP-PATH®) Resource Manual, 3rd Edition* [Data collection tools]. Canadian Society for Exercise Physiology.

Cavill, N. A., & Foster, C. E. M. (2018). Enablers and barriers to older people's participation in strength and balance activities: A review of reviews. *Journal of Frailty, Sarcopenia and Falls*, *3*(2), 105–113. https://doi.org/10.22540/JFSF-03-105

Chen, C., Jerome, G. J., LaFerriere, D., Young, D. R., & Vollmer, W. M. (2009). Procedures used to standardize data collected by RT3 triaxial accelerometers in a large-scale weight-loss trial. *Journal of Physical Activity & Health*, *6*(3), 354–359. https://doi.org/10.1123/jpah.6.3.354

Clarke, C. L., Taylor, J., Crighton, L. J., Goodbrand, J. A., McMurdo, M. E. T., & Witham, M. D. (2017). Validation of the AX3 triaxial accelerometer in older functionally impaired people. *Aging Clinical and Experimental Research*, *29*(3), 451–457. https://doi.org/10.1007/s40520-016-0604-8

Cohen, D. A., Marsh, T., Williamson, S., Golinelli, D., & McKenzie, T. L. (2012). Impact and cost-effectiveness of family fitness zones: A natural experiment in urban public parks. *Health & Place*, *18*(1), 39–45. https://doi.org/10.1016/j.healthplace.2011.09.008

Copeland, J., Good, J., & Dogra, S. (2019). Strength training is associated with better functional fitness and perceived healthy aging among physically active older adults: a cross-sectional analysis of the Canadian longitudinal study on aging. *Aging Clinical and Experimental Research*, *31*(9), 1257–1263. https://doi.org/10.1007/s40520-018-1079-6

Cyarto, E. V., Brown, W. J., & Marshall, A. L. (2006). Retention, adherence and compliance: important considerations for home- and group-based resistance training programs for older adults. *Journal of Science and Medicine in Sport*, *9*(5), 402–412. https://doi.org/10.1016/j.jsams.2006.06.020

Doherty, T. J. (2001). The influence of aging and sex on skeletal muscle mass and strength. *Current Opinion in Clinical Nutrition & Metabolic Care*, *4*(6), 503–508.

El-Kotob, R., Ponzano, M., Chaput, J.-P., Janssen, I., Kho, M. E., Poitras, V. J., Ross, R., Ross-White, A., Saunders, T. J., & Giangregorio, L. M. (2020). Resistance training and health in adults: An overview of systematic reviews. *Applied Physiology, Nutrition, and Metabolism*, *45*(10 (Suppl. 2)), S165–S179. https://doi.org/10.1139/apnm-2020-0245

Goodpaster, B. H., Park, S. W., Harris, T. B., Kritchevsky, S. B., Nevitt, M., Schwartz, A. V., Simonsick, E. M., Tylavsky, F. A., Visser, M., Newman, A. B., & for the Health ABC Study. (2006). The loss of skeletal muscle strength, mass, and quality in older adults: the health, aging and body composition study. *The Journals of Gerontology: Series A*, *61*(10), 1059–1064. https://doi.org/10.1093/gerona/61.10.1059

Grimes, L., Outtrim, J. G., Griffin, S. J., & Ercole, A. (2019). Accelerometery as a measure of modifiable physical activity in high-risk elderly preoperative patients: a prospective observational pilot study. *BMJ Open*, *9*(11), e032346. https://doi.org/10.1136/bmjopen-2019-032346

Habets, B., Staal, J. B., Tijssen, M., & van Cingel, R. (2018). Intrarater reliability of the Humac NORM isokinetic dynamometer for strength measurements of the knee and shoulder muscles. *BMC Research Notes*, *11*(1), 15. https://doi.org/10.1186/s13104-018-3128-9

Hurvitz, E. A., Richardson, J. K., Werner, R. A., Ruhl, A. M., & Dixon, M. R. (2000). Unipedal stance testing as an indicator of fall risk among older outpatients. *Archives of Physical Medicine and Rehabilitation*, *81*(5), 587–591. https://doi.org/10.1016/S0003-9993(00)90039-X

