Physical Activity in People with Mobility Impairments

by

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ABSTRACT

A mobility-impairing disability includes difficulty moving and maintaining body positions, handling, and moving objects, moving around in the environment, and difficulty with transportation. The negative impact of mobility impairments on daily life is profound and can lead to long-term negative health consequences. Mobility-impairing disabilities are associated with reduction in glucose tolerance, difficulty accessing healthy food, and physical inactivity. This dissertation investigated physical activity in people with mobility-impairing disabilities. First, Chapter 2 investigated the relationship between glucose disposal and physical activity in people with mobility-impairing disabilities. Chapter 3 explored collected survey data regarding physical access to food in a sample of 85 adults with mobility-impairing disabilities. The relationship between difficulty performing specific activities of daily living pertaining to food access and participation in muscle-strengthening activity was investigated. Chapter 4 consisted of an analysis of health-related outcomes to a 12-week self-guided Tai Chi and Qigong intervention compared to a video health information only control group. Results regarding the effects of physical activity on insulin sensitivity (Chapter 2) in people with mobility impairments were mixed. Self-reported muscle strengthening exercise frequency (Chapter 3) was negatively associated with difficulty loading or unloading groceries or other items from a car or transportation and difficulty with store check-out process. The results from Chapter 4 indicated no significant differences in handgrip strength following 12-weeks of self-guided Tai Chi and Qigong when compared to the control group. In sum, the overall results of this research indicated that physical activity is important for individuals with mobility impairments but that interventions to increase

muscle strength in this group may need to be more specific or create more overload to elicit muscle-strengthening stimulus. Furthermore, the feasibility of conducting a remotely delivered exercise intervention in individuals with mobility impairments was confirmed; however, future research on a larger sample population is needed to determine the efficacy of this type of intervention on strength outcomes. Clinicians should continue to recommend regular exercise in people with mobility impairments due to the large body of research supporting its use across a variety of populations.

DEDICATION

I dedicate this dissertation to my family and my friends for their unwavering support throughout the 7 years. My mother, Eva Lambesis, has stood behind me from birth to now and has been my number one supporter. My father, Roberto Santana, taught me from a young age to find my own path and push through adversity. I am forever grateful to have been born from two wonderful parents. I also thank Thomas Waller, who was my stepfather throughout most of my youth and young adult years and encouraged me to follow a path that made sense for me. My role models throughout my youth set the foundation that led to these life changing accomplishments, and I am forever grateful.

I dedicate this dissertation to the underdogs of the world, those who have a late start in life, and those who struggle to spread their wings. This long academic journey has taught me that there are always people out there who understand your struggle, understand your needs, and are ready and willing to help you succeed. The time, energy, and resources that I received my mentors over the years is invaluable and I can only aim to do the same throughout my career. This document would have never materialized without the support of a good family, friends, and mentors throughout the years.

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CHAPTER 1

INTRODUCTION

Over 1 billion people worldwide live with a disability, with 3.8% having difficulties functioning and requiring healthcare services (Rimmer & Marques, 2012). According to the Centers for Disease Control and Prevention, a disability "is any condition of the body or mind (impairment) that makes it more difficult for the person with the condition to do certain activities (activity limitation) and interact with the world around them. (Centers for Disease Control and Prevention [CDC], 2018)." A disability with impaired mobility includes difficulty moving and maintaining body positions, handling, and moving objects, moving around in the environment, moving around, and difficulty with transportation. The negative impact of mobility impairments on daily life is profound and can lead to long-term negative health consequences. Mobility-impairing disabilities are associated with reduction in glucose tolerance, difficulty accessing healthy food, and physical inactivity (Kressler, et al., 2014; Lee et al., 2020; Marco-Ahulló et al., 2021).

The prevalence of mobility impaired disabilities in adults in the United States is approximately 13.7%. Of these, females have a slightly greater prevalence as compared to their male counterparts (~14% vs. ~10%).(CDC, 2018). On average, females, who tend to have lower baseline muscle mass and strength than their male counterparts, are at greater risk of negative health consequences associated with mobility-impairing disabilities. These include a reduction in ability to perform activities of daily living (ADL) and a greater risk of glucose intolerance and type 2 diabetes (Booth et al., 2012) and overall lower quality of life. Clearly there is an urgent need to understand the physical challenges associated with mobility impairments and develop targeted interventions to mitigate potentially negative health consequences and improve quality of life.

Physical mobility impairments inevitably result in overall physical inactivity, especially those of the lower extremities, which can negatively impact overall cardiometabolic health and performing basic ADLs such as bathing, dressing, accessing, and preparing foods for meals. Increasing physical activity participation can enhance one's ability to perform ADLs, improve glucose tolerance and reduce cardiometabolic risk factors. The magnitude by which physical activity modifications can result in improvements in these variables depends on prescriptive variables such as type, duration, intensity, and volume (Booth et al., 2012).

The prescriptive (frequency, type, duration, intensity, and volume) elements of physical activity are captured by the term exercise. Whereas physical activity is defined as any physical movement that is performed, exercise is a subtype of physical activity that is structured and typically subdivided into aerobic and resistance types (Piercy et al., 2018). Aerobic exercise typically consists of rhythmic activities that can be done continuously and target the systemic cardiorespiratory metabolic pathways and tissues. In contrast, resistance exercise consists of performing movements against an external resistance and tend to target neuro-muscular-skeletal systems and tissues. Aerobic and resistance exercise that progresses through incremental increases in volume, intensity, duration fall into the realm of training (Kilgore & Rippetoe, 2007). Although both types of exercise are associated with cardiometabolic risk reduction, resistance exercise results in greater improvements in lean body mass, bone mineral density, and muscle strength

(Yang et al., 2014). However, untrained people with mobility impairments may have difficulty performing traditional resistance training due to the balance and neural control required to maintain stability throughout the movements. Tai Chi & Qigong (TCQ) are forms of structured physical activity called, meditative movement, that emphasize breathing, balance and stability. These movements primarily depend on isometric strength of the muscles of the trunk, back and waist. Since these movements can be performed from a sitting position, they may be particularly appropriate for those who have mobility impairments. TCQ exercise may lead to improvements in kinesthetic awareness and isometric strength in previously untrained people with mobility impairments. Adults with physical mobility impairments can benefit profoundly from such an intervention since balance and stability are often a limiting factor in performing ADLs.

Neuro-muscular adaptations from resistance exercise training result from chronic exposure to a series of training sessions that produce overload on the system (Kraemer & Ratamess, 2004). Previous training experience, and overload intensity influence the rate of adaptation, with untrained novices demonstrating a faster rate of progress than intermediate or advance trainees (Kilgore & Rippetoe, 2007). This is true because when beginners first start a resistance training program there is an initial rapid rate of neuromuscular adaptations that improve muscular contraction strength and efficiency resulting in measurable improvements in muscle strength prior to any change in muscle size. This means that even the most fundamental exercise levels can yield significant increases in untrained individuals. Any untrained population, including adults with physical mobility impairments who are deconditioned, can achieve significant improvements with minimal exercise intensity, complexity and/or equipment. Thus, simple resistance exercise in those with physical mobility impairments is recommended as it maximizes benefits, while minimizes potential burden or need for specialized equipment.

TCQ exercise is comprised of movement activities that typically fall into the light to moderate end of the exercise overload intensity spectrum. Although historically used as a meditative movement, TCQ requires balance and muscular control to perform the basic movements (Rogers et al., 2008). Although the overload stimulus is likely insufficient for developing measurable increases in strength in experienced strength trained people, TCQ may serve as an appropriate introductory level stimulus for an untrained population to improve basic functional strength necessary for ADLs. In fact, there is evidence showing significant improvements in handgrip strength following 3-5 hours per week of seated TCQ in adults with physical mobility impairments (Qi et al., 2018; Tsang et al., 2015). Thus, TCQ training could serve as an ideal introductory exercise stimulus prior to engaging in a more targeted strength training program. TCQ training would be a valuable to establish a foundation of strength and motor control prior to progressing to a more individually targeted strength training program. Additionally, the simplicity of delivery and lack of needed exercise equipment solidifies TCQ as the exercise of choice for those with limited mobility.

Clearly designing and offering time efficient and minimally demanding exercise programs for those with physical mobility impairments, with the goal of improving physical function and ADLs are urgently needed to facilitate improvements in their overall health. Currently there are few studies indicated in the research literature that concentrate on resistance exercise programs for adults with physical mobility impairments. The purpose of this study was threefold: a) to review and evaluate the literature on the effects of resistance exercise on glucose control in those with physical mobility impairments; b) assess the relationship between self-reported muscle-strengthening exercise frequency on the physical ability to obtain food in a sample of adults with physical mobility impairments and c) to assess the efficacy of an online delivered TCQ program to increase handgrip strength in adults with physical mobility impairments.

Scientific Rationale

Addressing the needs of adults with physical mobility impairments is an urgent public health issue. Physical mobility impairments often lead to reductions in physical activity, which may result in reductions in the ability to perform ADLs (Cunningham et al., 2020). Impaired ADLs can lead to reductions in muscle strength, which can impair glucose tolerance through a reduction in glucose disposal (AbouAssi et al., 2015; Booth et al., 2012; Croymans et al, 2013; Lee et al., 2013; Roberts & Barnard, 2005). Traditional resistance training has been shown to improve glucose tolerance in healthy adults of all ages. However, the state of the science regarding the influence of physical activity, strength, balance, and stability in adults with mobility impairments is currently lacking. To address some of these gaps in the literature this research will present a thorough systematic review of the effects of resistance exercise on glucose control in those with physical mobility impairments; provide an analysis of self-reported physical activity behavior in a population of adults with physical mobility impairments, and a describe the feasibility and effects of a TCQ intervention delivered online that can easily introduce exercise with minimal burden and potentially improve fundamental strength in those with mobility impairments.

Specific Aims and Research Hypotheses

Specific Aim 1: Assess the state of the science through systematic review with meta-analysis on the extent to which physical activity improves glucose tolerance in adults with physical mobility impairments as measured by fasting glucose and 2h glucose values.

- Hypothesis: Adults with physical mobility impairments who engage in physical activity would show greater improvements in measures of glycemic control than those who do not.

Specific Aim 2: Examine associations among participation in muscle-strengthening exercise and physical ability to obtain food in a sample of adults with physical mobility impairments.

- Hypothesis: Adults with physical mobility impairments who engage in muscle-strengthening activity would have greater physical ability to obtain food than those who do not.

Specific Aim 3: Assess the efficacy of TCQ to increase handgrip strength compared to controls from time 1 to time 2.

- Hypothesis: Isometric handgrip strength would increase after 12-weeks of TCQ compared to the control group.

Relationship Among Chapters

Aim 1 is addressed in Chapter 2, which was completed to assess the state of the science on the association between exercise and glucose tolerance in adults with physical mobility impairments. This chapter serves to identify the association between physical activity and glucose tolerance in adults with physical mobility impairments. Aim 2 was addressed in Chapter 3 by investigating the association between participation in muscle-strengthening exercise and physical ability to access food, an important ADL. Aim 3 was addressed in Chapter 4 by testing the impact of 12-weeks of TCQ on isometric handgrip strength in mid-life adult women with physical mobility impairments.

CHAPTER 2

THE ASSOCIATION BETWEEN PHYSICAL ACTIVITY AND GLUCOSE DISPOSAL AMONG ADULTS WITH PHYSICAL MOBILITY IMPAIRMENTS: A SYSTEMATIC REVIEW

Introduction

The global prevalence of diabetes has dramatically increased from 108 million to 422 million between 1980-2014 and has become the fourth leading cause of death. (Ampofo & Boateng, 2019). In the United States, ~23 million US adults have been diagnosed with diabetes, with 91% of diagnosed cases classified as type 2 diabetes (Bullard, et al., 2017). The cost burden of diagnosed diabetes is substantial with an estimated at ~$27 million in 2017. Prediabetes, which is classified by non-diabetic elevations in blood glucose has been reported in 35% of US adults over the age of 20 and 50% of US adults over the age of 65 (Tudor-Lock & Schuna, 2012). The most alarming statistic is that the prevalence of diabetes is expected to increase over the next decade. Effective treatment and prevention of this complex disease involves medical, exercise, and nutritional interventions.

The increasing prevalence in diabetes in the United States is a significant public health problem that impacts individuals across various populations. An overlooked population is adults with physical mobility impairments, who are at increasingly high risk of diabetes due the inevitably lower physical activity levels than the general population. Lower physical activity levels result in fewer muscle contractions, which results in a reduction in glucose disposal and could lead to insulin resistance and eventually type 2 diabetes. Approximately 34 million people, or 12% adults, in the United States suffer from a physical disability that impairs mobility (CDC, 2019). As of 2019, 21% of adults with physical mobility impairments in the United States report having diabetes (CDC, 2019). Although physical mobility impairment is commonly associated with an aging population, approximately 55% of these adults were under the age of 65 years, and ~64% earn an annual income ≤ $35,000. These figures are alarming since they highlight the need to mitigate diabetes risk in a population of working-age individuals with limited access to resources.

It is well established that aerobic exercise training improves glucose tolerance in diabetic and non-diabetic individuals (AbouAssi et al., 2015; Booth et al., 2012; Croymans et al., 2013; Lee et al., 2013; Roberts & Barnard, 2005). This has been confirmed at a variety of training intensities (Dumortier et al., 2003; Hawley & Gibala, 2012; Houmard et al., 2004; Wens et al., 2016). Resistance exercise training also improved glucose tolerance in obese and nonobese individuals with type 2 diabetes (Croymans et al., 2013; Hurley et al., 2011). This is of notable importance because continuous movement and cardiorespiratory burden demanded by aerobic activity may be more challenging for an untrained individual with obesity, and especially so in people with obesity and who also have mobility impairments. In contrast, to aerobic exercise, traditional resistance training is shorter, involves higher intensity muscle contractions, and includes rest periods to recover before subsequent sets. However, traditional resistance exercises require specialized equipment and a reasonable level of isometric strength in the muscles of the back and waist to maintain stability during the exercises. Alternative exercise modalities, such as Tai Chi and Qigong, that target balance and coordination, can serve as both a light aerobic and resistance stimulus to introduce exercise to untrained people with mobility impairments.

The 2018 Physical Activity Guidelines for Americans issued by United States Department of Health and Human Services recommends the performance of muscle-strengthening activities on 2 or more days per week and selecting exercises that work all major muscle groups (legs, hips, back, abdomen, chest, shoulders, and arms) (Piercy, et al. 2018). These activities include, but are not limited to, lifting weights, working with resistance bands, doing exercises that use bodyweight for resistance (e.g., Tai Chi & Qigong), heavy gardening (e.g., digging shoveling), and some forms of yoga. According to the CDC, approximately 30% of Americans participate in muscle-strengthening activities between 2011 and 2017, with that figure trending up to 35% in 2019 (CDC, 2019). However, a reduction in access to strength training facilities as the result of COVID-19 mitigation measures, makes it unclear whether this recent increase is a true trend.

It has been firmly established that resistance training creates improvements in strength, lean mass, and bone mineral density. These are the most common and expected benefits of chronic strength training and transfer to function by improving the performance of activities of daily living (ADLs). Notably, the initial improvements in strength are the result of improvements in neuro-muscular efficiency, which can be achieved with very light resistance, including, but not limited to, bodyweight exercises. Resistance training also has an important role in diabetes prevention (Croymans et al., 2013). Acute resistance exercise improves glucose disposal through insulin independent glucose transport, thereby reducing diabetes risk (Strasser & Pesta, 2013). Aguilar et al.

(2014) reported in a systematic review with meta-analysis, that multi-component lifestyle interventions comprised of aerobic and resistance exercise training resulted in improvements in impaired fasting glucose, glucose tolerance and modest weight loss in individuals at risk for diabetes. Strasser et al. (2010) in their systematic review with meta-analysis on the impact of resistance training on metabolic syndrome, identified similar findings. Improvements in glycosylated hemoglobin and reductions in body fat were reported with resistance training performed for a duration greater than 6 weeks. Also, improvements in hemoglobin A1c have been observed with resistance training regardless of training style (e.g. strength-style training (<5 repetitions, higher load), hypertrophy-style resistance training (e.g. moderate (8-12) repetitions, moderate load) or muscular endurance style resistance training (e.g. >12 repetitions) (Acostsa-Manzano et al, 2020; Yang et al., 2014).

