University of Wisconsin Milwaukee
UWM Digital Commons

Theses and Dissertations

May 2020

Prescribing Vigorous Intensity Exercise to Older Adults

Taylor Rowley
University of Wisconsin-Milwaukee

Follow this and additional works at: https://dc.uwm.edu/etd

Part of the Kinesiology Commons

Recommended Citation

Rowley, Taylor, "Prescribing Vigorous Intensity Exercise to Older Adults" (2020). *Theses and Dissertations*. 2417.
https://dc.uwm.edu/etd/2417

This Dissertation is brought to you for free and open access by UWM Digital Commons. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of UWM Digital Commons. For more information, please contact open-access@uwm.edu.

PRESCRIBING VIGOROUS INTENSITY EXERCISE TO OLDER ADULTS

by

Taylor Rowley

A Dissertation Submitted in

Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

in Kinesiology

at

The University of Wisconsin

May 2020

ABSTRACT

PRESCRIBING VIGOROUS INTENSITY EXERCISE TO OLDER ADULTS

by

Taylor Rowley

The University of Wisconsin-Milwaukee, 2020
Under the Supervision of Professor Scott Strath, PhD

As the older adult segment of society grow, rates of chronic disease and poor fitness continue to climb. Physical activity (PA) and exercise are effective methods to offset incidence of disease and improve physical fitness. However, despite these known benefits, older adults exhibit low rates of PA engagement. Barriers to PA that are specific to older adults include lack of knowledge and perceived lack of time. Interventions targeting older adults and addressing these barriers by way of behavioral theory implementation are one method to increase PA and physical fitness. Assessment of physical fitness can be challenging for this group, however, as certain methods can be unsafe and are not recommended. Maximal oxygen consumption (VO_{2max}) is a common measure of aerobic fitness and is often used to determine the effectiveness of an exercise intervention. Field tests to estimate VO_{2max} are a practical solution to this dilemma, as they are easy to administer and do not require the participant to work to maximal effort. Still, there are limitations as to the validity and application of these tests.

For VO_{2max} to improve, a certain training intensity threshold needs to be met. Traditional exercise recommendations involve long, continuous bouts of moderate intensity activity. This extended time commitment is a common barrier for many adults. High intensity interval training (HIT) is a protocol that was developed in response to the time constraints associated with traditional exercise. The vigorous intensity and small exercise volume (i.e. alternating between

quick bursts of activity and low intensity recovery periods) allow for participants to improve health and fitness parameters to a similar or greater extent as traditional training, but with a much smaller time commitment. As many of these protocols require maximal or near maximal exertion, and sometimes involve running, a protocol more appropriate for older adults has been developed. High intensity interval walking (HIW) is a type of HIT training that has recently been developed but not studied extensively in older adults. Further, little to no work has been done to investigate the translational effects of HIT or HIW to a community-based setting.

The purpose of this dissertation was to evaluate changes in VO_{2max} and PA levels in older adults by prescribing vigorous intensity exercise. The aims of this dissertation are twofold: 1.) to create and determine the most valid equation to predict VO_{2max} between a series of field-based walking and stepping tests among adults age 18-79 years, and 2.) to determine if older adults' VO_{2max} and PA levels will increase following a theoretically guided, 4-week high intensity interval walking intervention.

A series of eight different walking (n=5) and stepping (n=3) field tests were analyzed to create the highest performing VO_{2max} prediction equations that varied in duration and number of stages. Demographic, anthropometric, and physiological covariates (e.g. heart rate, gait speed, and step cadence) were entered into each model. Final models were then entered into a jackknife validation analysis, and percent bias and root mean square error (RMSE) were assessed. Overall, the tests accounted for ~81% of the variance (R^2) of VO_{2max} and had a RMSE of <4.5 $ml \cdot kg^{-1} \cdot min^{-1}$. The stepping tests outperformed the walking tests by having higher R^2 and lower RMSE values. Collectively though, the difference across the tests were minimal enough that there is flexibility in selecting a test appropriate for various populations.

A 4-week HIW intervention was administered to older adults (age 60-85) to determine its effectiveness in increasing VO_{2max} and time spent in intensities equal or greater to a normal walking speed. Theoretical constructs were implemented to improve adherence and address barriers by addressing self-efficacy for exercise (SE). VO_{2max} did not significantly improve for either the control (CON) or intervention (HIW) group, despite 70% of the HIW group seeing an improvement. Physical activity levels did increase significantly for the HIW group from baseline to post-testing ($p<0.01$), yielding large effect sizes around [0.88]. Further, the changes in PA levels for the HIW group were significantly greater than those in the CON group ($p<0.01$), also yielding large effect sizes around [0.79]. Additionally, SE significantly improved from baseline to post-testing for the HIW group ($p<0.05$) but not the CON group, yielding moderate effect sizes ([0.73] and [0.59], respectively).

The findings from this dissertation support the need to continue to develop and validate field tests to most accurately predict VO_{2max} among diverse populations. Further, this dissertation supports continued research pertaining to large-scale HIW protocols in older adult populations, as it appears to be a feasible option for improving PA and SE. Future studies should continue to examine the lasting effects of HIW interventions to see if it is an activity that individuals will continue to engage in.

© Copyright by Taylor Rowley, 2020
All Rights Reserved

I dedicate this to my parents, Drs. David and Jeanne Wenos, and to my husband, Paul Rowley. Thank you for believing in me even when I did not believe in myself.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ACC	Accelerometer
ES	Effect Size
HIT	High Intensity Interval Training
HIW	High Intensity Interval Walking
HR	Heart Rate
HRR	Heart Rate Reserve
MPA	Moderate Intensity Physical Activity
PA	Physical Activity
RPE	Rating of Perceived Exertion
SE	Self-Efficacy
SEE	Self-Efficacy for Exercise
VO_2max	Maximal Oxygen Consumption
VPA	Vigorous Intensity Physical Activity

ACKNOWLEDGEMENTS

This dissertation would not be possible without the help and support of several people. First and foremost, I would like to thank my committee who has helped guide my research and develop me as an academic. Without your support and commitment to learning, I would not be where I am today. A special thank you to my advisor, Dr. Scott Strath, for your mentorship throughout the years and pushing me to get to the finish line with this project. Under your guidance I have become a stronger researcher and will continue to strive to fill my PA “toolbox”. I believe the agreement was that you would finish building your sailboat by the time I graduated, so I wish you smooth sailing on the Michigan waters. Dr. Swartz, thank you too for your guidance and mentorship in my time at UWM. I especially appreciate your teaching mentorship and believe that many of my teaching strengths are attributed to the time you took with me. You have become one of my greatest role models and I will always think of you when I teach my students that oxygen is the final electron acceptor in the electron transport chain. Chris, I cannot thank you enough for the hours we spent looking over my data, analyzing, and reanalyzing as one does. Your positivity and patience with me were very much appreciated, especially on days when I was on the verge of tears because I couldn’t figure out my SAS codes. Dr. Greenleaf, thank you for always being a bright spot of encouragement on the fourth floor of Enderis. Your dedication to your students was evident from the first day I had class with you. Finally, Dr. Cho, thank you for your willingness to sit on both the comprehensive and dissertation committees of a student you didn’t know very well. Your statistical expertise and methodological input have made this project all the richer.