Izquierdo, M., Merchant, R. A., Morley, J. E., Anker, S. D., Aprahamian, I., Arai, H., Aubertin-Leheudre, M., Bernabei, R., Cadore, E. L., Cesari, M., Chen, L.-K., de Souto Barreto, P., Duque, G., Ferrucci, L., Fielding, R. A., García-Hermoso, A., Gutiérrez-Robledo, L. M., Harridge, S. D. R., Kirk, B., … Singh, M. F. (2021). International exercise recommendations in older adults (ICFSR): expert consensus guidelines. *The Journal of Nutrition, Health & Aging*, *25*(7), 824–853. https://doi.org/10.1007/s12603-021-1665-8

Jansson, A. K., Lubans, D. R., Smith, J. J., Duncan, M. J., Haslam, R., & Plotnikoff, R. C. (2019). A systematic review of outdoor gym use: current evidence and future directions. *Journal of Science and Medicine in Sport*, *22*(12), 1335–1343. https://doi.org/10.1016/j.jsams.2019.08.003

Jones, C. J., Rikli, R. E., & Beam, W. C. (1999). A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. *Research Quarterly for Exercise and Sport*, *70*(2), 113–119. https://doi.org/10.1080/02701367.1999.10608028

Lee, J. L. C., Lo, T. L. T., & Ho, R. T. H. (2018). Understanding outdoor gyms in public open spaces: A systematic review and integrative synthesis of qualitative and quantitative evidence. *International Journal of Environmental Research and Public Health*, *15*(4), Article 4. https://doi.org/10.3390/ijerph15040590

Leiros-Rodríguez, R., & García-Soidan, J. L. (2014). Balance training in elderly women using public parks. *Journal of Women & Aging*, *26*(3), 207–218. https://doi.org/10.1080/08952841.2014.888220

Luppa, M., Luck, T., Weyerer, S., Konig, H.-H., Brahler, E., & Riedel-Heller, S. G. (2010). Prediction of institutionalization in the elderly. a systematic review. *Age and Ageing*, *39*(1), 31–38. https://doi.org/10.1093/ageing/afp202

Lyons, R. A., Perry, I. M., & Littlepage, B. N. C. (1994). Evidence for the validity of the short-form 36 questionnaire (SF-36) in an elderly population. *Age and Ageing*, *23*(3), 182–184.

Migueles, J. H., Rowlands, A. V., Huber, F., Sabia, S., & Hees, V. T. van. (2019). GGIR: A research community–driven open source R package for generating physical activity and sleep outcomes from multi-day raw accelerometer aata. *Journal for the Measurement of Physical Behaviour*, *2*(3), 188–196. https://doi.org/10.1123/jmpb.2018-0063

Mora, R. (2012). Moving bodies: open gyms and physical activity in Santiago. *Journal of Urban Design*, *17*(4), 485–497.

R Core Team. (2022, April 4). *R: The R project for statistical computing*. R Foundation for Statistical Computing. https://www.r-project.org/

Radaelli, R., Taaffe, D. R., Newton, R. U., Galvão, Daniel. A., & Lopez, P. (2021). Exercise effects on muscle quality in older adults: A systematic review and meta-analysis. *Scientific Reports*, *11*, 21085. https://doi.org/10.1038/s41598-021-00600-3

Ross, R., Chaput, J.-P., Giangregorio, L. M., Janssen, I., Saunders, T. J., Kho, M. E., Poitras, V. J., Tomasone, J. R., El-Kotob, R., McLaughlin, E. C., Duggan, M., Carrier, J., Carson, V., Chastin, S. F., Latimer-Cheung, A. E., Chulak-Bozzer, T., Faulkner, G., Flood, S. M., Gazendam, M. K., … Tremblay, M. S. (2020). Canadian 24-hour movement guidelines for adults aged 18–64 years and adults aged 65 years or older: an integration of physical activity, sedentary behaviour, and sleep. *Applied Physiology, Nutrition, and Metabolism*, *45*(10 (Suppl. 2)), S57–S102. https://doi.org/10.1139/apnm-2020-0467