However, both Aguilar et. al. (2014) and Strasser et al. (2010) were not able to identify the independent effects of the exercise modality nor any diet intervention because of the vast heterogeneity in the resistance training protocols used. Their commentaries highlighted the longstanding problem often encountered with resistance training programs in that there is little standardization in the protocol duration, volume, or intensity. Thus, it is difficult to clearly identify and understand the minimum effective dose necessary for clinical improvements with resistance training research.

Although the optimal protocol is unknown, evidence suggests that with resistance training muscle mass can maintain its plasticity and capacity to hypertrophy until the 10th decade of life (Strasser et al., 2010). After the 5th decade of life, humans lose on average 0.46 kg of skeletal muscle mass per annum (Strasser et al., 2010). Thus, maintaining muscular strength and endurance is important throughout the lifespan and becomes increasingly important in those with mobility impairments.

While, aerobic activity provides clear benefits for cardiorespiratory fitness and glycemic control, it typically provides minimal stimulus for muscular strength development. Basic muscular strength is a necessary factor in maintaining and performance of ADLs in individuals with mobility impairments (Piercy et al., 2018). In those with mobility impairments, performing some ADLs become increasingly difficult due to lack of strength from muscular atrophy associated with the disability status (Wang et al., 2020). Muscular atrophy from extended sedentary time that often accompanies those who have mobility impairments, can also lead to impaired glucose tolerance (Booth et al., 2012; Elliot et al., 2002). Since those with mobility impairments are typically sedentary, increasing physical activity needs to begin at very low intensities and progress very slowly. Importantly, in previously untrained individuals, even with relatively light resistance and/or isometric muscle contractions rapid and profound neuromuscular improvements can be achieved. Also, significant improvements in glycemic control with even light physical activity has been reported in previously untrained individuals (Herzig et al., 2014).

In summary, a greater understanding the effects of resistance training for improving physical function and glucose control in those with mobility impairments is urgently needed to facilitate improvements in their overall health and quality of life. The Physical Activity Guidelines for Americans, (2018), outlined several key guidelines for adults with chronic health conditions or disabilities. Most notable is that adults with chronic conditions or disabilities should avoid inactivity and engage in regular physical activity (including muscle-strengthening activities) according to their abilities. However, there is limited research currently available that concentrates on the effects of resistance exercise programs on glycemic control in those with mobility impairments.

In theory, adults with physical mobility impairments who increase their physical activity should have greater improvements in glycemic control and ADLs compared to those who remain sedentary. The purpose of this study was to review, evaluate and describe the impact of various physical activity interventions on measures of glycemic control and insulin sensitivity in adults with mobility impairments.

Methods

This systematic review was conducted and reported according to the Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA).

Data Sources and Search Strategy

The literature search for this review was conducted using PubMed, Medline, Embase, SportDiscus, Web of Science, and Cochrane Library. Advanced searching options were used when applicable, while using identical search strings in each database. Searches were limited to English, but there were no restrictions used for date or country. Initial searches were conducted by a single author and entered onto an excel spreadsheet. All duplicates were removed, and an additional author reviewed the final list of titles to determine study eligibility for inclusion into the systematic review. Additional studies were identified by reviewing the reference lists for the studies that met the inclusion criteria and previously conducted systematic reviews. Detailed search information, including search strings, can be found in **Appendix B.**

Eligibility Criteria

All research studies reviewed had study characteristics extracted and recorded. The information extracted included: 1) targeted T2DM randomized control trial (RCT) in at risk or prediabetic adults (18-64); 2) Documented mobility impairment; 3) Inclusion of resistance training, aerobic training, Tai Chi & Qigong, or physical activity interventions; and 4) Reported anthropometrics, fasting glucose, and the results of an oral glucose tolerance test. Studies were excluded if they: 1) recruited individuals with type 2 diabetes; 2) recruited individuals with full mobility; 3) used drug therapy or surgical procedures as part of the intervention, 4) included a dietary intervention.

Data extraction

All research studies were reviewed multiple times with study characteristics extracted and recorded. The information obtained included: 1) Study setting, including city, state, and country (if reported); 2) Characteristics of sample population, including size, race, ethnicity, sex, age, and mobility impairment; 3) Research design; 4) Data collection time points, including follow up time; 5) Type of strength assessments; 6) Blood glucose measures, including those obtained from an oral glucose tolerance test; 7) Dependent variables with measurement methods; 8) Covariates; 9) Description and explanation of findings.

Quality Assessment

Risk-of-bias was assessed for randomized trials using Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) short version (Sterne et al., 2019). The scale and explanations of scoring for each item are available. Each item was scored with a ‘yes,’ ‘probably yes’, ‘no’, ‘probably no’, and ‘not indicated’. The tool includes 5-domain risk-of-bias judgement assessments. Two reviewers (RS, MA) independently completed the 5-domain risk-of-bias assessments for each study that met the inclusion criteria, which is displayed in **Table 2.1**. In the event of disagreement, a discussion took place until a consensus was reached.

Data synthesis

The primary outcomes for the review were between group differences in fasting glucose and two-hour oral glucose tolerance test, and HOMA-IR. Study characteristics synthesized are shown in **Table 2.2** and included the following: a) Study setting, including city, state, and country (if reported), b) Sample characteristics (sample size, age, sex, race, ethnicity, and nature of mobility impairment), c) Study design, d) Outcome variables of interest (fasting glucose, postprandial glucose, fasting insulin, postprandial insulin, insulin sensitivity indices, glucose and/or insulin area under the curve (AUC)), e) Measurement method of glucose, insulin, and indices of insulin sensitivity, f) Description of significant findings for each variable of interest, and g) Quality assessment rating. Data were independently collected and coded by one investigator (RS). Due to the clinical heterogeneity of training protocols included in the trials reviewed, the extracted outcome data were combined using narrative synthesis. Differences between studies were discussed in the text, and study details can be found in **Table 2.2**.

Results

Sample

A total 125 studies were screened after duplicates were removed (**Figure 2.1)**. The full text of all studies that included disability (or any other mobility impairment related term) and any diabetes related outcome in the title were assessed for eligibility, resulting in six studies that met the inclusion and exclusion criteria that were included in this review. All six studies were randomized control trials (Bailey, et al 2020; Bombardier et al., 2021; Ivey et al., 2007; Moore et al., 2015; Wang et al., 2014; Zou et al., 2015). All studies reviewed listed a significance level that was set at 0.05.

Demographic Characteristics

The studies were published between 2007 and 2021, with sample sizes ranging from 14 to 56 and participants 18 to 70 years old. Five of the six studies were published between 2014 and 2021. Four of the studies enrolled >40 participants, with the remaining two studies enrolling fewer than 20 participants (Bailey et al., 2020; Bombardier et al., 2021). All studies recruited both male and female participants.

The studies reviewed took place in three countries. Two were conducted in the United States (Ivey et al., 2007; Bombardier et al., 2021), two in China (Wang et al, 2014; Zou 2015), and two in the United Kingdom (Bailey et al., 2020; Moore et al., 2015). Ethnicity was not reported in the studies from the UK and China. One sample in US was comprised of 80% white, 13% mixed racial background, and 7% marked other with 7% Hispanic, and the other US study included 46% African American or Black in the intervention group, 55% in the control group, with the remainder being non-Hispanic whites. Demographic data is located in **Table 2.2**.

Quality Assessment

All studies analyzed were randomized control trials (n=6). Risk-of-bias analysis indicated that approximately 33% of the studies were categorized either in the “low risk”, “some concerns” and “high risk” categories (2 studies each). All studies listed inclusion/exclusion criteria as well as some demographic information. Convenience sampling was used in all studies. Two studies (Bailey et al., 2020; Bombardier et al., 2021) recruited individuals with spinal cord injuries (SCI). The remaining four studies recruited stroke survivors (Ivey et al., 2007; Moore et al., 2015; Wang et al., 2015; Zou et al., 2015). Approximately 50% (n=3) investigated the impact of aerobic exercise training, 33% (n=2) investigated the impact of a multi-component exercise program, and 16% (n=1) prescribed resistance exercise training. Glucose and insulin measurements reported included: a) fasting venous blood values (n=3), b) capillary blood collection during exercise (n=1), c) OGTT (n=2), d) fasting and postprandial venous blood for insulin and glucose (n=2). No study used the hyperinsulinemic-euglycemic clamp technique to measure insulin sensitivity. Approximately 66% of studies (n=4) reported a power analysis.

Physical Activity Interventions

Approximately 83% of the studies reviewed included a longitudinal physical activity intervention. One study (~17%) was a crossover physical activity intervention. Intervention length ranged from 8 weeks to 24 weeks in longitudinal studies. Resistance training was prescribed exclusively in ~17% (n=1) studies and included a portion of a multi-component intervention, with 83% (n=5) of all studies including aerobic exercise. Aerobic exercise was exclusively prescribed in 50% of the studies (n=3), with multi-component interventions prescribed in 33% of the remaining studies. Aerobic exercise intensity was moderate in 33% (n=2) of studies and low in 50% (n=3) of studies reviewed. Resistance training intensity was described in only two studies and was moderate. Exercise duration ranged from 32 min to 40 min. One study was a telehealth intervention and did not disclose a detailed exercise prescription. An arm crank ergometer was used in 50% (n=3) of the studies reviewed. One study included the use of a treadmill and one study used resistance training machines. One multi-component study prescribed resistance training with exercise bands and calisthenics for the aerobic component (Moore et al., 2015). The other multi-component study prescribed a variety of exercise equipment including exercise machines, calisthenics, and arm crank ergometry (Bambardier et al., 2021).

Measures of Glucose and Insulin Sensitivity

Glucose and insulin sensitivity data extracted from studies can be found in **Table 2.2**. Summary of findings can be found in be found on **Table 2.3.** A total of 67% (n=4) of studies investigated the impact of a physical activity intervention on fasting glucose and fasting insulin. One study reported HOMA-IR without fasting insulin. Two-hour glucose was reported in 50% (n=3) of studies reviewed. Approximately 33% of studies (n=2) reported glucose and insulin incremental and total area under the curve. Of the six studies reviewed, 50% (n=3) reported significant reductions in fasting insulin and HOMA-IR with exercise. Postprandial glucose significantly decreased in approximately 67% (n=4) of studies reviewed. No significant differences in glucose or insulin responses were found in 33% (n=2) studies reviewed.

Discussion

The purpose of this review was to determine the impact of physical activity interventions on measures of glycemic control and insulin sensitivity in people with mobility impairments. Of the 125 non-duplicate studies screened for this review, only six met the eligibility parameters determined for this study (**Figure 2.1**). In the six randomized control trials reviewed, there were a total of five exercise training studies

(Bambardier et al., 2021; Ivey et al., 2007;, Moore et al., 2015; Wang et al., 2014; Zou et al., 2015), and one (Bailey et al., 2020) study that evaluated the acute changes in glucose indices in response to interrupted sedentary time. In general, it was found that increasing physical activity in people with mobility impairments resulted in improvements in post-prandial glucose and insulin sensitivity in 67% (n=4) of the studies reviewed. These outcomes are consistent with research results on adults without mobility impairments (Conn et al., 2014). People with physical mobility impairments have higher levels of sedentary behavior and overall lower levels of physical activity than those without mobility impairments. Thus, it would be expected that any novel physical activity training is likely to foster a positive training overload of the muscles.

While the results of the studies reviewed indicated some evidence of a favorable relationship between increasing physical activity training and glucose control in people with mobility impairments, the quality of the evidence for this training effect is mixed. Of the four studies showing improvements, only 50% showed a "low risk-of bias" categorization (Bailey et al., 2020, Ivey et al., 2007, Moore et al., 2015, & Zou et al., 2015). And while the Bailey et al. (2020) study had low-risk-of bias, it was not actually an exercise training study. It was a crossover study comparing Uninterrupted and Interrupted Sedentary Time using 2 min moderate intensity arm ergometry every 20 min. Thus, the only intervention study that had a low-risk-of bias rating was reported by Zou et al., (2015) on stroke survivors (i.e., 8 weeks of 40 min resistance training 3x/wk vs conventional stroke physical therapy). The other intervention studies (Ivey et al, 2007; Wang et al., 2014) indicated "some concerns" or "high-risk-of-bias" respectively. For the most part, the high risk-of-bias assessment was due to lack of blinding of outcome assessors. Thus, although the data are promising, additional studies with improved risk-of-bias scores are needed to confirm the efficacy of physical activity to improve glucose control in this population.

The findings of this review reflect the limitations in the state of the science regarding research in people with mobility impairments. The review uncovered very few randomized control trials in the published literature that focus on physical activity in mid-life people with mobility impairments with a focus on insulin sensitivity or glucose control. Additionally, because people with mobility impairments represent a broad population due to a variety of etiologies for the mobility impairment, it is necessary to identify specific clinical populations, such as spinal cord injury or stroke, that had the most likelihood be applicable to the outcomes of interest.

The ambulatory ability of the participants may have also impacted the results of the studies reviewed. One third of studies reviewed (Bailey et al., 2020; Bombardier et al., 2021) recruited were wheelchair users, with the remainder including ambulatory participants (Ivey et al., 2007; Moore et al., 2015, Wang et al., 2014; Zou et al., 2015). Wheelchair users can sufficiently exercise but because they are typically limited to using smaller muscle mass of their arms to perform the prescribed exercise, should not be compared to those who do not use wheelchairs. For example, prescribing upper body exercises for wheelchair users often requires a different volume, intensity, and/or duration of exercise prescription compared to those who do not use wheelchairs. Perhaps some of the mixed results in the studies reviewed can be explained by this inappropriate comparison.

This review was unable to capture the impact of the specific exercise modalities on indices of glucose control because of the vast heterogeneity of the exercise training protocols used. The physical activity or exercise prescribed in the six studies reviewed ranged in every aspect. The intensity range was between low intensity to moderate; duration ranged from acute to up to 8 weeks; time was 2 minutes every 20 minutes, up to 40 minutes, and type consisted of aerobic activity, progressive resistance training and multi-component physical activities. As noted previously, the lack of standardization in resistance training protocols is an ongoing challenge in research. Vast variations in volume, intensity, type, and duration of the exercise prescription stymie the ability to generalize results between studies and make it exceedingly difficult to identify the minimum effective dose necessary for clinical improvements. An optimal program typically establishes a dose response relationship between the specific individual exercise modalities and the outcome measure prior to combining them with other modalities. In the studies reviewed, there was no way to identify any dose-response effects of these multi-component programs.

How insulin sensitivity and postprandial glucose was measured also varied across the studies reviewed. The oral glucose tolerance test (OGTT) was used in 67% of studies (n=4), with the remainder of studies utilizing fasting glucose and/or insulin and 2-hour glucose (Ivey et al., 2007; Moore et al., 2015; Wang et al., 2014). However, not all studies reported incremental and/or total area under the curve and insulin sensitivity indices. This is important because the incremental or total area under the curve reflects the insulin response to a glucose load and insulin sensitivity indices provide an estimate of insulin sensitivity. Approximately 75% of studies that utilized an oral glucose tolerance test reported homeostatic model assessment of insulin resistance (HOMA-IR), which is based on fasting insulin and fasting glucose, and/or 2-hour glucose obtained from the test. Although, HOMA-IR, was used in several studies reviewed, it tends to primarily reflect *hepatic* insulin sensitivity and not *peripheral* insulin sensitivity which is the most responsive to exercise (Winnick et al., 2008). Thus, this measure may not have been as applicable to an exercise training study.

Fasting glucose was reported in 33% (n=2) of studies, with the remaining studies not reporting fasting glucose (Ivey et al., 2007; Bailey et al., 2020). One study collected multiple glucose samples within the intervention and plotted glucose and insulin curves (Bailey et al., 2020). However, these data reflect the glucose and insulin curves in response to exercise and not in response to a glucose load since exercise can induce glucose transport independent of insulin. The heterogeneity in measurement methods and lack of full data reporting presents difficulty in detecting relationships and comparing the results of various studies. The expense, time, and labor required to carry out oral glucose tolerance testing, and to a greater extent euglycemic hyperinsulinemic clamp procedure, presents a legitimate challenge and may not always be feasible. This is expensive and burdensome, which can limit recruitment and participation despite being able to obtain more precise measurements. Nonetheless, in the studies reviewed, many used procedures that required extensive time and resource commitments (e.g., multiple blood collection time points within a single session), which are similar to the OGTT and clamp procedure. Finally, to directly measure peripheral insulin sensitivity requires frequent sampling (e.g., clamp procedure, OGTT, FSIVGTT, etc.) to assess glucose and insulin responses to a glucose load.