They say it takes a village, and I am blessed to have a pretty large village backing me up. A HUGE thank you to my friends and colleagues who have believed in and supported me through this intense, somewhat crazy, journey. First, thank you to my PAHRL crew: Dr. Whitney Welch (and Dom and Gracie), Dr. Nicholas Lerma (and Sicilia, Sammy, and Theo), Nathan Tokarek, Autumn Decker (and Jake), Julian Martinez, Saira Talwar, Nikki Woolston, Kristen Deal, Christa Wamsley, Kat O'Connel Valuch, and Nora Miller. My other UWM graduate student friends: Natalie Upson (and Matt), Alex Hayden (and Mikey), Matt Richie, and Carissa Weis (and Winnie). Thank you to our non-graduate school friends who checked in and provided Paul with friendship and support as well when I was busy: Karlee Sweere and Justin Kurtz (and Luke), Emily and John Bowen, Laura and Davis Holt, and Courtney and JJ Strosnider. A special thank you to my new friend and colleague, Dr. Christine Pacewicz, who helped me navigate my first semester as a faculty member at SVSU while completing my dissertation. Again, I feel truly blessed to have had all of you in my corner.

To the College of Health Sciences for funding my graduate student research grant and to the Department of Kinesiology for fostering my love for teaching and learning, thank you. To the Center for Aging and Translational Research for introducing me to a love for older adults and providing me with opportunities and support to pursue a graduate certificate, thank you. To my participants who decided to take time out of their schedule to help support my research, thank you. A special thank you to Saira Talwar and Frankie Moore for assisting me with data collection. All of these research experiences and opportunities are not taken for granted.

Finally, last but certainly not least, I need to thank my family. To the Rowley clan, thank you for sharing your son/brother with me and supporting us as we moved halfway across the country so that I could pursue my dream! To my parents, Jeanne and David, who inspired me to pursue academia in the first place, thank you for your unconditional love and support. I realized early on how lucky I was to have parents who understand academia. I'm honored that, ten years

after my Roanoke graduation, that I can officially call you my colleagues, but know that I will forever be thankful to call you my parents. To my siblings, my brother Parker and his wife Gabrielle, and my sister Haley (and Riley and PepperJack), thank you for always being there to talk and regularly checking in to make sure I was making it. The three of you are about to venture out on your own cross-country adventures, and I look forward to repaying the favor. To my grandfather, Dr. Frank Zeller, thank you for being a voice of wisdom and reassurance in my final months of this journey. And finally- thank you to my amazing husband Paul. There really are no words to describe how much I appreciate your love and support the last five and a half years. Thank you for taking everything in stride and when you unknowingly agreed to what would end up being a seven and a half year-long grad school journey when we met eight and a half years ago. I look forward to moving forward to the next phase of our lives together. “Physiologically speaking,” we have many fun years ahead of us!

Chapter 1: Introduction

Introduction

Older adults, age 65+ years, are among the fastest growing segment of the United States population. The Administration on Aging (2016) reports that as of 2013 older adults comprised 14.1% of the United States population, which was a 28% increase from 2004 (Administration on Aging (AoA), 2016). The Centers for Disease Control predict that within the next 20 years this segment of the population will double in size (Centers for Disease Control and Prevention (CDC), June 10, 2015). This dramatic shift in population demographics, largely affected by the baby boomer generation (CDC, 2015), has created new challenges and new opportunities within the healthcare field. Unfortunately, with increasing age comes an increased prevalence of health problems including but not limited to cardiovascular disease, type 2 diabetes, and declined cognition and functionality (Bauer, Briss, Goodman, & Bowman, 2014). Individually these conditions have a severe impact on health, but as conditions start to compound and comorbidities arise, health spirals downward.

Preventative health measures, specifically lifestyle modifications, can be a cost-effective method of attenuating the rate of declining health. Regular exercise and physical activity (PA) are known to offset chronic disease risk and development and improve physical fitness (American College of Sports Medicine (ACSM), et al., 2009). An additional benefit of PA and exercise, specific to older adults, is improved functionality, which translates into improved activities of daily living and independence (Taylor, 2014). Regrettably, despite the overwhelming body of evidence to support the benefits to older adults, PA and exercise engagement tends to decline with increasing age (Taylor, 2014). While part of this can be attributed to declining health, older adults also identify several unique barriers to PA and exercise. These barriers can include accessibility, cost, and lack of knowledge of how to engage in PA and exercise (Zaleski et al., 2016). Efforts to increase PA and exercise in an older adult population would therefore benefit by designing theoretically guided interventions to address these barriers to promote adherence to PA and exercise programming.