RStudio Team. (2022). *RStudio: integrated development environment for R.* https://www.r-project.org/conferences/useR-2011/abstracts/180111-allairejj.pdf

Sabia, S., Van Hees, V. T., Shipley, M. J., Trenell, M. I., Hagger-Johnson, G., Elbaz, A., Kivimaki, M., & Singh-Manoux, A. (2014). Association between questionnaire- and accelerometer-assessed physical activity: The role of sociodemographic factors. *American Journal of Epidemiology*, *179*(6), 781–790. https://doi.org/10.1093/aje/kwt330

Schaap, L. A., Koster, A., & Visser, M. (2013). Adiposity, muscle mass, and muscle strength in relation to functional decline in older persons. *Epidemiologic Reviews*, *35*(1), 51–65. https://doi.org/10.1093/epirev/mxs006

Van Hees, V. T., Fang, Z., Langford, J., Assah, F., Mohammad, A., da Silva, I. C. M., Trenell, M. I., White, T., Wareham, N. J., & Brage, S. (2014). Autocalibration of accelerometer data for free-living physical activity assessment using local gravity and temperature: An evaluation on four continents. *Journal of Applied Physiology*, *117*(7), 738–744. https://doi.org/10.1152/japplphysiol.00421.2014

Van Hees, V. T., Gorzelniak, L., León, E. C. D., Eder, M., Pias, M., Taherian, S., Ekelund, U., Renström, F., Franks, P. W., Horsch, A., & Brage, S. (2013). Separating movement and gravity components in an acceleration signal and implications for the assessment of human daily physical activity. *PloS one*, *8*(4), e61691. https://doi.org/10.1371/journal.pone.0061691

Wright, A. A., Cook, C. E., Baxter, G. D., Dockerty, J. D., & Abbott, J. H. (2011). A Comparison of 3 methodological approaches to defining major clinically important improvement of 4 performance measures in patients with hip osteoarthritis. *Journal of Orthopaedic & Sports Physical Therapy*, *41*(5), 319–327. https://doi.org/10.2519/jospt.2011.3515

Table 1. Participant characteristics at baseline (n=29)

	Values (n=29)
Age (years)	72.0 (66.5-75.5)
Sex (female)	19.0 (65.5)
Body mass index (kg/m^2)	28.2 (24.7-31.9)
Self-reported chronic conditions (#)	2.0 (1.0-3.0)
Daily medications (#)	1.0 (1.0-2.5)
Marital Status (married)	19.0 (65.6)
Education (college or above)	23.0 (79.3)
Employment (retired)	23.0 (79.3)
Income (less than $50,000)	9.0 (31.0)
SF-36 Health Survey domains (0-100)	
Physical functioning	90.0 (85.0-95.0)
Physical role limitations	100.0 (100.0-100.0)
Emotional role limitations	100.0 (100.0-100.0)
Energy and fatigue	75.0 (47.5-85.0)
Emotional well-being	88.0 (80.0-92.0)
Social functioning	100.0 (100.0-100.0)
Pain	90.0 (68.8-100.0)
General health	80.0 (72.5-87.5)

Data are presented as either Median (IQR) or n (%)