Two studies had disproportionately more males than females recruited for participation (Bombardier et al., 2021; Moore et al., 2015), which may limit generalizability to female populations since responses to exercise differ between male and female participants. Additionally, those two studies also included older adults > 64 years old in their sample along as did one additional study (Ivey et al., 2007). Older adults often have lower baseline strength, have less baseline muscle mass, and can be less insulin sensitive than younger adults (Krentz & Sinclair, 2012). The remaining studies included an even mix of males and females. When examined by race and ethnicity only two studies included race and ethnicity data, with one study including a diverse sample of approximately half of the sample in each group consisting of African Americans, with the remainder being non-Hispanic whites (Ivey et al., 2007). The other study recruited a sample that was 80% white (Bombardier et al., 2021). The demographic breakdown of the participants in the remaining studies is not known. Two studies were conducted in China, with no race and ethnicity data reported (Wang et al., 2014; Zou et al., 2015). Including race and ethnicity data is critical to identify if differences exist between various ethnic groups since there is a well-documented heterogeneity in cardiometabolic disease risk across various ethnic groups. This is important in identifying groups that are at highest risk so that health disparities can be adequately addressed.

Other potential factors or mechanisms involved in the mixed findings or general weakness of the outcomes, may be related to the participant's initial metabolic status (Type 2 diabetes or not) and the relationship between fasting glucose, peripheral insulin sensitivity and hepatic insulin sensitivity. The fact that many participants in the studies reviewed did not have Type 2 Diabetes and had normal baseline fasting glucose levels could make it unlikely that an exercise intervention would significantly change the glucose response following training. In addition, recognizing the relationship between metabolic status and how measures of insulin sensitivity were made may have also influenced the results. For example, with exercise, contractions of the exercising muscles directly improve *peripheral* insulin sensitivity thereby lowering postprandial glucose. This is due to the skeletal muscle being the primary site of glucose disposal. Muscle glycogen, glucose stored in the skeletal muscle, cannot be released into the bloodstream, and is primarily used as energy by the skeletal muscles themselves. Therefore, a more active skeletal muscle is going to use more of the glucose disposed within it. However, there is some evidence that exercise training has little impact on *hepatic* insulin sensitivity in those who do not have Type 2 Diabetes. This is likely since healthy adults with normal fasting blood glucose and fasting insulin levels are unlikely to see changes in response to chronic exercise. As noted previously, the measurement of HOMA-IR, which was used in several studies reviewed, (Winnick et al., 2008) is based on fasting insulin, which reflects *hepatic* insulin sensitivity and not *peripheral* insulin sensitivity. Thus, this measure may not have been as applicable to an exercise training study.

Strength and Limitations

This systematic review updates the state of the science regarding the effects of physical activity on glucose control in those with mobility impairments. This review includes studies not previously included in other reviews as well as more current studies. Several methodological issues were identified regarding the lack of standardization of measurement methods, lack of reporting on key outcomes, and exercise program heterogeneity. The main limitations of this review were that people with mobility impairments encompass a broad range of individuals with various etiologies of mobility impairments. This presents a challenge since there are other factors and co-morbidities to consider when studying a group of adults with mobility impairments. The lack of representation of underserved populations of color is another important issue to consider since mobility-impairing disabilities can impact members of all demographic groups. A statistical meta-analysis was not done because of the vast heterogeneity of the procedures and the number of high risk-of-bias ratings of the studies. Additionally, due to data collection timelines, we were unable to register this review with PROSPERO.

Conclusion

The need for understanding the relationship between physical activity and insulin sensitivity on health outcomes in mid-life adults with mobility impairments is urgently needed to facilitate improvements in their overall health and quality of life. The quality of evidence for increasing physical activity in mid-life adults with mobility impairments is mixed based on the randomized controlled trials reviewed. The evidence for physical activity improving insulin sensitivity derived from this review is mixed due to methodological concerns in our limited sample of studies. Future randomized controlled trials need to utilize valid instrumentation, prescribe valid exercise protocols, and clearly define the population of interest. Future studies investigating the interplay between exercise and insulin sensitivity should focus measurements on oral glucose tolerance testing or euglycemic hyperinsulinemic clamp since they are the most valid measures in response to exercise. Similar to exercise modalities, it is necessary to use standardized instrumentation and measurement procedures to maximize the validity of the research and allow for comparisons within the literature. The overall definition of mobility impairment needs to be updated to understand the difference in response in people with mobility impairments with chronic diseases vs mobility impairments caused by genetic abnormalities and/or acute events such as a stroke and/or acute trauma. In conclusion, despite the limited number of studies in this population and the difficulty to ascertain the extent to which the treatment influenced the outcome, practitioners and healthcare providers should continue to encourage physical activity for individuals with mobility impairments based on the CDC recommendations (Piercy et al., 2018).

Figure 2.1

Flow Diagram of study selection

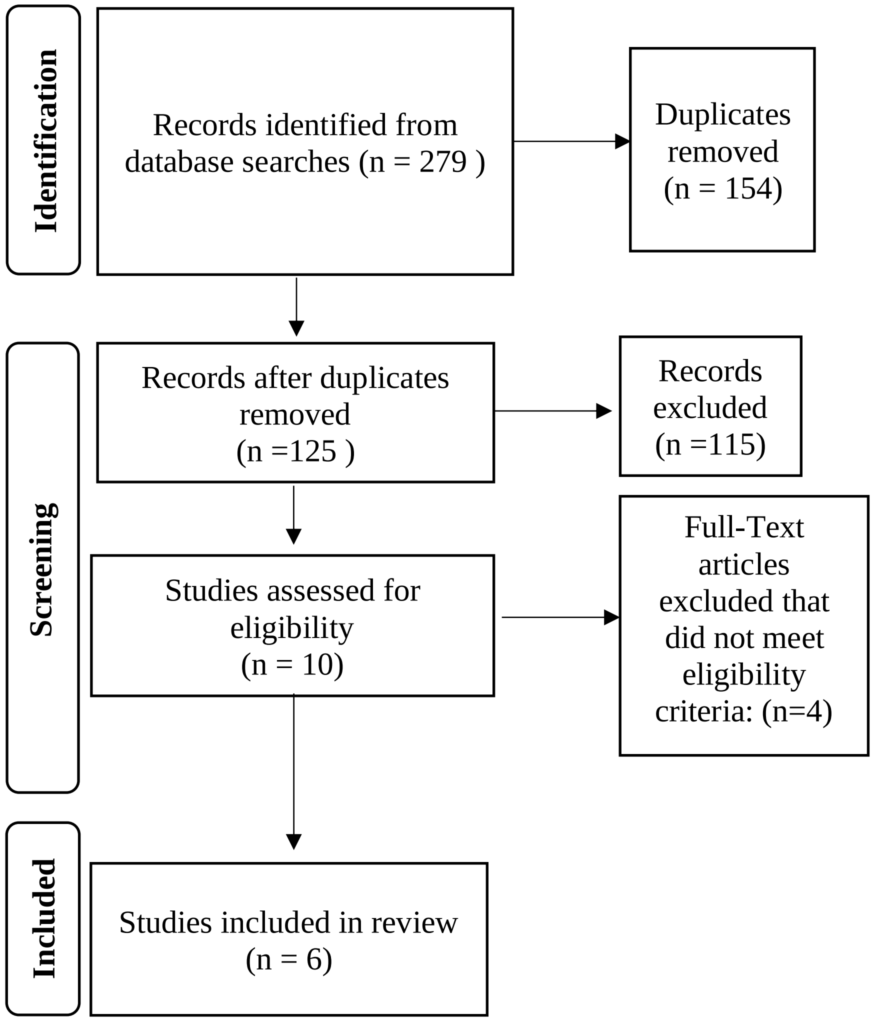

Table 2.1

Quality Assessment risk of bias tool for randomized trials

Risk of Bias Domains	Response Options	Risk-of-Bias Score
1. Risk of Bias Arising from Randomization Process	Y, PY,NI,N,PN [1]	Low, High, Some concerns
2. Risk of bias due to deviations from the intended interventions	Y, PY,NI,N,PN [1]	Low, High, Some concerns
3. Missing Data Outcome	Y, PY,NI,N,PN [1]	Low, High, Some concerns
4. Risk of Bias Measurement in outcome	Y, PY,NI,N,PN [1]	Low, High, Some concerns
5. Risk of bias in selection of the reported result	Y, PY,NI,N,PN [1]	Low, High, Some concerns
6. Overall risk-of-bias judgement	N/A	Low, High, Some Concerns

[1] Y = Yes, PY = Probably Yes, NI = Not Indicated, N = No, PN = Probably No

Table 2.2

Studies that examine exercise and glycemic control and/or insulin sensitivity in people with mobility impairments

Author & Year	**Sample Characteristics**	**Conditions**	**Outcomes**	**Significant Findings**	**Risk-of-bias judgement**
Bailey et al 2020	N= 14 Age range =18-60, 42% male, 58% female with SCI. Mean age = 51, Complete injury = 4, Incomplete Injury = 10, Wheelchair user = 9, Waist Circumference = 100.9 cm	ACUTE Crossover: Uninterrupted Sedentary time (SED) vs interrupted sedentary time + 2 min moderate intensity arm ergometry (SED-ACT) every 20 min	Fasting glucose, Fasting Insulin, Glucose iAUC, Glucose tAUC, Insulin iAUC, Insulin tAUC	Interrupted sedentary time + 20 min moderate intensity arm ergometry attenuated glucose levels at 2.5 hours (lunch time) **(p=0.015)**	Low

Bambardier et al 2021	N=15, Age range = 18-70, one year post SCI, manual wheelchair use most of the time, BMI > 21 kg/m2, 73% Male, 27% female, Mean age: 52, Mean years post SCI = 16. 80% White, 13% mixed racial background, 7% "other" racial background. Mean BMI = 29.3, Mean WC = 43.1 in,	TRAINING 6 mo PA counseling vs Usual Medical Care	ISI, HOMA-IR	There was no difference in insulin sensitivity indices between participants receiving telehealth PA counseling and those receiving usual medical care. Glucose data was not reported.	High

Ivey et al 2007	N=46, Age Range = >45, mean age 63 (intervention) and 62 (control), chronic hemiparetic gait >6 months post physical therapy completion, mean percent body fat 36.8 (intervention) and 35.6 (control), 50% female and 50% male in intervention group, 35% female and 65% male in control group, Assistive device use = 77% in intervention and 75% in control. 46% blacks in the intervention group and 55% in the control group, with the remainder being non-Hispanic whites. Abnormal OGTT = 46% in intervention and 55% in control group. T2DM = 4 in intervention and 3 in control. IGT = 8 in intervention and 8 in control group.	TRAINING 6 months of Aerobic Exercise (40 minutes) @ 60-70% HRR vs matched duration exposure to healthcare personnel and continued physical therapy	Fasting glucose, fasting insulin, insulin iAUC, insulin tAUC, glucose tAUC, HOMA-IR	There was a significant reduction in fasting insulin in T-AEX compared with control as well as significant reductions in insulin iAUC and insulin tAUC.	High

Moore et al 2015	N= 40, Male = 34, Female = 6. Mean Age = 68 years (intervention), 70 years (control), Mean BMI = 26 (intervention) and 26 (control), Mean months since stroke = 21 months (exercise), 16 months (Control), IGT = 6, DM = 3.	TRAINING 19 weeks of Multicomponent aerobic + resistance and balance training vs matched duration home stretching program (Control)	2 hour glucose, HOMA index	There was no significant difference s between or within groups difference in 2 hour glucose or HOMA-IR.	Low
Wang et al 2014	N=45, Male=36, Female = 18. Mean age = 54 (intervention), 27 (control). Months post stroke = 1-6 month, no diagnosed diabetes, fasting glucose = ≤7mmol/L, IGT = 13 (intervention), 15 (control), Diabetic = 2 (intervention), 1 (control)	TRAINING 6 weeks of Low Intensity Aerobic Training 3x/wk x 6 weeks @ 30 minutes + 5d/wk routine 40 min of traditional training vs 40-minute rehab training.	2h glucose, HOMA-IR, Fasting Insulin, Fasting Glucose	There were significant differences between and within groups differences in 2h glucose, HOMA-IR, and fasting insulin with additional low intensity aerobic exercise + rehab vs control.	Some concerns

Zou et al 2015	N= 56, chronically disabled stroke patients, Mean age = 52.3 (intervention) and 51.4 (control), Mean time since stroke onset = 15 mo (intervention) and 8 mo (control), Female = 15 (intervention), Male = 13 (intervention), Female = 19 (control), Male - 9 (control), fasting glucose level ≤7mmol/L	TRAINING 8 weeks of 40 min resistance training 3x/wk x 8 weeks vs conventional stroke physical therapy	Fasting Glucose, Fasting insulin, 2h glucose, HOMA-IR	There were significant between and within groups differences in fasting insulin, HOMA-IR, and 2h plasma glucose with 8 weeks of resistance training vs the control group.	Low

Table 2.3

Synthesis Table

Source	Finding 1	Finding 2	Finding 3	Finding 4
Bailey et al., 2020	Glucose AUC significantly lower with 5.5 hours of interrupted sedentary time during the lunch post prandial period.	No differences between conditions for the breakfast or total 5.5 hours of postprandial periods.	N/A	N/A
Bombardier et al., 2021	No significant differences in HOMA-IR with 24 weeks of self-guided multi-component exercise + counseling versus usual care.	No significant differences in Insulin Sensitivity Index with 24 weeks of self-guided multi-component	N/A	N/A

		exercise + counseling versus usual care.		
Ivey et al., 2007	There were significant reductions in fasting insulin (*P*<0.05) with 6 months of treadmill exercise training versus a stretching matched control.	There were significant reductions in 3-hour insulin response (*P*<0.05) with 6 months of treadmill exercise training versus a stretching matched control.	There were significant reductions (*P*<0.05) in 3-hour glucose response in patients with abnormal glucose tolerance at baseline with 6 months of treadmill exercise training versus a stretching matched control.	N/A
Moore et al., 2015	No significant changes in HOMA-IR with 19 weeks of community-based exercise versus a stretching control group.	No significant changes in 2-hour glucose with 19 weeks of community-based exercise versus a stretching control group.	N/A	N/A
Wang et al., 2014	There were significant reductions in 2-hour glucose with 6 weeks of aerobic training +	There were significant reductions in HOMA-IR with 6 weeks of aerobic training +	There were significant reductions in Fasting Insulin with 6	There were no significant differences in fasting glucose with 6

	rehabilitation versus rehabilitation only.	rehabilitation versus rehabilitation only.	weeks of aerobic training + rehabilitation versus rehabilitation only.	weeks of aerobic training + rehabilitation versus rehabilitation only.
Zou et al., 2015	There were significant improvements in fasting insulin with 8 weeks of lower body resistance training versus stretching control.	There were significant improvements in HOMA-IR with 8 weeks of lower body resistance training versus a stretching control.	There were significant improvements in 2-hour blood glucose levels with 8 weeks of lower body resistance training versus a stretching control.	N/A

CHAPTER 3

THE RELATIONSHIP BETWEEN MUSCLE-STRENGTHENING EXERCISE FREQUENCY AND ACCESS TO FOOD IN ACTIVITIES OF DAILY LIVING

Introduction

Approximately 13.7% of adults in the United States suffer from a physical disability that impairs mobility (CDC, 2018). Over 200,000 people suffer from spinal cord injuries, with 100,000 of those injuries occurring annually (Tomey et al., 2005). Spinal cord injuries are devastating to those who experience them and lead to chronic disruption in daily life. Muscular atrophy and disuse are an obvious negative consequence of spinal cord injuries, which leads to a reduction in ADLs (Khalil et al, 2013). A reduction in ADLs leads to a reduction in physical activity and/or exercise and loss of muscle mass, muscular strength, and flexibility. Muscular atrophy, along with loss of strength in the muscles that continue to function, can lead to chronic pain and an increased risk of chronic diseases including Type II diabetes and cardiovascular disease (Booth et al., 2012). The lack of physical activity results in fewer muscle contractions throughout the day, which is associated with reductions in insulin sensitivity (Black et al., 2010). The subsequent insulin resistance and diabetes onset results in hyperglycemia, which creates favorable conditions for an inflammatory milieu, which leads to additional pathological processes such as greater vascular stiffness, endothelial dysfunction, and hypertension (Ohnishi et al., 2003).