Walking is an accessible, low cost, alternative to other forms of exercise, and is one of the most commonly prescribed exercises (Ogilvie et al., 2007) as it requires minimal to no training or equipment. Promoting walking behavior by way of theoretically guided walking intervention programs has become common for older adults, with some documenting some health improvements for reductions in body weight (Stewart et al., 2005), resting blood pressure (Lee, L., Arthur, & Avis, 2007), and fasting glucose and insulin (Avery, Flynn, van Wersch, Sniehotta, & Trenell, 2012), all with good short-term adherence and positive changes in walking volume (Rothman, 2000; Rowley, Espinoza, Akers, Wenos, & Edwards, 2017). Walking prescriptions have often been shown to produce less benefit compared with other more vigorous exercise programs (Swain & Franklin, 2006), partially due to a higher PA and exercise intensity being linked to added health and fitness benefits (Swain & Franklin, 2006). However, walking prescriptions for older adults are easily modified, and do not just need to be characterized by a "leisurely stroll" intensity. A high intensity, low volume walking protocol, known as High Intensity Interval Walking (HIW), is an example of a modified walking protocol (Nemoto, Gen-no, Masuki, Okazaki, & Nose, 2007). Based on a similar method of training, High Intensity Interval Training (HIT), HIW consists of alternating bouts of increased walking speeds and slower walking speeds. High Intensity Interval Training has shown to produce similar health benefits as traditional, moderate intensity longer duration exercise training. Additionally, HIT or HIW protocols are modifiable, making them appropriate for healthy, diseased, or elderly populations. To date, most of the published HIT literature surrounds cycling or running modalities prescribed to young, healthy, recreationally active adults. Only recently have studies started to focus on more clinical and older adult populations. Consequently, less is known about how the older adult population will respond to a low cost, theoretically guided HIT or HIW intervention.

Purpose

The purpose of this dissertation was to evaluate changes in VO_{2max} and PA levels in older adults by prescribing vigorous intensity exercise. This was be assessed over two different but related studies:

Study 1: The purpose of this study was to create and determine the most valid equation to predict VO_{2max} between a series of field-based walking and stepping tests among adults age 18-79 years.

Study 2: The purpose of this study was to determine if older adults' VO_{2max} will increase following a theoretically guided, 4-week high intensity interval walking intervention. The second purpose of this study was to determine if older adults will increase PA spent in intensities equal or greater than a normal walking speed intensity, post-intervention.

Research Hypotheses

Study 1: It was hypothesized that field-tests with ramped intensity stages are more precise than single stage field tests for non-exercise VO_{2max} prediction equations.

Study 2: It was hypothesized that older adults will experience improvements in VO_{2max} following a theoretically guided, 4-week high intensity interval walking intervention compared to baseline, and to a greater extent than a non-exercise control group. It is also hypothesized that older adults will engage in more PA following the intervention than at baseline and compared to a non-exercise control group.

Assumptions

Assumption 1: Participants were inactive at baseline, defined as not meeting the current ACSM guidelines (150-minutes of moderate or 75-minutes of vigorous of aerobic activity) for aerobic activity (American College of Sports Medicine, 2013).

Assumption 2: Participants were ambulatory and free of any walking devices or any medication that might otherwise affect balance.

Assumption 3: Participants were mentally competent.

Assumption 4: Participants exhibited stable cardiovascular, metabolic, or pulmonary diseases.

Limitations

Results from study 2 are limited to United States older adults, aged 60-85 years.

For safety reasons, submaximal testing procedures were used to estimate maximal oxygen consumption, which is not as valid as clinically supervised maximal graded exercise tests.

Delimitations

The results of this study are restricted to inactive, healthy older adults. Additionally, to ensure participant safety the primary testing method to determine the intensity range for the high intensity walking bouts was a submaximal, prediction test.

Definitions

Healthy- Free of or exhibiting stable cardiovascular, metabolic, or pulmonary diseases.

Older adults- For the sake of this dissertation, older adults are defined as 60-85 years of age.

Physical Activity- Any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level (CDC, 2015).

Moderate Intensity Physical Activity (MPA)- On an absolute scale, physical activity is done at 3.0 to 5.9 times the intensity of rest. On a scale relative to an individual's personal capacity, moderate-intensity physical activity is usually a 5 or 6 on a scale of 0 to 10 (CDC, 2015).

Vigorous Intensity Physical Activity (VPA)- On an absolute scale, physical activity that is done at 6.0 or more times the intensity of rest. On a scale relative to an individual's personal capacity, vigorous-intensity physical activity is usually a 7 or 8 on a scale of 0 to 10 (CDC, 2015).

High Intensity Interval Training- Brief, repeated bursts of relatively intense exercise… [and] periods of rest or low-intensity exercise (Gibala, M. J. & McGee, 2008).

Chapter 2: Review of Literature

Introduction

The Old, Old-Old, and Oldest-Old: Aging in America

The United States is currently facing a dramatic shift in demographics, specifically where the older adult population is concerned. People are living longer due to the modernization of medicine, and improved treatment and care (Centers for Disease Control and Prevention, 2013). As of 2014, men aged 65 were projected to live an additional 18 years, and women were projected to live an additional 20.5 years (U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC), National Center for Chronic Disease Prevention and Health Promotion, Division of Nutrition, Physical Activity and Obesity, Atlanta, GA, 2015). Paired with the large baby boom at the end of World War II, the result is the fastest growing section of the United States population to date (CDC, 2013). Adults aged 65 years or older are anticipated to comprise ~20% of the United States population by 2030 (CDC, 2013), which equates to roughly 72 million older adults (CDC, 2013). This number is expected to continue to grow to approximately 80 million by 2050 (CDC, 2013).

Although people are living longer into old age, quality of health tends to be negatively affected with advancing years. Chronic disease rates are high in older adults, with many older adults exhibiting multiple chronic disease conditions (Barrett & Fiqueiredo, 2009). Heart disease is the leading cause of death for older adults, affecting 27.7% of the population age 65 or older (CDC, 2013). Cancer is the second leading cause of death, affecting 22.1% of the older adult population (CDC, 2013). Unfortunately, poor health into old age has a major negative impact on quality of life. Older adults affected by chronic disease are at an increased risk for declined ability to engage in instrumental activities of daily living (i.e. maintaining a household independently financial affairs) and/or activities of daily living (i.e. bathing or feeding oneself). Consequently, this health decline is highlighted by loss of independence, mobility, and overall functionality (CDC, 2013; Cohen-Mansfield et al., 2013).

The combination of longer life spans and a trend of declining health and function have had a serious impact on health care costs and economic structure of the United States. The cost of medical care for an individual 65 years or older is three-to-five times greater than those younger than 65 years of age (CDC, 2013). Additionally, Medicare spending is projected to jump to $903 billion in 2020, from $555 billion in 2011 (CDC, 2013). Breaking down health care costs specific to older adults, 95% of costs for older adults goes towards treating chronic disease conditions (CDC, 2013). This presents a major public health issue for the 21st Century. Fortunately, chronic disease and functional decline, even in old age, can be attenuated or prevented with engagement in regular physical activity (PA).