Table 2. Baseline characteristics of completers and non-completers

	Completed the intervention (n=17)	Did not complete the intervention (n=12)
Age (years)	71.0 (67.5-76.0)	73.5 (66.0-75.8)
Sex (female)	12.0 (70.6)	7.0 (58.3)
Anthropometrics		
Weight (kg)	68.6 (54.1-80.2)	88.1 (72.2-92.2)*
Body mass index (kg/m^2)	27.5 (23.3-30.3)	30.4 (26.4-33.5)
Body fat (%)	36.5 (30.8-44.6)	38.3 (32.1-42.2)
Total lean mass (kg)	39.7 (33.6-43.8)	48.4 (40.0-54.5)*
Chronic conditions (#)	2.0 (1.0-3.0)	2.0 (1.0-3.8)
Daily prescribed medications (#)	1.0 (0.5-2.5)	1.5 (1.0-4.3)
Predicted 1-RM chest press (kg)	34.0 (26.0-46.3)	39.5 (27.7-51.1)
Predicted 1-RM leg press (kg)	96.4 (82.2-104.7)	124.8 (91.9-164.6)*
Physical function		
30-second chair stand (reps)	15.0 (12.5-20.0)	12.5 (10.0-14.0)*
One-leg stance (secs)	16.9 (7.1-38.4)	5.4 (2.6-16.8)
Grip strength (kg)	50.0 (39.0-55.5)	56.5 (43.8-76.8)
Leg power (W)	136 (93.5-159.5)	141.5 (126.0-192.3)
Activity levels		
Sedentary time (hours/day)	13.2 (10.9-13.8)	13.9 (12.0-15.4)
MVPA (min/wk)	350.0 (257.8-599.7)	205.7 (100.5-478.9)
Meeting aerobic guidelines	15.0 (100)[a]	4.0 (50)[b]*

Data are presented as either Median (25th-75th) or n (%)
*p<.05
[a]n=15
[b]n=8

Table 3. Changes in physical variables (n=17)

	Baseline	**Post-Control**	**Post-Intervention**	***p*-value**
Predicted 1-RM leg press (kg)	96.36 (82.15-104.69)	102.39 (87.46-115.52)	116.14 (87.07-134.88)*	.002
Lower body lean mass (kg)	12.00 (10.73-14.35)	12.26 (10.80-14.56)	12.66 (10.79-14.99)	.035
30-second chair stand (reps)	15.00 (12.50-20.00)	17.00 (15.50-22.0)	20.00 (17.50-24.50)*	<.001
One-leg stance (sec)	16.90 (7.06-38.43)	20.43 (8.42-30.42)	35.52 (14.79-42.57)*	.003
Grip strength (kg)	48.00 (38.50-54.50)	49.50 (37.75-56.00)	50.00 (40.75-58.00)	.138
Leg extension power (W)	136.00 (93.50-159.50)	116.00 (83.00-163.00)	133.00 (103.50-170.00)	.039
Predicted 1-RM chest press (kg)	33.46 (26.05-44.73)	31.36 (26.84-38.60)	36.01 (30.14-49.37)*	.028
Moderate-vigorous physical activity (min/wk)	350.00 (257.83-599.67)	373.92 (181.13-595.00)	365.40 (237.30-593.83)	.931

Data are presented as Median (25^{th}-75^{th})