As a practical matter, reductions in physical mobility limit access to resources that are essential to good health, such as obtaining and preparing food. Specifically, constructing and adhering to a healthy diet is a serious challenge for the general population and especially challenging for individuals with physical mobility impairments. The definition of a “healthy diet” is broad and varies in definition across different sources. The consensus from government issued guidelines, epidemiological research, and randomized controlled trials data is that a healthy diet includes some combination of fruits, vegetables, lean meats and/or legumes, and fibrous whole grains. In an era where convenience foods are in high demand, time is limited, and people generally eat away from home, obtaining healthy food choices presents a logistical challenge. In the population with physical mobility impairments, this challenge is compounded by physical limitations that make the performance of physical tasks difficult, if not impossible. People with mobility impairments may have difficulty loading or unloading groceries, transferring foods, reaching for cabinets, or carrying multiple things at time. Thus, it is common for this population to suffer from poor dietary habits, in part, due to environmental physical barriers such as difficulty reaching items necessary for healthy eating, both in and outside the home (Lee et al., 2020).

The impact of the physical environment varies between sub-populations within those with physical mobility impairments. Much of the research on this population has focused on older adults and athletes with mobility impairments (Lee et al., 2020). However, these populations differ from young and mid-life adults with physical mobility impairments that are otherwise healthy. Older adults suffer from sarcopenia, which is a term used to describe age related loss of muscle, reductions in muscle quality, and reductions in muscle strength (Cawthon et al., 2020). In some instances, sarcopenia can lead to a physical mobility impairment or can act synergistically with an existing physical mobility impairment. In contrast, athletes with mobility impairments have greater physical abilities that are likely unachievable by the general population of people with mobility impairments. Very limited research is available in adults with physical mobility impairments in the general population.

Muscular strength is associated with greater functional abilities in young and older adults across various populations (Wang et al., 2020). Muscle strength is also associated with improvements insulin sensitivity, reductions in vascular stiffness, and improvements in endothelial function (Artero et al., 2012; Fahs et al., 2010: Westcott, 2012) Since muscle strength is associated with improved physical function and adults with physical mobility impairments likely have functional decline due to the inherent sedentary time that accompanies physical mobility impairments and the greater prevalence of obesity, understanding the relationship between muscle-strengthening exercise and physical access to healthy food is essential.

The purpose of this study was to assess the relationship between muscle-strengthening exercise frequency and physical access to healthy food in individuals with physical mobility impairments. We hypothesized that greater muscle-strengthening exercise frequency will be associated with greater physical access to healthy foods.

Methods

Data Source

This study was a secondary data analysis of data collected as part of the Food Environment Assessment Survey Tool (FEAST) study, a cross sectional study conducted between 2018 and 2021 to develop a measurement tool to assess access to healthy food in adults with physical mobility impairments (Lee et al., 2021, 2020). All surveys were conducted in English language only. Participants completed nominal group technique focus group-based interviews to develop stimulus questions about barriers to obtaining and preparing healthy food. These data were used to develop the FEAST pilot instrument and the FEAST final instrument to reflect participant responses. The data analyzed in this study was part of the FEAST COVID Panel Survey I conducted in 2021.

Research Design

This cross-sectional design investigated relationships between muscle-strengthening exercise frequency and physical access to healthy foods. This exploratory study took place in the context of a larger study aimed at validating a research survey. A sample of 88 participants were recruited broadly throughout the state in Arizona in both rural and metropolitan areas. Survey questions included questions regarding place of residence to account for zip codes that may include metropolitan and rural areas.

Sample

Inclusion Criteria. We recruited 88 male and female volunteers with physical mobility impairments to participate in the study. Participants were a minimum of 18 years of age, provide a self-reported physical mobility impairment due to a chronic disabled condition, and suffered from the condition for a minimum of one year. Physical mobility impairments were limited to those of the lower extremities. Participants were free from cognitive impairment that would impede study participation. Participants had access to a working phone, email account, personal computer and/or smart device, with a high-speed internet connection. Participants were otherwise be able to compete study protocols in English.

Exclusion Criteria. Participants who were physically mobile were excluded from participation since they lacked an impairment. Participants with upper extremity physical mobility impairments were also be excluded from participation to standardize strength testing. Cognitively impaired individuals were excluded from participations since the cognitive impairment may have synergistic effects with the physical mobility impairment. Individuals with physical impairments due to acute injuries, or who were recently become impaired in under a year were excluded from participation since individuals in this demographic were likely undergoing short- and/or long-term rehab to learn how to manage the impairment. Individuals without regular phone, computer, smart device, or high-speed internet access were excluded from participation since this would have impeded their ability to complete the screening, consenting, and survey procedures and/or effectively communicate with study staff.

Individual Measures

Demographic variables. Demographic variables included race, ethnicity, age, and anthropometrics including height, weight, and body mass index. These were collected from the FEAST Survey.

Muscle-strengthening Exercise Frequency. Self-reported muscle-strengthening exercise training frequency were measured using an adapted version of the Godin-Shephard Leisure Time Physical Activity Survey.

Physical Access to Food and Food Frequency Questionnaire. Self-reported physical access to food was measured using questions from the FEAST survey measuring access in the physical environment obtained from the FEAST COVID Panel Survey I. Questions that pertained to physical activities of daily living that participants could perform with difficulty were selected. These items can be found in **Figure 3.1.**

Dietary Intake Measures.

Three screeners were administered to assess dietary intake. The National Cancer Institute Fruit and Vegetable intake screener was used to assess fruit and vegetable intake. The National Cancer Institute Percentage Energy from Fat Screener was used to assess dietary fat intake. The Protein+ Screener was used to assess protein intake.

Data Collection and Management

Confidentiality was preserved throughout the duration of the study. Records were stored by identification number only in a locked office. Physical files were kept in a locked file cabinet. Computers were password protected. Risk to participants was low. Personal information, including name, address, date of birth, phone number, and email address was de-identified using a coding system with an ID number. Personal identifying information was stored in a separate file from de-identified data and kept locked using similar procedures. Data obtained from surveys was collected using REDCap. Study data and safety progress was reviewed weekly by the primary investigator and project director. Any adverse events that arise were documented using Arizona State University forms and protocols as established by the Institutional Review Board (IRB). If the participants experienced any adverse events due to the study, they were advised to cease participation and were referred to a healthcare professional.

Data Analysis

Data was analyzed using SPSS version 28. Descriptive statistics were reported as mean ± SD. Data was tested for normality using Shapiro-Wilk test. Multiple correlations were measured to assess relationships between both the outcome variables and potential confounders. Relationships between muscle-strengthening exercise frequency and physical access to food, as measured by seven questions derived from the FEAST survey that pertained to activities of daily living, were measured. Those questions can be located on Figure 3.1. Linear regression analyses were conducted to examine the relationship between muscle-strengthening exercise frequency and physical access to healthy food when controlling for potential confounding variables such as age, sex, body mass index, fruit and vegetable intake, percentage of energy from fat intake, and protein intake. Statistical significance was set at $p<0.05$.

Results

Of the 88 participants enrolled in the study, 85 completed all survey questions pertaining to muscle-strengthening exercise frequency and the specific activities of daily living within the FEAST survey.

Participant Characteristics

Demographic characteristics are described in **Table 3.1**. The means and standard deviations for age and BMI are included. Frequencies for sex and race ethnicity are also included.

Bivariate Correlations

Correlations between strength training frequency and seven activities of daily living derived from the FEAST survey are included in **Table 3.2.** Muscle-strengthening exercise frequency was inversely associated with difficulty loading or unloading groceries or other items from a car or transportation ($r=-0.407$; $p<0.001$) and difficulty with store check-out process ($r=-0.338$; $p<0.002$).

Linear Regression Models

Linear regression analysis adjusting for demographic variables (age, BMI, and gender) and diet (fruit and vegetable intake, percentage energy from fat intake, probability of low protein intake), muscle-strengthening exercise frequency was negatively associated with difficulty loading or unloading groceries or other items from a car or transportation ($b = -0.181$, $t = -3.044$, $p = 0.003$) and difficulty with store check-out process ($b = -0.137$, $t = -2.411$, $p = 0.018$). There were no significant associations between muscle-strengthening exercise frequency and other activities of daily living. Linear regression models are shown in **Tables 3.3-3.9.**

Discussion

The purpose of this study was to investigate the relationship between muscle-strengthening exercise frequency and activities of daily living in people with mobility impairments. People with mobility impairments are limited in their abilities to perform activities of daily living due to the nature of the physical mobility impairment. Although limited, the activities that can be performed are also limited by the strength and neuromuscular control. This study was part of a larger study that validated the FEAST survey designed to assess access to healthy food in a mobility impaired population (Lee et al., 2020). A subset of the survey questions pertained to activities of daily living that can also be limited by strength. The results of this secondary analysis supported our hypothesis that difficulty performing two of the five activities of daily living investigated was inversely related to muscle-strengthening exercise frequency. This relationship was maintained when demographic and dietary variables were controlled for.

The findings of this study are in line with other reviews that reported associations between muscle strength and independence in activities of daily living in recovering stroke patients, elderly individuals, patients with heart failure, elderly individuals with osteoarthritis, and older adults who are wheelchair bound (Bae et al 2015; Chen et al, 2016; Venturelli et al. 2010; Wang et al., 2019). Most of the research on adults with mobility impairments has been restricted to older adults or clinical populations with mobility impairments secondary to chronic diseases such as stroke, heart failure, or multiple sclerosis. According to one review, older adults participating in functional training with a strength training component showed improvements in activities of daily living (Liu et al., 2014). However, it was noted that the training programs across studies varied, making it difficult to ascertain which program is the best for this population.

The optimal dose of volume, intensity, duration, and frequency remains unknown due to heterogeneity in training protocols prescribed in previous studies. The number of days per week, sets per exercise, repetitions per exercise, and loading schemes prescribed can vary dramatically. This compounds the challenge of designing studies in humans with physical limitations due to mobility-impairing disabilities. Additionally, the lack of studies on mid-life adults with mobility impairments presents a prescriptive challenge since most guidelines for people with mobility impairments are intended for older adults. Older adults have mobility impairments for reasons different than mid-life adults, with age-related muscle loss being a primary reason. Mid-life adults with mobility impairments may be otherwise functional in terms of effectively utilizing muscles and joints that are not limited to perform movements against an external resistance.

Therefore, it is likely that mid-life adults with mobility impairments may require a greater stimulus than older adults with mobility impairments.

This study is the first observational study investigating this relationship in adults with mobility impairments across a broader age range. The younger and mid-life population are currently underrepresented in the research and understanding this relationship serves as the foundation to develop early interventions that can reduce the severity of physical decline that accompanies aging. Due to the remote nature of this study, we were unable to collect objective measures of strength or physically observe muscle-strengthening exercise. The modified GODIN survey allowed us to capture self-reported frequency of muscle-strengthening activity performance. However, the precise activities performed are unknown since questions pertaining to volume, intensity, duration, frequency, and other training related variables were not asked. Nonetheless, there appear to be relationships between muscle-strengthening exercise frequency and difficulty performing two of the 7 activities of daily living assessed. Unfortunately, no relationship was observed between the ability to transfer, which is a critical activity of daily living in people with mobility impairments, and muscle-strengthening exercise frequency. Transferring is likely a much more demanding physical activity than loading groceries or checking out a store and may require a robust and specific stimulus to improve the performance of that activity. This also highlights the need to consider which activities constitute activities of daily living more broadly, especially in people with mobility-impairing disabilities. Moreover, self-reported physical activity measures may result in over- or underreporting and/or social desirability bias. It is also important to note that causal relationships cannot be inferred due to the cross-sectional research design.

Future research should continue to investigate the relationship between muscle strength and activities of daily living in mid-life adults with mobility impairments. Randomized controlled trials should be implemented to determine the optimal dose of volume, intensity, duration, and frequency of muscle-strengthening exercise for this population. Exercise selection is equally important since mobility impairments reduce the number of movements that can be performed. Identifying the optimal combination of training variables will aide healthcare professionals by providing a framework to reference when prescribing exercise to ease the performance of activities of daily living in people with mobility impairments. By recommending effective muscle-strengthening programs, healthcare professionals may aid in reducing barriers to accessing to food and other vital resources, while also enhancing self-efficacy.

Conclusion

Muscle-strengthening exercise frequency is associated with improvements in difficulty loading and unloading groceries and difficulty with store check-out in people with mobility impairments. This was in line with our hypothesis and based on the association between muscle-strengthening activity and improvements in activity of daily living in adults with full mobility. However, five other activities of daily living, including difficulty transferring, did not demonstrate a relationship with muscle-strengthening frequency. This is likely due to the lack of specific information regarding the nature of the muscle-strengthening exercise performed. Future research is urgently needed to assess the impact of supervised strength training on activities of daily living in people with mobility impairments. Nonetheless, healthcare professionals should continue to encourage muscle-strengthening exercise in people with mobility impairments due to the well documented improvements in health outcomes in various populations.

Figure 3.1

FEAST COVID Panel Survey I

FEAST Survey

Instructions. Please rate how often each of these barriers got in the way of eating a variety of fresh, healthy foods for you, in the past year, during the pandemic.

Please mark never (1), rarely (2), sometimes (3), often (4), or always (5).

1. Trouble carrying more than one or two things at a time (e.g., on my lap, in a basket, in my bag).*
2. Trouble loading or unloading my groceries and other things from a car or transportation.*
3. Having boxes, displays or shopping carts that block the aisles in the store. *
4. Difficulty transferring or otherwise getting into or out of transportation.*
5. The store checkout process is difficult for me to manage. *
6. Fresh, healthy foods are too expensive for me to eat regularly.
7. There are no stores that sell healthy foods that are close to me.
8. Having the entrance to the restroom not accessible.
9. There is not enough space at the restaurant in between and around tables.
10. Restaurant tables and chairs are not designed for me to use comfortably.
11. Restaurants don't have accessible entryways (e.g., automatic doors, ramps).
12. Not being able to easily open or close food containers or storage bags.*
13. Not having enough accessible pantry, refrigerator or storage space to keep food.
14. My kitchen is not designed to make cooking easy for me.
15. I don't have the necessary ingredients on hand to plan and cook healthy meals and snacks.
16. I don't feel safe cooking at home.
17. Not having someone to help me with shopping.
18. Not having someone help me with cooking.
19. Not being able to access quickly food that is delivered to my home from a meal or grocery delivery service.*
20. Food delivery services are too expensive.
21. Meal or grocery delivery services are too slow.
22. Not having affordable, reliable or regular transportation, like a personal car, a friend's car, or transit service.
23. Not having enough (or any) accessible parking spots at my destination.
24. It takes too much discipline to stay on track with meal planning.
25. I don't know enough about eating healthfully to plan and cook healthy meals and snacks.
26. I don't have control over what food is purchased or prepared.
27. Servers or other restaurant staff ignore me, do not look at me, or do not speak to me.

*Questions selected for analyses.

Table 3.1

Participant Characteristics

	N	Mean	SD
Age	85	32.99	5.275
BMI	85	24.1918	3.69796

		N	Percent
Sex	Female	43	50.6
	Male	42	49.4
	Total	85	100.0
Race/Ethnicity	AIAN	1	1.2
	Asian	1	1.2
	Hispanic	2	2.4
	White	79	92.9
	Multiracial	2	2.4
	Total	85	100.0

Table 3.2

Correlations

		Strength Training Frequency	FEAST Q1	FEAST Q2	FEAST Q3	FEAST Q4	FEAST Q5	FEAST Q12	FEAST Q19
Strength Training Frequency	r	1	-.049	-.407**	-.186	-.112	-.338**	-.111	.028
	Sig. (2-tailed)		.655	<.001	.089	.308	.002	.313	.798
	N	85	85	85	85	85	85	85	85

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 3.3

Regression Coefficients for Predicting Trouble carrying more than one or two things at a time [a].