This literature review is set up in two parts. Part 1 will provide a general overview of PA and older adults. First, this section will discuss the effects of moderate and vigorous intensity PA on health and fitness. Next, it will highlight the importance of proper fitness assessment specific to older adults. Finally, it will discuss prevalence of PA within the older adult population, barriers unique to that population, and the benefits of theory-guided interventions to promote walking behavior. Part 2 will specifically discuss high intensity interval training (HIT), including the benefits of HIT and how it can be modified for use in older adult populations. The intent of this review is to identify knowledge gaps in the scientific literature and provide support for the proposed dissertation studies that follow this review.

Part One: Physical Activity and Older Adults

Defining Physical Activity

Physical activity is defined "any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level", where exercise is defined as "a subcategory of PA that is planned, structured, repetitive, and purposive in the sense that the improvement or maintenance of one or more components of physical fitness is the objective," (CDC, 2015). Physical activity can be described using the FITT principle (ACSM, 2013) which stands for Frequency, Intensity, Time, and Type. For the sake of this review, we will focus on the FITT principle as it pertains to aerobic activity.

- *Frequency* is "the number of times an exercise or activity is performed… generally expressed in sessions, episodes, or bouts per week," (CDC, 2015). The American College of Sports Medicine (ACSM) recommend 5 days of moderate intensity PA or 3 days of vigorous intensity PA per week (American College of Sports Medicine, 2013).
- *Intensity* "refers to how much work is being performed or the magnitude of the effort required to perform an activity or exercise," (CDC, 2015). Intensity can be absolute, which is the "amount of energy used by the body per minute of activity," or relative to the individual, which is "the level of effort required by a person to do an activity," (CDC, 2015). A common unit to describe absolute intensity is the metabolic equivalent (MET). One Met is equivalent to the amount of oxygen consumed while at rest and is equal to 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$. Relative intensities can be described as a percentage of maximal oxygen consumption (VO_{2max}) relative to the individual's body mass ($ml \cdot kg^{-1} \cdot min^{-1}$), or a percentage of maximal heart rate (HR_{max}). Further, intensity can be broken down into light (LPA), moderate (MPA), or vigorous (VPA) physical activity. Light intensity PA

falls between 2-<3 METS, MPA falls between 3-<6 METS, and VPA falls between 6-<8.8 METS (ACSM, 2013). For the sake of this review, MPA will be described as 50-<70% HR_{max}, and VPA will be described as 70-<90% HR_{max}.

- *Time* refers to the duration of the activity. The ACSM recommends 150 minutes of MPA or 75 minutes of VPA (ACSM, 2013) for health benefits. For MPA this equates to 30-minutes, 5-days per week, and for VPA this equates to 25-minutes, 3-days per week (ACSM, 2013).
- The *type* of activity refers to the modality of the activity, such as walking, running, cycling, etc.
- Frequency, intensity, and duration can be altered based on the goal of the PA or exercise program. The product of these three variables is known as the *volume* of activity (ACSM, 2013).

Benefits of Physical Activity and Exercise

Several dimensions of health and wellness benefit from regular PA and exercise, with the first documented reports surfacing in the early 1950’s from the landmark London Transport Study by Jeremiah Morris and colleagues (Morris, Heady, Raffle, Roberts, & Parks, 1953). Morris et al., (1953) reported that men who were employed in more physically active jobs (i.e. bus conductors with regular walking) had a lower incidence of coronary heart disease compared to men in more sedentary roles (i.e. bus drivers with high levels of sitting each day) (Morris et al., 1953). This finding influenced a wave of research that focused on the health and fitness benefits of regular PA. Activity intensity largely determines the magnitude of physiological adaptation, meaning a certain intensity threshold must be met to elicit certain physiological adaptations, or physiological benefit (Kemi & Wisloff, 2010). Moderate and vigorous intensity levels are understood to be the most effective for these physiological changes, and there is ample evidence to suggest that the cardio-protective effects of exercise will increase with these levels of exercise intensity (Haskell et al., 2007; Lee, I. M., Sesso, Oguma, & Paffenbarger, 2003; Manson et al., 2002; Tanasescu et al., 2002).

Physical Activity and Cardiovascular Disease

Cardiovascular disease (CVD) refers to several conditions that affect the function or structure of the heart (ACSM, 2013). These conditions include, but are not limited to: coronary artery disease, heart attack, heart failure, arrhythmias, hypertension, and congenital heart disease (ACSM, 2013). Approximately half of the United States adult population exhibit a risk factor for CVD, and as of 2014 one-in-three adult deaths were attributed to CVD (Mozaffarian et al., 2015). Cardiovascular disease has been linked to several modifiable lifestyle risk factors, including poor diet, lack of PA, obesity, and alcohol and tobacco use (Mozaffarian et al., 2015). Among adults age 60-79 years, 69.1% of men and 67.9% of women have CVD (Mozaffarian et al., 2015). This number increases in the 80+ population, where 84.7% of men and 85.9% of women have CVD (Mozaffarian et al., 2015). Additionally, hypertension rates for adults age 65-74 years is 62% for men and 67.8% in women. As seen with CVD trends, this percentage increases with the older age group; 76.4% of men and 79.9% of women age 75 and older have hypertension (Mozaffarian et al., 2015). Thus, the average age to experience one's first heart attack is 65.0 years for men and 71.8 years for women (Mozaffarian et al., 2015). Treatment for these conditions are costly, and annual costs associated with treatment, medication, and absence from work due to CVD sums to approximately $200 billion (CDC, 2017).

Comparing the Effects of MPA and VPA on CVD

Traditionally, MPA has been prescribed as a method to improve health and fitness profiles. A meta-analysis by Sattelmair et al., (2011) investigated the dose-response between MPA and CVD risk. After reviewing and analyzing 33 primary articles, they reported that individuals who completed 150-minutes of MPA per week had a 14% lower risk of CVD development (RR: 0.86, CI: 0.77-0.96) compared to individuals who did not engage in leisure-time MPA (referent: 1.00). The risk was even lower (20%) for individuals who completed 300-minutes of MPA per week (RR: 0.80, CI: 0.74-0.88) (Sattelmair et al., 2011). MPA is an effective intensity for reducing CVD risk, however as exercise volume increases (i.e. 300-minutes of MPA per week) the time commitment increases as well. Due to the higher intensity of VPA, the exercise volume is less.