*p<.0167 between post-control and post-intervention

Figure 1. Flowchart diagram of study participation

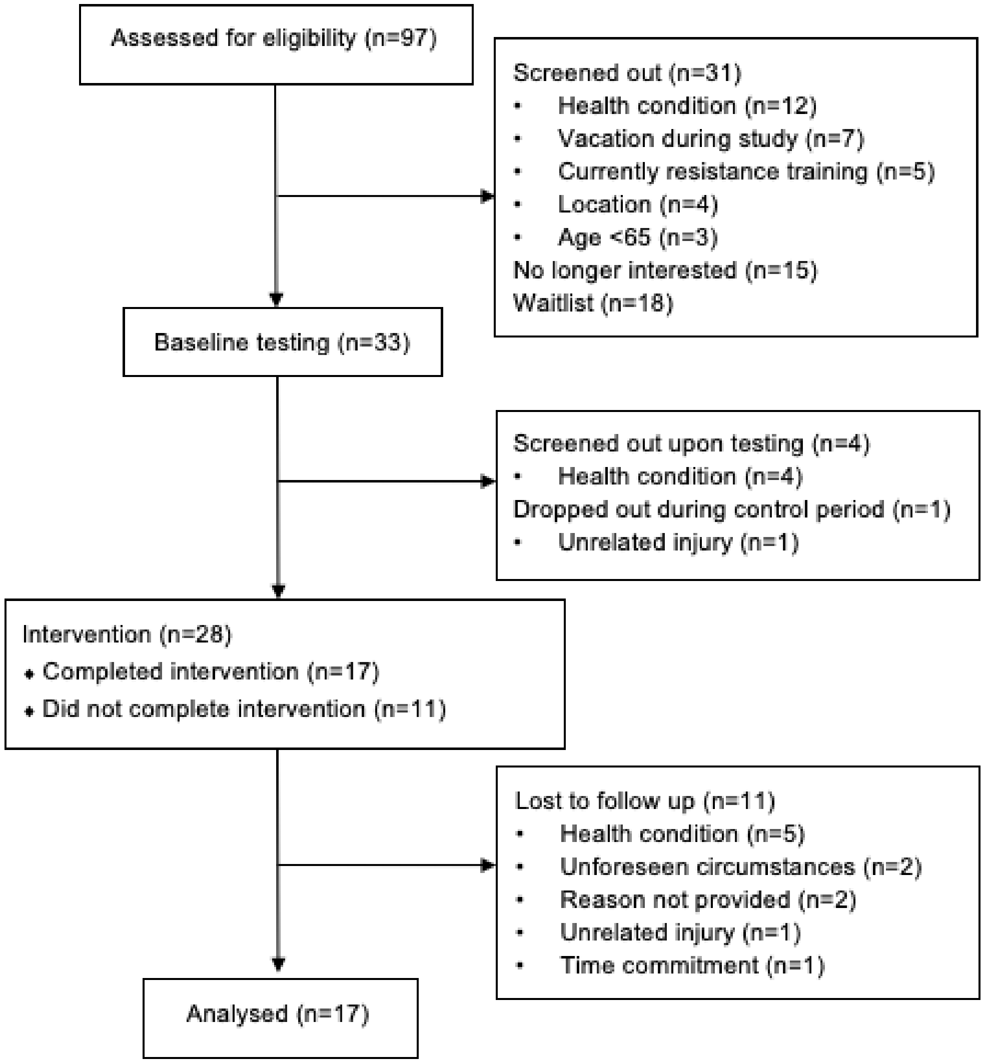
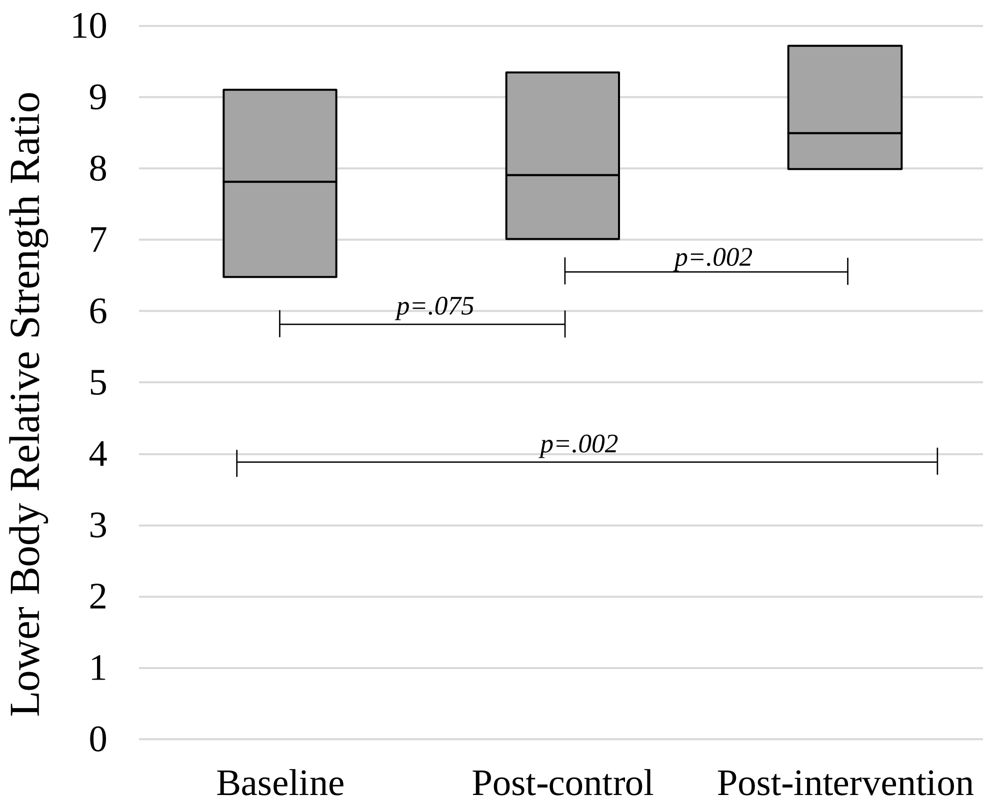