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
		B	SE	Beta	t	Sig.	Lower Bound	Upper Bound
1[b]	(Constant)	2.877	.173		16.67	<.001	2.533	3.220
	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.021	.047	-.049	-.449	.655	-.113	.072
2[c]	(Constant)	3.393	1.343		2.526	.014	.718	6.068

How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.011	.049	-.025	-.218	.828	-.109	.088
Fruit & Vegetable Servings	-.016	.021	-.100	-.778	.439	-.058	.025
Percent Energy from Fat	-.002	.025	-.012	-.097	.923	-.053	.048
Predicted Probability Protein Intake < 1.0 g/kg adj BW/d	-1.411	.473	-.385	-2.986	.004	-2.353	-.470
Biological Sex	-.072	.185	-.042	-.387	.700	-.439	.296
Age	-.018	.019	-.109	-.933	.354	-.056	.020
BMI	.026	.029	.111	.886	.378	-.032	.084

N = 85

a. Dependent Variable: Trouble carrying more than one or two things at a time (e.g., on my lap, in a basket, in my bag).

b. R Square = .002

c. R Square = .151

Table 3.4

Regression Coefficients for Trouble Loading or Unloading my Groceries and Other Things from a Car or Transportation.

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1[b]	(Constant)	3.346	.206		16.237	<.001	2.937	3.756
	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.225	.056	-.407	-4.053	<.001	-.336	-.115
2[c]	(Constant)	2.860	1.611		1.776	.080	-.347	6.068
	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.181	.059	-.326	-3.044	.003	-.299	-.062
	Fruit & Vegetable Servings	-.049	.025	-.229	-1.947	.055	-.099	.001
	Percent Energy from Fat	-.006	.030	-.023	-.209	.835	-.067	.054
	Predicted Probability Protein Intake < 1.0 g/kg adj BW/d	-1.187	.567	-.248	-2.095	.039	-2.316	-.059

Biological Sex	-.414	.222	-.184	-1.868	.066	-.855	.027
Age	.008	.023	.039	.362	.719	-.038	.054
BMI	.066	.035	.216	1.884	.063	-.004	.136

N=85

a. Dependent Variable: Trouble loading or unloading my groceries and other things from a car or transportation.

b. R Square = .165

c. R Square = .284

Table 3.5

Regression Coefficients for Predicting Difficulty with Boxes, Displays, or Shopping Carts Blocking Aisles in the Store[a].

		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1[b]	(Constant)	2.961	.226		13.100	<.001	2.512	3.411
	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.105	.061	-.186	-1.722	.089	-.226	.016
2[c]	(Constant)	4.232	1.824		2.320	.023	.600	7.864

How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.037	.067	-.066	-.557	.579	-.171	.096
Fruit & Vegetable Servings	-.036	.029	-.166	-1.269	.208	-.093	.021
Percent Energy from Fat	.003	.034	.012	.097	.923	-.065	.072
Predicted Probability Protein Intake < 1.0 g/kg adj BW/d	.229	.642	.047	.357	.722	-1.049	1.507
Biological Sex	-.036	.251	-.016	-.143	.887	-.535	.464
Age	-.046	.026	-.210	-1.756	.083	-.098	.006
BMI	.012	.040	.040	.313	.755	-.067	.092

N=85

a. Dependent Variable: Having boxes, displays or shopping carts that block the aisles in the store.

b. R Square .034

c. R Square = .117

Table 3.6

Regression Coefficients for Predicting Difficulty Transferring or Otherwise Getting Into or Out of Transportation[a]*.*

	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model	B	SE	Beta	t	Sig.	Lower Bound	Upper Bound

1[b]	(Constant)	2.866	.228		12.590	<.001	2.413	3.319
	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.063	.061	-.112	-1.026	.308	-.185	.059
2[c]	(Constant)	2.699	1.905		1.417	.161	-1.095	6.493

How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.033	.070	-.059	-.476	.635	-.173	.106
Fruit & Vegetable Servings	-.010	.030	-.047	-.340	.735	-.069	.049
Percent Energy from Fat	-.004	.036	-.015	-.119	.905	-.076	.067

Predicted Probability Protein Intake < 1.0 g/kg adj BW/d	-.287	.671	-.059	-.428	.670	-1.622	1.048
Biological Sex	.058	.262	.025	.222	.825	-.464	.580
Age	-.013	.027	-.062	-.493	.623	-.068	.041
BMI	.030	.041	.097	.726	.470	-.052	.113

N=85

a. Dependent Variable: Difficulty transferring or otherwise getting into or out of transportation.

b. R Square = .013

c. R Square = .029

Table 3.7

Regression Coefficients for Predicting Difficulty with the Store Checkout Process[a].

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
		B	SE	Beta	t	Sig.	Lower Bound	Upper Bound
1[b]	(Constant)	3.076	.191		16.09	<.001	2.696	3.456

	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.168	.052	-.338	-3.271	.002	-.271	-.066
2[c]	(Constant)	3.774	1.548		2.438	.017	.692	6.857
	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.137	.057	-.276	-2.411	.018	-.251	-.024
	Fruit & Vegetable Servings	.015	.024	.078	.619	.538	-.033	.063
	Percent Energy from Fat	-.003	.029	-.013	-.110	.912	-.062	.055

	Predicted Probability Protein Intake < 1.0 g/kg adj BW/d	-.084	.545	-.019	-.154	.878	-1.169	1.001
	Biological Sex	-.009	.213	-.005	-.043	.966	-.433	.415
	Age	-.046	.022	-.238	-2.077	.041	-.090	-.002
	BMI	.029	.034	.107	.871	.387	-.038	.096

N=85

a. Dependent Variable: The store checkout process is difficult for me to manage.

b. R Square = .114

c. R Square = 0.184

Table 3.8

Regression Coefficients for Predicting Difficulty Opening or Closing Food Containers or Storage Bags[a].

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
		B	SE	Beta	t	Sig.	Lower Bound	Upper Bound
1[b]	(Constant)	2.684	.224		11.98	<.001	2.239	3.130

	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.061	.060	-.111	-1.015	.313	-.181	.059
2[c]	(Constant)	5.176	1.762		2.937	.004	1.666	8.685
	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	-.105	.065	-.190	-1.620	.109	-.234	.024
	Fruit & Vegetable Servings	.033	.028	.154	1.198	.235	-.022	.088
	Percent Energy from Fat	.024	.033	.087	.726	.470	-.042	.091

Predicted Probability Protein Intake < 1.0 g/kg adj BW/d	.683	.620	.143	1.102	.274	-.552	1.918
Biological Sex	.201	.242	.090	.831	.409	-.281	.684
Age	-.048	.025	-.224	-1.900	.061	-.098	.002
BMI	-.097	.038	-.319	-2.537	.013	-.174	-.021

N=85

a. Dependent Variable: 12.Not being able to easily open or close food containers or storage bags.

b. R Square = .012

c. R Square = .142

Table 3.9

Regression Coefficients for Predicting Ability to Quickly Access Food that is Home Delivered from a Meal or Grocery Delivery Service[a].

		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model		B	SE	Beta	t	Sig.	Lower Bound	Upper Bound
1[b]	(Constant)	2.365	.218		10.84	<.001	1.931	2.799

	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	.015	.059	.028	.257	.798	-.102	.132
2[c]	(Constant)	1.018	1.724		.591	.556	-2.414	4.451
	How many times per week do you participate in strengthening exercises, like weight training, functional training, or sprinting?	.047	.063	.088	.745	.459	-.079	.174
	Fruit & Vegetable Servings	-.037	.027	-.176	-1.354	.180	-.090	.017
	Percent Energy from Fat	.074	.033	.276	2.276	.026	.009	.139

Predicted Probability Protein Intake < 1.0 g/kg adj BW/d	-.147	.607	-.032	-.243	.809	-1.355	1.061
Biological Sex	-.270	.237	-.124	-1.137	.259	-.742	.203
Age	-.035	.025	-.171	-1.435	.155	-.085	.014
BMI	.027	.038	.091	.717	.475	-.048	.102

N=85

a. Dependent Variable: Not being able to quickly access food that is delivered to my home from a meal or grocery delivery service.

b. R Square = .001

c. R Square = .124

CHAPTER 4

THE IMPACT OF A REMOTE LIGHT INTENSITY PHSYICAL ACTIVITY INTERVENTION ON HANDGRIP STRENGTH

Introduction

According to the Centers for Disease Control and Prevention (CDC), approximately 1 in 4 US adults suffer from some type of disability, with 13.7% suffering from a mobility-impairing disability. In 2018, 18.5% of mid-life adults, between ages 45-64, suffered from mobility-impairing disabilities (CDC, 2018). Mid-life adults are important to consider, because health trends found in this age group are predictors of future disability levels as the cohort's age and become older adults (Karvonen-Gutierrez, 2015). This is also a critical time to develop or improve upon positive health behaviors to mitigate the inevitable physical decline that accompanies each decade of age.

Mid-life women with mobility impairments (WMI) have a greater risk of cardiometabolic disease, higher prevalence of adiposity, and less lean mass and muscle strength than other groups (Chevarley et al., 2006; Froehelich et al., 2013; Hughes et al., 2006; Nosek et al., 2019). Unfortunately, due to mobility impairment-imposed limitations, many exercise interventions are difficult to perform, and vigorous-intensity activities are unrealistic in previously untrained WMI. Alternatively, participating in light activity can offer a gateway to structured physical activity and potentially develop a foundation to build on with safe and effective activities.

Tai Chi and Qigong (TCQ) offers a lighter-to-moderate intensity alternative to traditional moderate or vigorous physical activity that can be modified for a population with physical mobility impairments (Qi, et al., 2018; Rogers et al., 2008; Tsang et al., 2015). TCQ is considered a multicomponent physical activity. It consists of a combination of specific breathing, balance, coordination, and neuromuscular control techniques which can be used to improve physical function and manage stress. Typical benefits of correctly performed TCQ include improved blood pressure and lower resting heart rate (Castro et al., 2022). Additionally, the various movements of the limbs and postural stability requirements of TCQ increases kinesthetic awareness that can directly improve muscle strength in a sedentary population (Archer, 2005). This kinesthetic "mind-to-muscle" connection and control is heavily emphasized in TCQ. It is likely that these components of TCQ also explain the improvements in handgrip strength that have been observed in prior studies (Qi, et al., 2018; Tsang et al., 2015). Since initial increases in strength are primarily driven by neuromuscular efficiency, a TCQ intervention has the potential of increasing muscular strength and endurance in those who are sedentary and have limited mobility.

Modifying a TCQ program specifically for WMI would provide a unique and practical approach to addressing physical inactivity and the deleterious effects that accompany it in this population. As noted previously, untrained and/or deconditioned adults experience an initial profound rate of strength and muscle mass acquisition when compared to strength-trained counterparts (Kraemer et al., 1998). This is due to neural adaptations that occur in the early weeks of engaging in a muscle-strengthening program (Kraemer et al., 1998). Thus, while additional strength gains would require a more intense strength training program (Kraemer & Ratamess, 2004), TCQ could serve as a precursor to traditional strength training by offering the necessary basic isometric, balance, and muscle control components. The purpose of this study was to test the feasibility and preliminary efficacy of a 12-week, TCQ intervention and its impact on muscle strength, as measured by isometric handgrip strength, when compared to watching health information videos in WMI. The central hypothesis was that TCQ would increase isometric handgrip strength in comparison to the control group.

Methods

Participants

We recruited 20 community dwelling mid-life WMI (ages 35-64). Participants were randomly assigned to a self-guided, remotely delivered, TCQ intervention vs. a health information videos control condition. Participants all had a self-reported mobility impairment, due to a chronic (>1 year) mobility-impairing disability. Eligible participants reported regularly use of an assistive device and had upper extremity mobility. Access to an email address and a working phone, mobile device with an internet connection, or personal computer with high-speed internet connection was required. Females who were pregnant, lactating, or planning to become pregnant in the next 6 months were excluded from participation.

Research Design

This pilot study was a randomized controlled trial that tested the feasibility and preliminary efficacy of a 12 week, remotely delivered and self-guided TCQ intervention and its impact on muscle strength, as measured by isometric handgrip strength, compared to watching health information videos in women with physical mobility impairments. Participants were randomly assigned to a TCQ intervention or information video control group. Upon obtaining consent and collecting baseline measurements, participants were randomly assigned to the TCQ or control arm using a covariate-adaptive allocation procedure to ensure balance by category (≥50 years vs. <50 years, based on the midpoint of our eligible age range. Participants completed 12 weeks of their assigned condition, with testing at baseline (T1), week 4 (T2), week 8 (T3), and week 12 (T4).

Study Arms

Intervention

Participants assigned to the intervention group were required to complete 12 weeks of self-guided TCQ. Participants were required to demonstrate mobility in seated position via Zoom to determine if the required movements were appropriate. Eligible participants received daily text messages and emails to distribute videos and record which sessions were completed. Participants had the option to participate in ~10 or ~20-minute TCQ practices. TCQ was adapted for people with physical mobility impairments and consisted of seated TCQ. TCQ included strengthening components to emphasize muscle actions targeted at balance, stability, and kinesthetic awareness. Total weekly practice time was recommended between 70-140 minutes/week (~10-20 min/day on most days).

A library of existing TCQ videocasts, developed by Larkey, Smith, and Jahnke, were available to participants to offer a variety of video length and presenter options. All videos demonstrated *seated* TCQ practice with specific instructions and discussions on how to accommodate various mobility limitations using visualizations and somatic cues to help participants "experience" the practice despite non- or limited movement. For example, while fluid body motion was highlighted, the discussion described how to incorporate non-movement or limited movement as an option. TCQ movements emphasized breathing in sync with movements and pursuing a meditative state.

Control Group

The control arm received text messages and emails with links to health information videos for the same time lengths as the intervention group. Existing video content was reviewed and adapted to assure avoidance of topics that can impact outcome variables. Videocasts excluded topics on physical activity and nutrition to avoid influencing outcome variables.

Recruitment

We coordinated with our existing online social network to disseminate recruitment information. Participants were screened by phone or email to establish eligibility criteria. Eligible participants regularly used an assistive device, such as a walker, wheelchair, or cane “most of the time” to physically navigate outside the home. Potential participants demonstrated upper extremity mobility (via Zoom as a final eligibility check to assure ability to perform the TCQ intervention. Online consent was provided via a virtual face-to-face meeting. Interviewers reviewed study requirements and procedures and answer questions prior to completing the final consent to participate in the study.

Measurements

Demographics

We collected demographic information including age, education level, relationship status, race and ethnicity, rural/urban residence, employment status, biological sex, gender identity, annual household income, and number of people supported by household income. Disability related information including age of onset, duration of disability, type of disability, severity of disability, and need for assistance with activities of daily living, or instrumental activities, physical limitation, and pain, were collected. If participants were on medications, they were encouraged to continue to maintain their dosages throughout the 12 weeks of intervention unless indicated by their primary care provider.

Handgrip Strength.

Handgrip strength has been regarded as a significant indicator of whole-body strength in the elderly population and is commonly measured to indicate the change in overall muscle strength before and after Tai Chi training. Handgrip strength was assessed at baseline (T1), 4-week midpoint (T2), 8-week midpoint (T3), and post-test (T4). Video guidance for adaptations were provided via Zoom. Isometric handgrip strength was measured using a handgrip dynamometer to assess muscle strength (Tsang et al., 2015). A Camry hand dynamometer (Camry Scale USA, South El Monte, CA) was used to measure handgrip strength. Participants were instructed to sit in a chair with the test shoulder adducted and rotated neutrally and the elbow flexed at 90°, the forearm in a neutral position, and the wrist between 0° and 30° of extension and between 0° and 15 degrees of ulnar deviation. Both left and right handgrip strength were measured. Familiarization trials were allowed before the results of three measurements were averaged for comparison.

Self-reported dietary intake

Self-reported dietary intake was assessed using the self-administered 26-item Dietary Screener Questionnaire (DSQ) in the National Health and Nutrition Examination Survey (NHANES) (Thompson et al., 2017). The DSQ includes questions pertaining to food and beverage consumption frequency in the preceding month. The DSQ has been administered to large study populations and does not require extensive training to administer.

Data Analyses

Data were analyzed using SPSS version 28. Descriptive statistics were reported as mean ± SD. Data was tested for normality using Shapiro-Wilk test. Normally distributed data were analyzed using one-way analysis of variance (ANOVA) with repeated measures was used to assess within group differences and Tukey post hoc tests were run to assess between group differences. Non-parametric statistical tests were used for non-normally distributed data. Statistical Significance was set at $p<0.05$.

Results

Sample Characteristics

A total of 19 participants were enrolled and randomized into the study. One participant dropped out of the study after consent and before randomization due to an invasive health procedure. The total sample of participants that completed the intervention consisted of 14 women with mobility impairments. Participants completed a mean of 78.6 (SD-7.3) sessions offered, which constitutes ~94% of assigned sessions. **Figure 4.1** includes the flowchart for the randomized controlled trial. **Table 4.1** includes descriptive characteristics for each group. Race and ethnicity, education level, residence, employment, household income, number of people supported by household income, age, and baseline handgrip strength and anthropometrics are reported.