There are several epidemiological studies that directly compare the effects of MPA and VPA on CVD risk. Lee et al., (2003) reported significantly lower risk for CVD (p=0.03, trend) in older adult males who engaged in vigorous intensity PA (relative risk (RR): 0.75, confidence interval (CI): 0.58, 0.96) compared to no activity or light intensity activity (referent; RR: 1.00) or moderate intensity PA (RR: 0.98, CI: 0.80, 1.20), after a 7-year follow up (Lee et al., 2003). Moderate intensity activity still reduced risk of CVD, but not to the same extent as vigorous intensity activity. These results reflect similar findings to Tanasescu et al., (2002) who reported significantly lower risk of developing CVD (p=0.02, trend) over 12 years in men who engaged in moderate (RR: 0.94, CI: 0.83-1.04) and vigorous (RR: 0.83, CI: 0.72-0.97) intensity PA compared to light intensity (referent, RR: 1.00), regardless of activity volume (Tanasescu et al., 2002). Finally, a study by Franco et al., (2005) reported that years lived without CVD were higher for men and women aged 50 and older, who engaged in moderate intensity (1.1 years, men; 1.3 years, women) and high intensity (3.2 years, men; 3.3 years, women) exercise (Franco et al., 2005). These studies show a clear advantage for engaging in VPA over MPA in terms of CVD risk.

Summary: Physical Activity and Cardiovascular Disease

Cardiovascular disease affects a large portion of the adult population, and greater than 50% of the population aged 65 years and older. Many adults exhibit at least one risk factor for CVD, many of which are lifestyle related. Routine PA and exercise have a positive impact on CVD, with higher intensities of PA having the most dramatic impact on CVD risk in both disease rate and additional years lived.

Physical Activity and Metabolic Disorders

For the sake of this review, "metabolic disorders" will be generalized to Type 2 Diabetes Mellitus (T2DM)/insulin resistance and obesity. Currently, more than 84 million and 30 million US adults have prediabetes and diabetes, respectively (CDC, 2017). Adults with prediabetes account for more than 1/3 of the adult US population, most of whom are unaware that they are at risk for developing T2DM (CDC, 2017). Diabetes rates have tripled in recent years due to increased obesity rates and the rapidly increasing older adult section of the US population (CDC, 2017). Prediabetes is defined as a fasting blood glucose level of 100-125 $mg \cdot Dl^{-1}$, and diabetes is defined as a fasting blood glucose level of 126 $mg \cdot Dl^{-1}$ or higher (CDC, 2017). Medical costs associated with treatment and care for T2DM total $245 billion annually (CDC, 2017). Risk factors for T2DM include being older than 45 years, being physically inactive, and being overweight/obese (CDC, 2017). Besides increased age, physical inactivity and excess weight are both risk factors that can be improved through lifestyle modifications to decrease the risk of developing T2DM.

Obesity levels in the United States are at epidemic proportions, with greater than 1/3 of the adult population being obese (Ogden, Carroll, Fryar, & Flegal, 2015). Compared to younger populations, middle aged and older adult populations have higher rates of obesity (32.3%, 40.2%, and 37.0%, respectively) (Ogden et al., 2015). In 2008, annual medical costs associated with obesity was calculated to be $147 billion (Ogden et al., 2015).

Physical Activity and Improved Insulin Resistance and Glucose Control

Insulin resistance and glucose control are improved with habitual PA. A systematic review by Jeon, Lokken, Hu, and van Dam (2007) evaluated the relationship between MPA and risk of T2DM. They reviewed 10 epidemiological studies that studied adults ranging in age from 35 to 75 years. Jeon and colleagues found that people who engage in regular weekly MPA had an almost 30% lower risk of developing T2DM (RR: 0.69, CI: 0.58-0.83) compared to sedentary behavior (referent: 1.00). There was a similarly reduced risk for individuals who engaged in >2.5 hours of brisk walking per week (RR: 0.70, CI: 0.58-0.83) compared to those who did very little or no walking activity (referent: 1.00) (Jeon, Lokken, Hu, & van Dam, 2007).

Alternatively, an 8-year longitudinal study by Manson et al., (1991) reported a significant reduction (on average) in T2DM risk for women who engaged in at least one day of VPA per week (RR=0.67; $p<0.0001$) compared to women who completed no VPA. Of note, the lowest risk of developing T2DM was not in the group that completed the most days per week of VPA (4+ days, RR=0.63, CI= 0.53, 0.75), but the group that completed 2 days of VPA per week (RR=0.55, CI=0.44,0.68) (Manson et al., 1991). This exercise volume is dramatically lower than that presented by Jeon and colleagues (2007) and yields a higher risk reduction (45% lower risk of developing T2DM). Kirwan, Kohrt, Wojta, Bourey, and Holloszy (1993) also described improvements in plasma insulin concentration after a 9-month exercise intervention that progressed to a vigorous intensity (80-85% HR_{max}) in adults aged 60-70 years. Participants displayed significantly lower plasma insulin concentrations under hyperglycemic conditions ($p<0.05$) in addition to improved insulin action as determined by glucose disposal rate to insulin concentration action (24 ± 5 to 30 ± 5, $p<0.05$) (Kirwan, Kohrt, Wojta, Bourey, & Holloszy, 1993). Similarly, Finucane et al., (2009) reported significantly lower 120-minute insulin levels following 12-weeks of an aerobic exercise intervention prescribing 1-hour exercise sessions, 3-days per week at an intensity that equated 70% maximal watts by the end of the intervention (344.0 (215.5, 549) to 270 (149.5, 421); $p=0.02$) (Finucane et al., 2010). It appears that VPA is more effective at reducing incidence of T2DM and improving insulin resistance.

Perhaps one of the more compelling studies to support this is by DiPietro, Dziura, Yeckel, & Neufer (2006) compared the effects of different exercise intensities on insulin-sensitivity. Participants completed a 9-month exercise intervention in 25 women, with a mean age of 73 years. Participants were randomized into one of three groups, light-, moderate-, and high-intensity exercise groups, which met 4 days per week. The light-intensity group was viewed as a control group and was prescribed 45-minute sessions that included exercises such as stretching, TheraBand's, balance boards, etc., that coincided with an intensity of 50% VO_{2max}. The moderate-intensity (65% VO_{2max}) and high-intensity (80% VO_{2max}) exercise groups were equated for energy expenditure (300 kcals/session). Therefore, exercise sessions lasted 55 and 65 minutes, respectively. Post testing revealed that glucose utilization improved by 21% from baseline in the high intensity group ($p=0.02$), but not in the other two groups (DiPietro, Dziura, Yeckel, & Neufer, 2006). Although, these results differ slightly from those of Bell, Harber, Murray, Courneya, & Rodgers (2010) who reported similar improvements in fasting blood glucose and 2-hour glucose (main effect, $p<0.05$) for three different groups of varied intensities (fitness = 70% VO_{2peak}, 10,000 steps per day, and control). Perhaps the fact that total energy expenditure was matched between the activity groups resulted in similar levels of improvement making it difficult to determine if the change resulted from increased energy expenditure or as a result of decreased caloric intake (Bell, Harber, Murray, Courneya, & Rodgers, 2010).