Figure 2. Changes in lower body relative strength



Data are presented as Median (25th-75th)

APPENDIX A: EXERCISE PROGRAM PROGRESSIONS

Exercise Type	Initial Exercise	Exercise Progression 1	Exercise Progression 2	Exercise Progression 3
Upper body	High elevated push-up	Low elevated push-up	Half push-up (knees)	Full push-up
Lower body	Assisted squat	Assisted squat w/ 3sec ECC	Air squat	Air squat w/ ISO hold
Lower body	Assisted DL calf raise	Unassisted DL calf raise	Assisted SL calf raise	Unassisted SL calf raise
Upper body	High inverted row	Low inverted row	Inverted row w/ ISO hold	Parallel inverted row
Lower body	Assisted split squats	Unassisted split squats	Reverse lunges	Step-ups
Lower body	Assisted SL glute kickbacks	Assisted SL glute sidekicks	Assisted SL glute kickbacks w/ ISO hold	Assisted SLDL w/ hand walk-down
Balance	Assisted SL balance	Unassisted SL balance	Assisted tandem walk	Unassisted tandem walk
Lower body	Assisted hamstring curl	Assisted hamstring curl w/ ISO hold	Hamstring curl w/ short ISO hold against bar	Hamstring curl w/ long ISO hold against bar

Abbreviations: w/=with; sec=seconds; ECC=eccentric; ISO=isometric; DL=double leg; SL=single leg; SLDL=single leg deadlift

CURRICULUM VITAE

Candidate's Full Name:

Brianna Kimberley Leadbetter

Universities Attended:

Bachelor of Kinesiology, Acadia University 2020

Publications:

Macdonald, M., Sénéchal, M., **Leadbetter, B**., Bouchard, D. R. (2023). Fear of falls following an online exercise program for aging adults. *Gerontology and Geriatric Medicine* (DOI: 10.1177/23337214231151357/ ID: GGM-22-0156.R2)

Conference Presentations:

Resistance Training on an Outdoor Exercise Structure Improves Lower Body Relative Strength in Older Adults
Atlantic Provinces Exercise Scientists and Socio-Culturalists (APES+) Conference 2023

Cross-sectional and Longitudinal Associations Between Sedentary Behaviour and Fall-related Injuries in Middle-Aged and Older Adults from the CLSA
New Brunswick Health Research Foundation (NBHRF) Conference 2022

Online Exercise Programs for Older Adults: What is Offered and What are the Potential Benefits – A Scoping Review
Canadian Society for Exercise Physiology (CSEP) Conference 2022

Embedding a Clinical Exercise Physiologist into a Collaborative Family Practice to Improve Physical Activity Levels and Functional Outcomes
Canadian Society for Exercise Physiology (CSEP) Conference 2022

Usage of Outdoor Gyms for Older Adults 65+ Living in New Brunswick
Canadian Active Aging Research Meeting (CAARM) 2022

Validation of Physical Function Tests for Older Adults
New Brunswick Health Research Foundation (NBHRF) Conference 2021

Effects of Cardiorespiratory Fitness on Executive Function & Prefrontal Oxygenation in Older Adults
Atlantic Provinces Exercise Scientists and Socio-Culturalists (APES+) Conference 2019