Handgrip Strength

The Shapiro-Wilk test was run for normality testing and all assumptions were met ($P>0.05$). Descriptive statistics for handgrip strength data at T2 and T4 can be found on

Table 4.2 and **Table 4.3**. There were no significant between ($F(1,12) = 0.011$, $p = 0.919$, $\eta p2 = 0.001$) or within (($F(1,12) = 1.594$, $p = 0.231$, $\eta p2 = 0.117$) group differences in mean handgrip strength of the right hand after 12 weeks of TCQ versus control. There were no significant group x time interactions ($F(1,12) = 1.061$, $p = 0.323$, $\eta p2 = 0.081$) for mean handgrip strength of the right hand. There were no significant between ($F(1,12)$ = , $p = 0.679$, $\eta p2 = 0.015$) or within ($F(1,12) = 2.409$, $p = 0.147$, $\eta p2 = 0.167$) group differences in mean handgrip strength of the left hand after 12 weeks of TCQ versus the control. There were no group x time interactions ($F(1,12) = 0.976$, $p = 0.343$, $\eta p2 = 0.075$) for mean handgrip strength of the left hand. Within-subjects effects for hand grip strength for the right and left hands can be found on **Table 4.4 and Table 4.5** respectively. Between-subjects effects for handgrip strength for the right and left hands can be found on **Table 4.6** and **Table 4.7** respectively.

Dietary Screening Questionnaire

The Shapiro-Wilk test was run for normality testing. Predicted intake of dairy (cup equivalents) per day, predicted intake of fruits (cup equivalents) per day, were non-normally distributed at T1 ($P>0.05$).

Predicted intake of vegetables including legumes and French fries (cup equivalents) per day, predicted intake of fruits and vegetables including legumes and excluding French fries (cup equivalents) per day, and predicted intake of vegetables including legumes and excluding French fries (cup equivalents) per day were non-normally distributed at T4 ($P>0.05$). Predicted intake of whole grains (ounce equivalents) per day was non-normally distributed at both T1 and T4 time points ($P>0.05$).

The remaining dietary screening questionnaire variables were all normally distributed. There was a significant group effect ($P = 0.047$) in predicted intake of dairy. There were no significant between or within group differences in the remaining dietary intake variables obtained from the dietary screening questionnaire.

Discussion

The purpose of this study was to investigate the impact of a 12-week TCQ intervention on handgrip strength when compared to the control group. This is the first study to investigate the impact of a self-guided, virtually delivered, TCQ on handgrip strength in mid-life women with mobility impairments. People with mobility impairments are often untrained and physically inactive. Therefore, it was expected that handgrip strength would improve with minimal stimulus because of improvements in neuromuscular efficiency. However, the results of this RCT do not support our initial hypothesis that handgrip strength would increase after 12 weeks of self-guided TCQ with no improvement in the control group.

The findings of this study contrast with previous research showing improvements in handgrip strength (Qi et al., 2018; Tsang et al., 2015). There are several potential explanations for the failure to detect an effect when compared to the control group. In the previously mentioned studies, a longer duration of TCQ was prescribed, which may have provided a more robust stimulus. It is well established that Tai Chi and Qigong are low intensity activities and may not have provided a sufficient stimulus to elicit a change in muscle strength at the dosage prescribed in our study. Modifications can be made to include more strengthening movements since some of the movements of this modality can be isometric in nature.

Mean handgrip strength was greater at T4 versus T1, but this change was not statistically significant. The mean handgrip strength values measured in this study are approximately within the range of normative values for 35–64-year-old women in the United States. Wang et al. (2018) listed reference values by sex and age, with 18–64-year-old adult females ranging between 23.6-29.2 kg for the dominant hand and 22.9-28.0 kg for the non-dominant hand. Our mean baseline values were mostly below these ranges, irrespective of hand dominance, except for the right hand of the control group measuring 23.6 kg at baseline, which is on the low end of the reference range. Standard deviation deviations (6.0-7.0) per age cohort shared by Wang et al. (2018) were similar to those reported in our study (4.3-5.6). Therefore, since participants had low handgrip strength at baseline, any improvement, or even maintenance, of handgrip strength would be a positive result.

Since this was a pilot study, we recruited a small sample of 20 participants. There was a 30% attrition rate, which resulted in a smaller sample of 14 participants. The most common reason for attrition was loss to follow-up. However, participants who completed the study reported completing 94% of assigned video sessions, which suggests that this approach may be feasible for future studies.

The virtual delivery is another aspect of the study design worth noting. Since the onset of the COVID-19 pandemic, the demand for telehealth services has increased. meta-analysis conducted by Bossen et al. (2014) reported conflicting evidence regarding the effectiveness of web-based physical activity interventions. Jahangiry et al. (2017) reported a significant increase in physical activity with web-based interventions, although they noted that the effect of web-based interventions was influenced by the characteristics of mean age of participants, trial duration, and study quality. Galiano-Castillo and colleagues (2016) reported improvement in handgrip strength after 12 weeks of web based multicomponent exercise program that consisted of aerobic and resistance style exercise. Hwang et al. (2016) reported improvements in handgrip strength with 6 months of Tai Chi Chuan in 334 adults over the age of 60 years. In addition to reporting mixed evidence, these studies were not conducted on a population with mobility impairments. To our knowledge, there are currently no reported virtual Tai Chi and Qigong interventions as of the date of this manuscript.

Although telehealth interventions expand access to services, the removal of real-time, physical interaction may reduce both the efficacy and effectiveness of an intervention. Real-time supervision and encouragement are two elements of physical activity delivery that can contribute to improvement in physical performance. Supervision provides oversight, which results in more detailed instruction and real time feedback, which ensures that activities are being performed as intended. Encouragement has been shown to improve performance in exercise performance (Andreacci et al., 2010; Edwards et al., 2018). Improvements in modern technology has led to the development and use of virtual meeting platforms in remote employment settings. These platforms can also be used to delivery exercise programs, which can allow for encouragement and supervision.

Despite the limitations of self-guided Tai Chi and Qigong, this study provides a foundation for improve the design for a larger scale trial. Recruiting a larger sample, increasing duration and intensity of sessions, and using a virtual meeting platform could enhance the internal validity of the study, while also more closely mimicking a live exercise program. The data on the muscular benefits of Tai Chi and Qigong on mid-life women with mobility impairments are currently limited and future research is critical to optimize delivery of web-based activities to maximize success and improve outcomes in this vulnerable population.

Conclusion

Tai Chi and Qigong did not result in an improvement in handgrip strength in mid-life women with mobility impairments. However, the intervention did highlight the challenges of a relatively new method of delivering exercise to this population. Web-based, self-guided interventions present challenges by design regardless of the population. This population is physically limited due to their disability and may benefit from real-time supervision and encouragement more than the general population of mid-life women. Normal activities of daily living are often more challenging and thus adding a more complex activity, despite the low intensity, may be more demanding. Although no statistically significant findings were found in this study, future studies can design interventions that address the logistical challenges of web-based delivery for this population to provide a more robust program that could potentially result in improvements in handgrip strength and/or other health outcomes.

Figure 4.1

Flow diagram of study

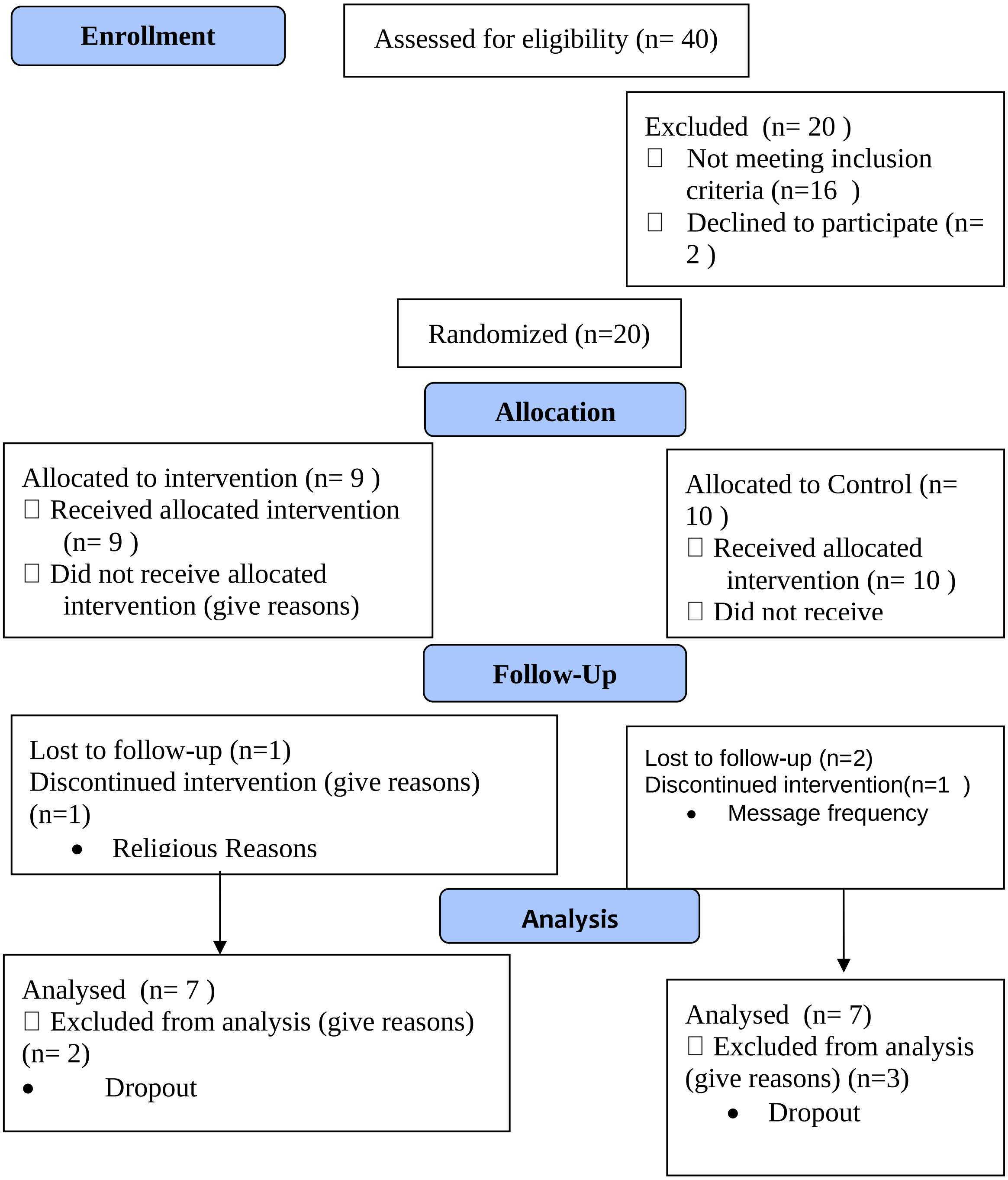

Figure 4.2

Handgrip Strength of the Right Hand by Participant

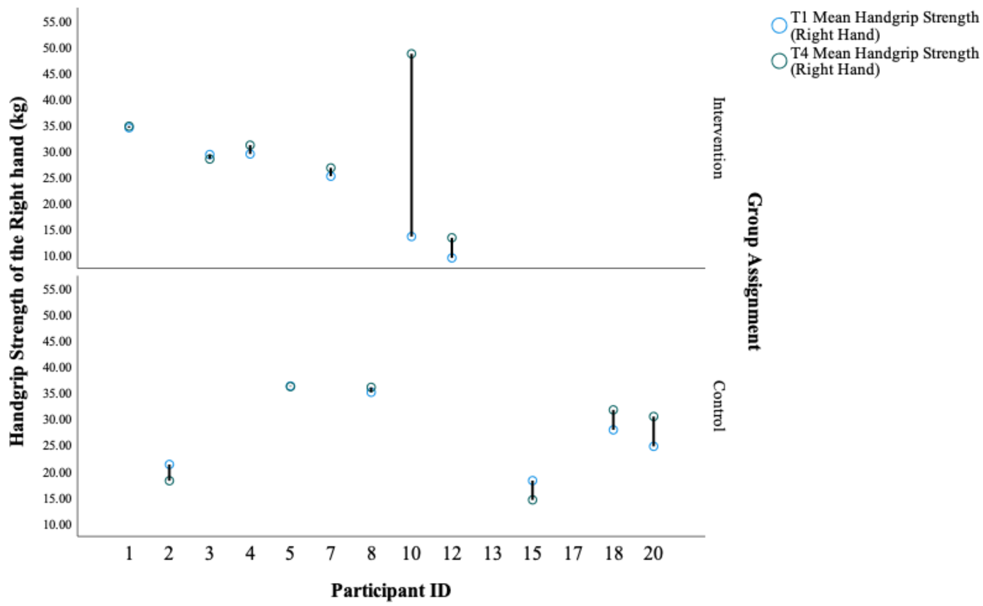

Figure 4.3

Handgrip Strength of the Left Hand by Participant

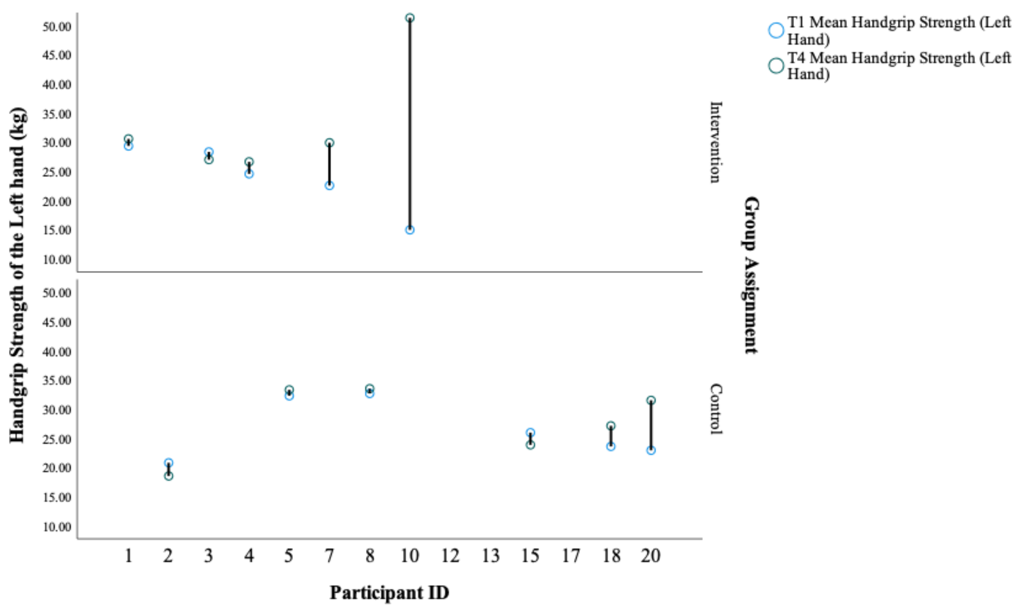

Figure 4.6

Mean Handgrip Strength of Right Hand

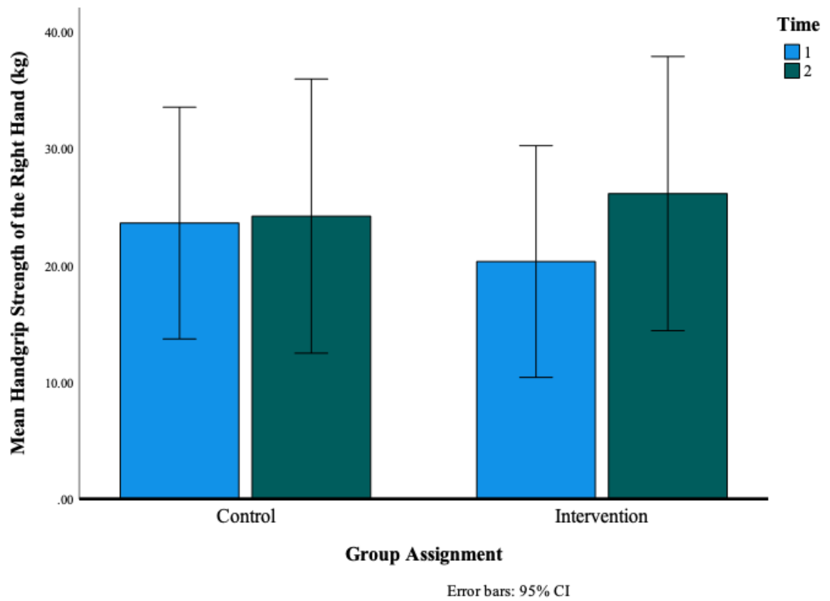

Figure 4.7.