Improved Body Size and Composition

Changing body size and composition is largely impacted by dietary habits but increasing energy expenditure by way of PA and exercise is also fundamental to seeing changes. A 10-year longitudinal study by Littmann, Kristal, and White (2005) investigated weight changes based on average weekly PA levels in middle aged adults (Littman, Kristal, & White, 2005). They found that obese men and women who completed 75-100 minutes of fast walking per week gained less weight over the 10-years than non-walkers (+5 and +9 pounds, respectively). Similarly, results from Larose et al., (2011) reported significant improvements in body mass (-2.6 kg, $p=0.008$) following an aerobic training program (3 days per week, 75% HR_{max}, 45 minutes per session) compared to the control group, in Type 2 diabetics, age 39-70 years. When energy expenditure and calorie restriction are controlled for, there are similar results between moderate and vigorous intensities (Littman et al., 2005).

A study by Nicklas et al., (2009) sought to determine if aerobic intensity affects the loss of abdominal fat of equal energy deficient women with abdominal obesity over 20-weeks. Participants were randomized into three groups, a caloric (kcal) deficit group (~400 kcals/day), a caloric deficit plus moderate intensity exercise group, and a caloric deficit plus vigorous intensity exercise group. The moderate intensity group exercised 3 days per week, walking on a treadmill at an intensity of 45-50% HRR, and progressed from 20 to 55 minutes over the 20-weeks. The vigorous intensity group also exercised 3 days per week, but at an intensity of 70-75% HRR, and progressed from 10 to 30 minutes over the 20-weeks. Post testing revealed that all three groups experienced similar significant decreases in body composition and fat distribution variables ($p<0.0001$). The exercise groups, however, retained more lean muscle tissue than the caloric deficient group alone (Nicklas et al., 2009). These results mirror those of Bell et al., (2010) who reported similar improvements in body mass and waist circumference among the fitness (4 days per week, 70% VO_{2peak}, 43-minute sessions) and walking (10,000 steps per day) groups, where total energy expenditure was matched (Bell et al., 2010).

Summary: Physical Activity and Metabolic Disorders

Older adults exhibit higher rates of T2DM and obesity compared to younger populations. The medical costs associated with treatment and care for these conditions is vast. Physical activity and exercise are lifestyle behaviors that can greatly reduce or prevent these conditions. Moderate and vigorous intensities of PA are instrumental in this reduction/prevention. However, when comparing the two, vigorous intensity PA is more effective in promoting insulin sensitivity, as well as increasing daily caloric expenditure for weight maintenance. This is especially beneficial due to the link between obesity and T2DM, and should be considered when promoting the health benefits of PA.

Physical Activity and Fitness

A key adaptation and benefit of regular aerobic exercise is improved VO_{2max}, which corresponds to increased physical fitness levels. Higher levels of cardiorespiratory fitness are also linked to a decreased relative risk for mortality and CVD. Specifically, a 1 MET increase in VO_{2max} is shown to decrease risk of all-cause mortality by 13% and CVD risk by 15% (Kodama et al., 2009). Healthy older adults have been reported to have VO_{2max} values ranging from ~12 $ml \cdot kg^{-1} \cdot min^{-1}$ to ~30 $ml \cdot kg^{-1} \cdot min^{-1}$ (Simonsick, Fan, & Fleg, 2006), whereas for older adults with functional declines it is not unheard of to have a VO_{2max} that is lower than 12 $ml \cdot kg^{-1} \cdot min^{-1}$ (Church et al., 2008). Taylor et al., (2014) reported that regular PA and exercise delays the onset of functional limitation and decline and reduces risk of functional limitation by 30-50% (Taylor, 2014). While older adults are generally not concerned with high levels of physical fitness for performance purposes, they are concerned with maintaining high enough fitness levels to carry out activities of daily living (ADL). Tak, Kuiper, Chorus, Hopman-Rock, (2013) reported that medium to high activity levels decreased risk of basic ADL disability by 45%. This has massive implications for older adult independence and successful aging (Tak, Kuiper, Chorus, & Hopman-Rock, 2013).

It has been established that with every decade of age, VO_{2max} decreases ~10% (Hagberg, 1987). Physical activity can offset this decline by as much as 50% (Hagberg, 1987), and even increase VO_{2max} levels. Activity intensity is a primary factor in determining changes in VO_{2max}. Several studies report the effects of moderate intensity PA on changes in VO_{2max}. A meta-analysis by Huang, Gibson, Tran, and Osness (2005) found that training at an intensity of 60-70% VO_{2max} resulted in greater improvements in VO_{2max} for older adults, than other intensities. Specifically, training at greater than 60% VO_{2max} can improve cardiorespiratory fitness on average by 16.3% compared to a control group, or an increase of 3.78 ± 0.28 $ml \cdot kg^{-1} \cdot min^{-1}$ ($p<0.001$) (Huang, Gibson, Tran, & Osness, 2005).

Effect of Moderate Intensity PA on VO_{2max}

A 6-month intervention by Bell et al., (2010) investigated the effects of a higher intensity fitness intervention compared to a 10,000-step walking intervention, and a control group. Adults, age 49 ± 11 years were randomized to one of the three groups. The fitness group (n=40) completed 43-minute sessions, 4 days per week, at 70% VO_{2peak}. The walking intervention was prescribed a daily goal of 10,000 steps per day. Total energy expenditure was matched between the two groups. Between the groups, the fitness group was the only group that experienced a significant, 9% increase in VO_{2max} (24.9±5.4 to 27.2±6.4 $ml \cdot kg^{-1} \cdot min^{-1}$; $p<0.05$) (Bell et al., 2010). Setting a step goal of 10,000 steps per day likely increased PA levels, but it was not enough to elicit changes in fitness level. Similarly, a study by Finucane et al., (2010) investigated the effects of a 12-week moderate intensity exercise intervention on maximal work capacity. Ninety-six adults, average age 71.4 years, were randomly assigned to the control group or exercise intervention group. Participants in the exercise group were prescribed 1-hour exercise sessions, 3-days per week, at an intensity that progressed from 50 to 70% maximal power output (watts, W_{max}). The fitness group experienced a significantly higher ($p=0.012$) 16.5% increase in W_{max} compared to the control group (Intervention, 143.9 ± 48.9 W to 167.7 ± 49.7 W versus Control, 158.8 ± 61.1 W to 160.6 ± 53.8 W) (Finucane et al., 2010). While this was not a direct measure of fitness, studies have shown that peak power output is strongly linked to VO_{2max} (Sartor et al., 2013). Clearly, for improving aerobic fitness, a higher intensity level is necessary to elicit improvements.

Effect of Vigorous Intensity PA on VO_{2max}

There are several studies that report the effects of vigorous intensity PA on changes in VO_{2max}. Martin and Kauwell, (1990) compared the benefits of Continuous Assistive-Passive

Exercise (CAPE), which was advertised as a series of stretches and exercises that provided the same benefits as vigorous intensity exercise, to traditional vigorous intensity cycling. Forty-three postmenopausal women, age 50+ years, were randomized into a control (n=14; mean age ± SD, 60.6 ± 7.4), cycle ergometer (n=14, 58.6 ± 4.5), and CAPE (n=15, 58.7 ± 6.3 years) group, for 12-weeks. Continuous Assistive-Passive Exercises were completed twice a week, for 60-minutes. The cycle ergometer group completed 30-minutes of cycle training, two days per week, at an intensity corresponding to 70-85% maximal heart rate (HR_{max}). The CAPE group did not exhibit any significant changes in VO_{2max}, but the cycle intervention group did increase VO_{2max} values by 10.6% (17.9 ± 2.5 to 19.8 ± 2.7 $ml \cdot kg^{-1} \cdot min^{-1}$, $p<0.05$) (Martin & Kauwell, 1990). A study by Jessup, Lowenthal, Pollock, and Turner (1998) intervened on 21 men and women, age 68.5 ± 4.7 years, randomized to either a control group or aerobic intervention. Individuals in the aerobic intervention group were prescribed treadmill and stair-climbing exercises 3 days per week for 16-weeks, which started at 50% VO_{2max} for 25 minutes and progressed to 85% VO_{2max} for 45 minutes over the course of the intervention. Compared to the control group ($p=0.001$), the intervention group improved VO_{2max} by 14% (21.3 ± 4.4 to 24.3 ± 4.5 $ml \cdot kg^{-1} \cdot min^{-1}$), which was significant from baseline ($p<0.05$) (Jessup, Lowenthal, Pollock, & Turner, 1998). Likely, this improvement was greater than the results of Martin et al., (1990) because of the higher weekly frequency.

Another study by Kirwan et al., (1993) investigated the effects of a 9-month endurance exercise intervention on health parameters in 12 adult men and women, age 60-70 years. Participants alternated between walking or jogging and stationary cycling or rowing, for 45-minute sessions, 4-days per week. The intensity increased from 60-70% HR_{max} to 80-85% HR_{max} by the final 3-months of the intervention. VO_{2max} increased significantly, by 23%, overall. Men increased VO_{2max} from 28.2 ± 2.0 to 35.8 ± 3.9 $ml \cdot kg^{-1} \cdot min^{-1}$ (p<0.05), and women from 21.7 ± 0.4 to 26.5 ± 0.8 $ml \cdot kg^{-1} \cdot min^{-1}$ (p<0.05) (Kirwan et al., 1993).

Morton et al., (2010) compared the effects of a 7-week, supervised walking program on health parameters, including VO_{2max}, in Type 2 Diabetics to a control condition. Participants were randomized into the walking group (mean age 61 ± 10 years) and the control group (63 ± 9 years). The walking group engaged in 4 sessions per week, that ranged from 25-55 minutes and 70-80% HR_{max}, over the course of the intervention. The protocol varied throughout the week, incorporating some interval and some consecutive walking training. Speed and grade were manipulated throughout, to ensure the correct intensity was achieved. Post testing revealed that the walking group significantly increased VO_{2max} from baseline (26.9±4.9 to 28.3 ± 5.5 $ml \cdot kg^{-1} \cdot min^{-1}$, p<0.05) by 5.2% and compared to the control group (28.7 ± 8.3 to 27.9 ± 7.4 $ml \cdot kg^{-1} \cdot min^{-1}$, p<0.05), who experienced a decrease in VO_{2max} (Morton, West, Stephens, Bain, & Bracken, 2010).

Comparing Effects of Moderate and Vigorous Intensity PA

Some studies have directly compared moderate intensity and vigorous intensity interventions to determine changes in VO_{2max}. A study by Braith, Pollock, Lowenthal, Graves, and Limacher, (1994) investigated the effects of moderate intensity and high intensity exercise interventions compared to a control group, in adults age 60-79 years (Braith, Pollock, Lowenthal, Graves, & Limacher, 1994). This was a ramped, 6-month study that started participants in the moderate and high intensity groups at 50% heart rate reserve (HRR) to 70% HRR, and 20- to 40-minutes, within the first 8-weeks. For the remaining duration of the intervention, the moderate intensity intervention group maintained an intensity of 70% HRR for 45-minute sessions, and the high intensity training group maintained 80-85% HRR for 35-minute sessions. Post-testing revealed that both groups experienced significant increases in VO_{2max} across the 6-months. The moderate intensity group increased VO_{2max} from baseline (25±6 ml·kg^{-1}·min^{-1}) to 3-months (28±6 ml·kg^{-1}·min^{-1}; p<0.05), and from 3-months to 6-months (29±6 ml·kg^{-1}·min^{-1}; p<0.05), resulting in a 16% increase from pre-to-post. The high intensity group increased VO_{2max} from baseline (26±6 ml·kg^{-1}·min^{-1}) to 3-months (29±7 ml·kg^{-1}·min^{-1}; p<0.05), and from 3-months to 6-months (33±6 ml·kg^{-1}·min^{-1}; p<0.05), resulting in a 26% increase from pre-to-post. Both groups had significantly higher VO_{2max} values at 6-months compared to the control group (p<0.05) (Braith et al., 1994).