Mean Handgrip Strength of Left Hand

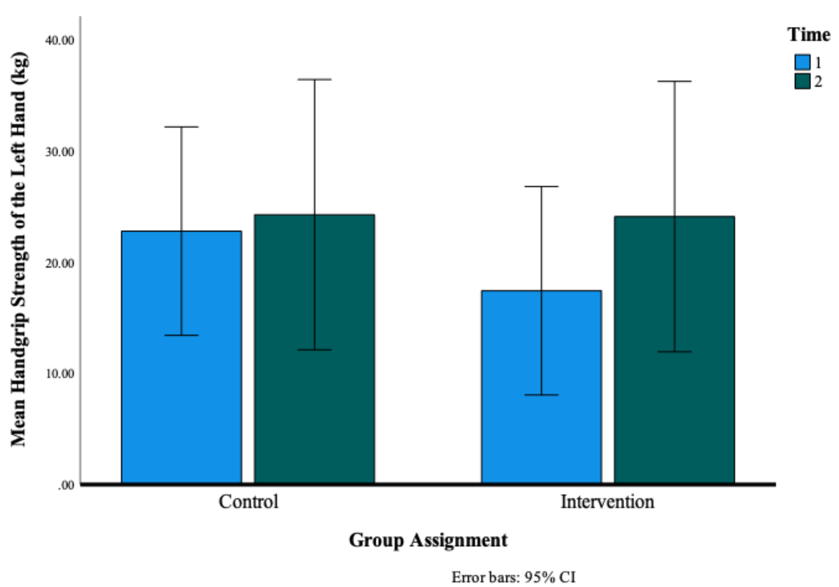

Table 4.1.

Baseline Descriptive characteristics of sample

	N	TCQ % (*n*)	Control % (*n*)
Race/Ethnicity	14		
White or Caucasian		71.4(5)	5 (71.4%)
Hispanic or Latino		-	2(28.6%)
African American		14.3(1)	14.3(1)
Pacific Islander		14.3(1)	-
Other		-	14.3(1)
Education Level (%)	14		
2 years of college		28.6(2)	14.3 (1)
3 years of college		14.3(1)	-
Graduated College		14.3(1)	28.6(2)
Some Graduate School		-	28.6(2)
Completed Graduate School		42.9 (3)	28.6(2)
Residence (%)			
Urban	14	28.6(2)	28.6(2)
Rural		-	14.3(1)
Suburban		71.4(5)	57.1(4)
Employment			
Full-Time	14	14.3(1)	28.6 (2)
Part-Time		14.3(1)	14.3 (1)
Self-Employed		28.6(3)	14.3 (1)
Wanting work, but unemployed due to a health-related condition		14.3(1)	14.3(1)
Full-Time student			
Unemployed		-	14.3(1)
Retired		14.3(1)	14.3(1)
Household Income		14.3(1)	-
$0-15,000			
$15,000-29,999	14	14.3(1)	14.3(1)
$30,000-$49,999		14.3(1)	28.6(1)
$50,000-$74,999		28.6(2)	14.3(1)
$75,000-99,999		-	42.9(3)
$150,000-149,999		14.3(1)	-
Mean (SD)		28.6(2)	-
Age	14		
Number of people supported by household		46.9(11.0)	42.6 (8.2)
income	14	2.0(1.2)	1.4(0.5)
Handgrip Strength	14		
Right Hand (kg)		20.4(12.4)	23.7(11.7)
Left Hand (kg)		17.4(12.2)	22.8(10.5)

Table 4.2

Handgrip Strength (Right Hand)

Group Assignment	Time	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Control	1	23.657	4.555	13.733	33.581
	2	24.248	5.390	12.505	35.991
Intervention	1	20.357	4.555	10.433	30.281
	2	26.181	5.390	14.438	37.924

Table 4.3

Handgrip Strength (Left Hand)

Group Assignment	Time	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Control	1	22.781	4.300	13.413	32.149
	2	24.262	5.578	12.109	36.415
Intervention	1	17.419	4.300	8.051	26.787
	2	24.086	5.578	11.933	36.239

Table 4.4

Tests of Within-Subjects Effects for Handgrip Strength (Right Hand)

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Sphericity Assumed	72.000	1	72.000	1.594	.231	.117
	Greenhouse-Geisser	72.000	1.000	72.000	1.594	.231	.117
	Huynh-Feldt	72.000	1.000	72.000	1.594	.231	.117

	Lower-bound	72.000	1.000	72.000	1.594	.231	.117
Time * Group	Sphericity Assumed	47.929	1	47.929	1.061	.323	.081
	Greenhouse-Geisser	47.929	1.000	47.929	1.061	.323	.081
	Huynh-Feldt	47.929	1.000	47.929	1.061	.323	.081
	Lower-bound	47.929	1.000	47.929	1.061	.323	.081
Error(Time)	Sphericity Assumed	542.084	12	45.174			
	Greenhouse-Geisser	542.084	12.000	45.174			
	Huynh-Feldt	542.084	12.000	45.174			
	Lower-bound	542.084	12.000	45.174			

Table 4.5

Tests of Within-Subjects Effects for Handgrip Strength (Left Hand)

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Sphericity Assumed	116.171	1	116.171	2.409	.147	.167
	Greenhouse-Geisser	116.171	1.000	116.171	2.409	.147	.167
	Huynh-Feldt	116.171	1.000	116.171	2.409	.147	.167
	Lower-bound	116.171	1.000	116.171	2.409	.147	.167
Time * Group	Sphericity Assumed	47.060	1	47.060	.976	.343	.075

	Greenhouse-Geisser	47.060	1.000	47.060	.976	.343	.075
	Huynh-Feldt	47.060	1.000	47.060	.976	.343	.075
	Lower-bound	47.060	1.000	47.060	.976	.343	.075
Error(Time)	Sphericity Assumed	578.657	12	48.221			
	Greenhouse-Geisser	578.657	12.000	48.221			
	Huynh-Feldt	578.657	12.000	48.221			
	Lower-bound	578.657	12.000	48.221			

Table 4.6

Tests of Between-Subjects Effects for Handgrip Strength (Right Hand)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	15609.043	1	15609.043	51.452	<.001	.811
Group	3.269	1	3.269	.011	.919	.001
Error	3640.483	12	303.374			

Table 4.7

Tests of Between-Subjects Effects for Handgrip Strength (Left Hand)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	13721.191	1	13721.191	45.896	<.001	.793
Group	53.673	1	53.673	.180	.679	.015
Error	3587.523	12	298.960			

CHAPTER 5

DISCUSSION

The purpose of this series of studies was to investigate the relationship between physical activity and muscle strength in people with mobility impairments. The rationale for these studies was based on the premise that mobility-impairing disabilities result in muscle loss, and reductions in muscle strength, which leads to a reduction in ADLs. Increasing physical activity and/or exercise can improve muscle strength due to rapid improvements in neuromuscular efficiency in sedentary and previously untrained adults and can occur with minimal stimuli. These improvements can be profound in people with mobility impairments since access to resources can be limited by the ability to perform activities of daily living. Physical access is limited both by the nature of the mobility-impairing disability as well as muscle strength. Increasing physical activity in this population can improve ADLs through increases in muscle strength, which can further improve through strength focused training.

In Chapter 2, a systematic review was carried out to determine the impact of physical activity and exercise interventions on insulin sensitivity. The systematic review resulted in mixed evidence for increasing physical activity in young and mid-life adults with mobility impairments. The studies showed a trend towards improvements in insulin sensitivity in most studies reviewed. However, risk-of-bias scores were mixed due to methodological limitations that are inherent to many exercise studies. The systematic review highlighted the ongoing issue of heterogeneity in training studies, including variability in prescriptive variables such as volume, intensity, duration, and frequency. Studies that had high risk-of-bias lacked sufficient blinding of investigators to study arms. Exercise studies cannot be double-blind, by design, since it is not possible to blind participants in an exercise treatment condition. The relatively small number of studies reviewed was the result of underrepresentation and broad definition of mobility-impairing disabilities.

The purpose of Chapter 3 was to investigate the relationship between the ability to perform seven physical activities pertaining to access to food and muscle-strengthening exercise frequency. This investigation found a significant relationship between muscle-strengthening exercise frequency and difficulty loading or unloading groceries or other items from a car or transportation and difficulty with the store check-out process. These relationships remained when demographic and dietary intake variables were controlled for. However, among other items, this investigation failed to detect a significant relationship between muscle-strengthening exercise frequency and difficulty transferring. The findings of this study supported our hypothesis and previous research on similar populations including those with heart failure and older adults who are exclusive wheelchair users (Bae et al., 2015; Chen et al., 2016; Venturelli et al., 2010; Wang et al., 2019).

Chapter 4 investigated the impact of performing 12 weeks of self-guided TCQ on handgrip strength when compared to a health information video control in people with mobility impairments. Twelve weeks of TCQ was not associated with significant increases in handgrip strength. Demographic and dietary variables did not vary at baseline or throughout the study. Although participants were sent daily videos, the lack of real-time instruction and potentially insufficient physical stimulus may have resulted in the absence of an effect. Furthermore, the 30% attrition rate, although comparable with in person studies, resulted in a small sample size, which may have limited our ability to detect an effect.

Integration of Studies

This dissertation provides evidence that performing muscle-strengthening activity may be associated with improvements in activities of daily living pertaining to food access in people with mobility impairments. Increases in muscle strength appear to be associated with improvements in insulin sensitivity, although the quality of evidence in this population is currently mixed, with additional inquiry needed. Although we did not find a statistically significant increase in muscle strength with 12 weeks of Tai Chi and Qigong in women with mobility impairments, a non-significant increase in mean handgrip strength was measured in a small sample of seven women with mobility impairments who completed the intervention arm. Since improvements in strength can be result from minimal stimuli due to improvements in neuromuscular efficiency, greater increases may be expected with a larger sample of participants. This is clinically significant for this population because of the limited access to resources due to the nature of mobility-impairing disabilities and the risk of insulin resistance and diabetes due to the lower physical activity levels that accompany mobility-impairing disabilities (Henson et al., 2016). This makes optimizing strength and motor control clinically important targets for this population.

Implementing physical activity interventions comes with various logistical challenges, with greater challenges present when attempting to accommodate mobility-impairing disabilities. People with mobility impairments are an underrepresented population and the term “mobility-impairing disability” is broad. This results in varying degrees of physical capabilities between participants. In the Tai Chi and Qigong intervention, all except two participants were wheelchair bound. Additionally, the etiology of the mobility-impairing disabilities studied in past research varied, which was why we narrowed our search to exclude mobility-impairing disabilities that were the result of more complex clinical conditions. These differences highlight the need for a clearer definition of people with mobility impairments.

One of the most challenging aspects of carrying out physical activity interventions is controlling for lifestyle factors. The interplay between dietary intake, and many other lifestyle factors, and exercise is difficult to capture due to the lack of supervision outside of interventions. Self-reported dietary intake fails to capture actual or habitual intake and may not provide an accurate depiction of them. Since dietary intake can influence physical activity or exercise performance, inadequate caloric and/or macronutrient intake can negative impact physical performance. Unfortunately, inpatient feeding studies are extremely expensive, burdensome to the participant, and may not capture habitual intake despite capturing actual intake. This is also a concern when implementing self-guided, remote exercise interventions, where exercise adherence is also self-reported, which carries similar limitations. Fortunately, untrained individuals can often improve physical performance under the least ideal of circumstances due to low baseline levels of physical activity. Therefore, remote interventions may still be beneficial for those with limited access, but additional studies are needed, specifically with both supervised and unsupervised protocols.

Strengths & Weaknesses

This research was the first to investigate the impact of remote and self-guided physical activity on mid-life women with mobility impairments. This was guided through preliminary survey research that highlighted a link between specific activities of daily living and muscle-strengthening exercise frequency. Previous research highlighted the importance of muscle strength in metabolic health and activities of daily living, which both tend to be poorer in a mobility impaired population when compared to the general population. Although Chapter 3 provided self-reported muscle-strengthening exercise frequency, measures of strength in Chapter 4 were objectively measured with a handgrip dynamometer, which is a validated method for measuring muscle strength, and which was observed and instructed on via videoconferencing.

There were also some limitations present in this dissertation. Self-reported measures of diet in Chapter 3 and Chapter 4, as with many studies, prevented us from capturing actual or habitual intake, which are variables known to influence physical performance. Self-reported muscle-strengthening exercise frequency in Chapter 3 limited our ability to ascertain the volume, intensity, frequency, and duration of exercise performed as well as exercise selection. The self-guided nature of the study arms in Chapter 4 limited our ability to determine whether interventions were being performed as intended. The small sample size in Chapter 4, combined with the high attrition rate, resulted in a failure to detect significant between and within group differences between 12 weeks of Tai Chi and Qigong and health informational videos. Participants recruited were also English speaking only. Future studies should aim to include under-represented ethnic groups and other language speakers since disabilities impact humans of *all* demographic groups.

Implications

Research Implications

Future research should focus on validating and testing basic exercise programs that reliably improve muscle strength in people with mobility impairments. As with the general population, heterogeneity in physical activity program design variables is a persistent problem in exercise physiology research. Muscle strength can improve with minimal stimuli. However, the heterogeneity makes it difficult to identify the minimum effective dose of physical activity and/or strength training needed to improve muscle strength and reduce metabolic health risk. The ACSM guidelines provide broad guidelines to prescribe exercise; however, they do not adequately address variability in equipment used to perform various types of exercise. Specifically, exercising at home limits the type of equipment that can be purchased, assembled, and utilized. Therefore, home based exercise that can call for modifications in program design variables.

This research has generated additional questions pertaining to the role of supervised remote physical activity interventions compared to self-guided interventions. Videoconferencing applications allow for supervised physical activity to occur remotely and should be utilized. A superiority trial comparing supervised remote physical activity interventions to self-guided physical activity interventions will be an important contribution to the scientific literature. People with physical mobility impairments have limited access to resources due to limits in physical capabilities. Remote and/or virtual physical activity interventions remain and important option for this population since sedentary behavior that accompanies mobility-impairing disabilities is associated with insulin resistance. Identifying the optimal methods for delivering remote physical activity interventions through larger scale clinical trials can help considerably with mitigating metabolic health risk.

Practice Implications

Healthcare providers should continue to recommend increasing physical activity to their patients with physical mobility impairments. Although 12 weeks of self-guided Tai Chi and Qigong failed to improve handgrip strength in mid-life women with mobility impairments, the literature supports the use of meditative movement for improving blood pressure (Yeh et al., 2008). Additionally, in wheelchair users, increasing manual wheelchair movement above baseline can serve as a stimulus to improve muscle strength.

Since access is limited, it is important to develop recommendations that require minimal resources to perform. People with mobility impairments often struggle with basic activities of daily living and contextualizing programs to accommodate them is important. The seated Tai Chi and Qigong used in Chapter 4 is an example of this. As stated in Chapter 4, encouragement from others is beneficial for physical performance. Engagement with an exercise instructor or other exercisers may enhance adherence while maximizing performance. This can vary between individuals, so it is also important to adequately interview patients to determine specific preferences when deciding whether to recommend group or individual exercise.

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APPENDIX A

IRB APPROVAL

ASU Knowledge Enterprise Development

APPROVAL: EXPEDITED REVIEW

Rebecca Lee
EDSON: Research Faculty and Staff
-
Rebecca.E.Lee@asu.edu

Dear Rebecca Lee:

On 10/20/2021 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Seated Tai Chi for Women with Mobility Impairing Disabilities
Investigator:	Rebecca Lee
IRB ID:	STUDY00014499
Category of review:	
Funding:	Name: Arizona State University (ASU)
Grant Title:	
Grant ID:	
Documents Reviewed:	• Center Epidemiologist Studies Depression Scale , Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Feasibility Questionnaire, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Generalized Anxiety Disorder Scale, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Mindful Eating Questionnaire , Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Pittsburgh Sleep Diary, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Protocol, Category: IRB Protocol; • Recruitment Flyer 10.21.21.pdf, Category: Recruitment Materials; • TCQ Consent form 10 25 21 rss FINAL Copy.pdf, Category: Consent Form; • TCQ Pre Screening Questionnaire, Category: Screening forms; • Video and Podcast descriptions, Category: Resource list;

The IRB approved the protocol from 10/20/2021 to 10/19/2022 inclusive. Three weeks before 10/19/2022 you are to submit a completed Continuing Review application and required attachments to request continuing approval or closure.

If continuing review approval is not granted before the expiration date of 10/19/2022 approval of this protocol expires on that date. When consent is appropriate, you must use final, watermarked versions available under the "Documents" tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

REMINDER - All in-person interactions with human subjects require the completion of the ASU Daily Health Check by the ASU members prior to the interaction and the use of face coverings by researchers, research teams and research participants during the interaction. These requirements will minimize risk, protect health and support a safe research environment. These requirements apply both on- and off-campus.

The above change is effective as of July 29th 2021 until further notice and replaces all previously published guidance. Thank you for your continued commitment to ensuring a healthy and productive ASU community.

Sincerely,

IRB Administrator

APPENDIX B

SEARCH TABLE

Database	Search Date	Search String	Filters Used	Number of results	Number of results after removing duplicates	After reviewing for quality articles kept
PubMed	02/15/22	((exercise) AND (glucose) AND (disability)	Clinical Trials RCT	33	33	5
PubMed	02/15/22	((aerobic exercise) AND (glucose) AND (disability)	Clinical Trials RCT	32	2	2
PubMed	02/15/22	((Tai-Chi) AND (glucose)	Clinical Trials RCT	26	26	1
PubMed	02/15/22	(Tai-Chi) AND (glucose) and (disability)	Clinical Trials RCT	0	0	0
PubMed	02/15/22	((resistance exercise) AND (glucose) AND (disability)	Clinical Trials RCT	6	0	0
PubMed	02/15/22	((exercise training) AND (glucose) AND (disability)	Clinical Trials RCT	32	0	0
Academic Search Premiere	03/01/2022	(exercise) AND (glucose) AND (disability) AND	Peer Reviewed	33	30	1

		(Randomized Control Trial)				
Academic Search Premiere	03/01/2022	(aerobic exercise) AND (glucose) AND (disability) AND (Randomized Control Trial)	Peer Reviewed	9	0	0
Academic Search Premiere	03/01/2022	(Resistance exercise) AND (glucose) AND (disability) AND (Randomized Control Trial)	Peer Reviewed	6	0	0
Academic Search Premiere	03/01/2022	(aerobic exercise) AND (glucose) AND (mobility impairment) AND (Randomized Control Trial)	Peer Reviewed	0	0	0
Academic Search Premiere	03/01/2022	(aerobic exercise) AND (glucose) AND (mobility impairment) AND (Randomized Control Trial)	Peer Reviewed	0	0	0
Academic Search Premiere	03/01/2022	(Tai Chi) AND (glucose) AND (disability) AND	Peer Reviewed	1	0	0

		(Randomized Control Trial)				
SportDiscus	03/01/2022	(aerobic exercise) AND (glucose) AND (mobility impairment) AND (Randomized Control Trial)	Peer Reviewed	0	0	0
SportDiscus	03/01/2022	(Resistance exercise) AND (glucose) AND (disability) AND (Randomized Control Trial)	Peer Reviewed	0	0	0
SportDiscus	03/01/2022	(exercise) AND (glucose) AND (disability) AND (randomized control trial)	Peer Reviewed	0	0	0
SportDiscus	03/01/2022	(Resistance exercise) AND (glucose) AND (disability)	Peer Reviewed	2	0	0
SportDiscus	03/01/2022	(exercise) AND (glucose) AND (disability)	Peer Reviewed			
Embase	03/03/2022	(exercise) AND (glucose)	Trials	40	28	1

		AND (disability)				
Embase	03/03/2022	(aerobic exercise) AND (glucose) AND (disability)	Trials	29	0	0
Embase	03/03/2022	((resistance exercise) AND (glucose) AND (disability)	Trials	5	0	0
Embase	03/03/2022	(Tai-Chi) AND (glucose)	Trials	25	6	0

APPENDIX C

DEMOGRAPHIC AND PHYSICAL FUNCTION SURVEY

Demographics and Physical Functioning Survey

* Required

1. What is your first and last name? *

2. What is your date of birth?

Example: January 7, 2019

3. What is the highest level of education you have completed? *

Mark only one oval.

- Did not attend school
- 1st grade
- 2nd grade
- 3rd grade
- 4th grade
- 5th grade
- 6th grade
- 7th grade
- 8th grade
- 9th grade
- 10th grade
- 11th grade
- 12th grade
- Graduated from high school
- 1 year of college
- 2 years of college
- 3 years of college
- Graduated from college
- Some graduate school
- Completed graduate school

4. Relationship Status *

Mark only one oval.

- Now married
- In a domestic partnership or civil union
- Widowed
- Divorced
- Separated
- Single, never married
- Single, but in a relationship with a significant other.

5. What is your race? *

Mark only one oval.

- White or Caucasian
- African American or Black
- American Indian or Alaska Native
- Asian American or Asian
- Pacific Islander
- Middle Eastern
- Multiracial
- Other: ____________________

6. Ethnicity *

Mark only one oval.

- Hispanic or Latino
- Not Hispanic or Latino

7. Do you live in a rural, urban, or suburban residence? *

Mark only one oval.

- Urban
- Rural
- Suburban

8. What best describes your employment situation? *

Mark only one oval.

- Working - Full-Time
- Working Part-Time
- Self Employed
- Temporarily laid off
- Wanting work, but unemployed due to a health related condition
- Full-Time Student
- Retired
- Unemployed
- Prefer not to answer

9. What is your biological sex? *

Mark only one oval.

- Male
- Female
- Prefer not to say

10. What is your gender identity? *

Mark only one oval.

- Woman
- Man
- Transgender
- Non-Binary
- Genderqueer or gender nonconforming
- Other: ______________________

11. Annual Household Income *

Mark only one oval.

- Under $15,000
- Between $15,000 and $29,000
- Between $30,000 and $49,999
- Between $50,000 and $74,999
- Between $100,000 and $150,000
- Over $150,000

12. Number of people supported by household income *

Physical Functioning

13. In general, you would say your health is *

Mark only one oval.

- 1 -Excellent
- 2 - Very good
- 3- Good
- 4- Fair
- 5- Poor

14. Compared to a year ago, how would you rate your health in general now? *

Mark only one oval.

- 1 - Much better than a year ago
- 2 - Somewhat better now than a year ago
- 3 - About the same
- 4 - Somewhat worse than one year ago
- 5 - Much worse now than one year ago

15. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much? *

Check all that apply.

	1 - Yes, limited a lot	2- Yes, limited a little	3 - No, not limited a all
Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports	☐	☐	☐
Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	☐	☐	☐
Lifting or carrying groceries	☐	☐	☐
Climbing several flights of stairs	☐	☐	☐
Climbing ONE flight of stairs	☐	☐	☐
Bending, kneeling, or stooping	☐	☐	☐
Walking SEVERAL blocks	☐	☐	☐
Walking ONE block	☐	☐	☐
Bathing or dressing yourself	☐	☐	☐

16. During the PAST 4 WEEKS, have you had any of the following problems with your work or oth regular daily activities AS A RESULT OF YOUR PHYSICAL HEALTH? *

Check all that apply.

	1- Yes	2- No
Cut down the AMOUNT OF TIME you spent on work or other activities	☐	☐
ACCOMPLISHED LESS than you would like	☐	☐
Were limited in the KIND of work or other activities	☐	☐
Had DIFFICULTY performing the work or other activities (for example, it took extra effort)	☐	☐

17. During the PAST 4 WEEKS, have you had any of the following problems with your work or oth regular daily activities AS A RESULT OF ANY EMOTIONAL PROBLEMS (such as feeling depressed or anxious)? *

Check all that apply.

	1 - Yes	2- No
Cut down the AMOUNT OF TIME you spent on work or other activities	☐	☐
ACCOMPLISHED LESS than you would like	☐	☐
Didn't do work or other activities as carefully as usual	☐	☐

18. During THE PAST 4 WEEKS, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups? *

Mark only one oval.

- 1 - Not at all
- 2 - Slightly
- 3 - Moderately
- 4 - Quite a bit
- 5 - Extremely

19. How much BODILY pain have you had during the PAST 4 WEEKS? *

Mark only one oval.

- 1 - None
- 2 - Very Mild
- 3 - Mild
- 4 - Moderate
- 5 - Severe
- 6 - Very Severe

20. During the PAST 4 WEEKS, how much did PAIN interfere with your normal work (including bo work outside the home and housework)? *

Mark only one oval.

- ⬭ 1 - Not at all
- ⬭ 2 - A little bit
- ⬭ 3 - Moderately
- ⬭ 4 - Quite a bit
- ⬭ 5 - Extremely

21. These questions are about how you feel and how things have been with you during the PAST WEEKS. For each question, please give the one answer that comes closest to the way you ha been feeling. How much of the time during the PAST 4 WEEKS... *

Check all that apply.

	1 - All of the time	2 - Most of the time	3 - A good bit of the time	4 - Some of the time	5 - A little of the time	6 - None of the time
Did you feel full of pep?	☐	☐	☐	☐	☐	☐
Have you been a very nervous person?	☐	☐	☐	☐	☐	☐
Have you felt so down in the dumps that nothing could cheer you up?	☐	☐	☐	☐	☐	☐
Have you felt calm and peaceful?	☐	☐	☐	☐	☐	☐
Did you have a lot of energy?	☐	☐	☐	☐	☐	☐
Have you felt downhearted and blue?	☐	☐	☐	☐	☐	☐
Did you feel worn out?	☐	☐	☐	☐	☐	☐
Have you been a happy person?	☐	☐	☐	☐	☐	☐
Did you feel tired?	☐	☐	☐	☐	☐	☐

22. During the PAST 4 WEEKS, how much of the time has your PHYSICAL HEALTH OR EMOTION/ PROBLEMS interfered with your social activities (like visiting with friends, relatives, etc.)? *

Mark only one oval.

- 1 - All of the time
- 2 - Most of the time
- 3 - Some of the time
- 4 - A little of the time
- 5 - None of the time

23. How TRUE or FALSE is each of the following statements for you. *

Mark only one oval per row.

	1 - Definitely true	2 - Mostly true	3 - Don't know	4 - Mostly false	5 - Definitel false
I seem to get sick a little easier than other people					
I am as healthy as anybody I know					
I expect my health to get worse					
My health is excellent					

24. Do you take any medications (including over-the-counter medications)? *

Mark only one oval.

- Yes
- No

25. If you take medications, please list below or write "none." *

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Google Forms

APPENDIX D

DIETARY SCREENING QUESTIONNAIRE

DIETARY SCREENER QUESTIONNAIRE

These questions are about foods you ate or drank during the past month, that is, the past 30 days. When answering, please include meals and snacks at home, at work or school, in restaurants, and anyplace else.

Mark an ☒ to indicate your answer. To change your answer, completely fill the box for the incorrectly marked answer (■). Then mark an X in the correct one. Your answers are important.

How old are you (in years)?

☐☐☐ years

Are you male or female?

- ☐ Male
- ☐ Female

During the past month, how often did you eat **hot or cold cereals**? *Mark one* ☒.

- ☐ Never → **Go to question 4.**
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

During the past month, what kind of cereal did you usually eat? – *Print cereal.*

[ ]

If there was another kind of cereal that you usually ate during the past month, what kind was it? – *Print cereal, if none leave blank.*

[ ]

During the past month, how often did you have any **milk** (either to drink or on cereal)? Include regular milks, chocolate or other flavored milks, lactose-free milk, buttermilk. Please do **not** include soy milk or small amounts of milk in coffee or tea. *Mark one* ☒.

- ☐ Never → **Go to question 8.**
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2-3 times per day
- ☐ 4-5 times per day
- ☐ 6 or more times per day

During the past month, what kind of milk did you usually drink? *Mark one* ☒.

- ☐ Whole or regular milk
- ☐ 2% fat or reduced-fat milk
- ☐ 1%, ½%, or low-fat milk
- ☐ Fat-free, skim or nonfat milk
- ☐ Soy milk
- ☐ Other kind of milk – *Print milk.*

[ ]

During the past month, how often did you drink **regular soda or pop** that contains sugar? Do **not** include diet soda. *Mark one* ☒.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2-3 times per day
- ☐ 4-5 times per day
- ☐ 6 or more times per day

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9 During the past month, how often did you drink **100% pure fruit juices** such as orange, mango, apple, grape and pineapple juices? Do **not** include fruit-flavored drinks with added sugar or fruit juice you made at home and added sugar to. *Mark one* ☒.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2-3 times per day
- ☐ 4-5 times per day
- ☐ 6 or more times per day

During the past month, how often did you drink coffee or tea that had **sugar** or **honey** added to it? Include coffee and tea you sweetened yourself and presweetened tea and coffee drinks such as Arizona Iced Tea and Frappuccino. Do **not** include artificially sweetened coffee or diet tea.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2-3 times per day
- ☐ 4-5 times per day
- ☐ 6 or more times per day

During the past month, how often did you drink **sweetened** fruit drinks, sports or energy drinks, such as Kool-Aid, lemonade, Hi-C, cranberry drink, Gatorade, Red Bull or Vitamin Water? Include fruit juices you made at home and added sugar to. Do **not** include diet drinks or artificially sweetened drinks.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2-3 times per day
- ☐ 4-5 times per day
- ☐ 6 or more times per day

During the past month, how often did you eat **fruit**? Include fresh, frozen or canned fruit. Do **not** include juices.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

During the past month, how often did you eat a green leafy or lettuce **salad**, with or without other vegetables?

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

14 During the past month, how often did you eat any kind of **fried potatoes**, including french fries, home fries, or hash brown potatoes?

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

● During the past month, how often did you eat any **other kind of potatoes**, such as baked, boiled, mashed potatoes, sweet potatoes, or potato salad?

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

● During the past month, how often did you eat refried beans, baked beans, beans in soup, pork and beans or any other type of cooked dried beans? Do **not** include green beans.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

● During the past month, how often did you eat **brown rice** or other cooked whole grains, such as bulgur, cracked wheat, or millet? Do **not** include white rice.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

● During the past month, not including what you just told me about (green salads, potatoes, cooked dried beans), how often did you eat **other vegetables**?

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

● During the past month, how often did you have Mexican-type **salsa** made with tomato?

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

20 During the past month, how often did you eat **pizza**? Include frozen pizza, fast food pizza, and homemade pizza.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

During the past month, how often did you have **tomato sauces** such as with spagetti or noodles or mixed into foods such as lasagna? Do not include tomato sauce on pizza.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

During the past month, how often did you eat any kind of **cheese**? Include cheese as a snack, cheese on burgers, sandwiches, and cheese in foods such as lasagna, quesadillas, or casseroles. Do **not** include cheese on pizza.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

During the past month, how often did you eat **red meat**, such as beef, pork, ham, or sausage? Do **not** include chicken, turkey or seafood. Include red meat you had in sandwiches, lasagna, stew, and other mixtures. Red meats may also include veal, lamb, and any lunch meats made with these meats.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

During the past month, how often did you eat any **processed meat**, such as bacon, lunch meats, or hot dogs? Include processed meats you had in sandwiches, soups, pizza, casseroles, and other mixtures.
Processed meats are those preserved by smoking, curing, or salting, or by the addition of preservatives. Examples are: ham, bacon, pastrami, salami, sausages, bratwursts, frankfurters, hot dogs, and spam.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

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25 During the past month, how often did you eat **whole grain bread** including toast, rolls and in sandwiches? Whole grain breads include whole wheat, rye, oatmeal and pumpernickel. Do **not** include white bread.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

26 During the past month, how often did you eat **chocolate** or any other types of candy? Do **not** include sugar-free candy.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

During the past month, how often did you eat **doughnuts**, sweet rolls, Danish, muffins, pan dulce, or pop-tarts? Do **not** include sugar-free items.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

During the past month, how often did you eat **cookies, cake, pie or brownies**? Do **not** include sugar-free kinds.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

During the past month, how often did you eat **ice cream or other frozen desserts**? Do **not** include sugar-free kinds.

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

During the past month, how often did you eat **popcorn**?

- ☐ Never
- ☐ 1 time last month
- ☐ 2-3 times last month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

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