A second study by Nicklas et al., (2009) investigated the effects of a 20-week exercise intervention in postmenopausal women, ages 50-70 years (Nicklas et al., 2009). The primary outcome was abdominal obesity, with a secondary outcome being changes in VO_{2max}. Participants were randomized to one of three groups: a caloric deficient group (~400 kcals/day; baseline VO_{2max}: 20.6 ± 2.9 ml·kg^{-1}·min^{-1}), a moderate intensity exercise intervention plus caloric deficient group (baseline VO_{2max}: 21.5 ± 3.2 ml·kg^{-1}·min^{-1}), and a vigorous intensity exercise intervention plus caloric deficient group (baseline VO_{2max}: 20.3 ± 3.7 ml·kg^{-1}·min^{-1}). Participants in the moderate intensity group completed 3 days of training per week, on a treadmill at an intensity of 45-55% HRR and progressed from 20/25 minutes to 55 minutes per session. The vigorous intensity group also completed 3 days of training per week, on a treadmill at an intensity of 70-75% HRR and progressed from 10/15 minutes per session to 30 minutes per session. Post testing revealed that the vigorous intensity group experienced the greatest increase in VO_{2max} compared to the other two groups (high intensity: 24.2 ± 27.6%; caloric deficient: 9.6± 11.2%, moderate intensity group: 12.7± 12.7%) (Nicklas et al., 2009). It is likely that the changes experienced in the caloric deficient and moderate intensity groups are largely impacted by changes in weight (Nicklas et al., 2009), although this is likely more the case in the caloric deficient group than the moderate intensity group.

Summary: Physical Activity and Fitness

Higher VO_{2max} values are associated with high cardiorespiratory fitness and a decreased risk for cardiovascular disease and mortality. Older adults, who are an increased risk for CVD and mortality, exhibit lower VO_{2max} values with increasing age. Moderate and vigorous intensity PA have both been shown to be effective in increasing VO_{2max} levels in older adults, and it is widely accepted that intensity of the activity is linked to the degree of change in VO_{2max} values. Vigorous intensity PA has been shown to increase VO_{2max} to a greater extent than moderate intensity exercise and should be considered when prescribing PA to older adults.

<u>Assessing Maximal Oxygen Consumption</u>

Maximal oxygen consumption assessment is a chief indicator of health and fitness. A graded exercise test (GXT) combined with open circuit spirometry is the standard method of measuring VO_{2max}. Standard GXT protocol, performed on a treadmill or cycle ergometer, is to incrementally increase intensity until the participant achieves maximal effort. A metabolic cart is required for open circuit spirometry assessment, a method of indirect calorimetry where air is inspired from the atmosphere, and the expired air that results is analyzed to determine oxygen utilization (Oxford University Press, 2007). Metabolic carts and their accessories are expensive to obtain and maintain, as are treadmills and cycle ergometers.

Economic factors aside, VO_{2max} testing is not always a safe option for certain populations, such as the elderly or those with increased risk of experiencing a cardiac event. There are several criteria from the exercise test that determine if an individual has truly reached maximal levels, which are: a plateau less than 2.1 $ml \cdot kg^{-1} \cdot min^{-1}$ between two stages, a respiratory exchange ratio greater than 1.1, a heart rate within 10-12 bpm of age predicted maximal heart rate (220-age), and a rating of perceived exertion greater than 18 (Church et al., 2008). Older adults might not have the capacity to meet all the VO_{2max} criteria, as evidenced by Church et al., (2008) who reported that most participants (low functioning, older adults, 74.7 ± 3.4 years) were unable to achieve high enough respiratory exchange rate, rating of perceived exertion, and age-predicted heart rate levels (Church et al., 2008). This led researchers to suggest that alternative methods of estimating VO_{2max}, such as submaximal testing, in this population be utilized (Church et al., 2008).

Estimating Maximal Oxygen Consumption

There are several submaximal and non-exercise methods to predict VO_{2max} with varying levels of precision and reliability. Determining which test to use depends on the reason for obtaining the VO_{2max} value, and there are multiple factors that need to be considered when selecting the most appropriate test. These prediction methods include treadmill, cycle, and step-based tests, over-ground walking and running tests (field tests), and non-exercise prediction equations. Tests vary in duration, which variables are collected (i.e. heart rate, walking speed, etc.), what information is entered into the predictive equation, required equipment, and the number of activity stages. Commonalities to all tests, are that they are submaximal, and they use a variety of physiological and non-physiological inputs to estimate a person's maximal oxygen consumption, or a person's $VO_{2maz.}$

When creating a VO_{2max} prediction equation, or deciding which equation to use, several factors should be considered as outlined by Sartor and colleagues in their 2013 review of submaximal field-testing methods. First, the population for which the test was created should match the population receiving the test (Sartor et al., 2013). For example, a test that is developed for younger adult populations might not capture different physiological responses in older adults that impact oxygen uptake. Similarly, tests developed in healthy populations might not be appropriate for clinical populations. Balance and cognition limitations, airway limitations, and safety of the test should be always be considered when selecting a submaximal test (Sartor et al., 2013). Older adults, for example, who might have balance issues could be at an increased fall risk if asked to walk on a treadmill or run. A better method might be a cycle based submaximal test that eliminates fall risk (Sartor et al., 2013). Alternatively, issues with local muscle fatigue could also be a barrier for individuals with poor musculature which could result in an under predicted VO_{2max} value (Sartor et al., 2013).

The level of accuracy and precision of the prediction equation should also be considered, especially if the VO_{2max} value is being used for research purposes (Sartor et al., 2013). Reliability of these equations vary, with more popular tests like the Cooper 12-min run or the Rockport 1-mile walk reporting R-values of 0.90 and 0.88 compared to measured VO_{2max}, respectively (Akalan, Robergs, & Kravitz, 2008; Kline et al., 1987). Error of the estimate can affect the ability to detect changes in VO_{2max} over time. Error estimates vary among submaximal prediction equations, but many equations possess an error of ~4.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (Akalan et al., 2008; Kline et al., 1987). Too large of an error can make it difficult to detect true change in a variable (i.e. VO_{2max}), which can complicate interpretation of results. Unfortunately, a limitation within this body of literature is a lack of reporting reliability, accuracy, and precision measures of $V0_{2max}$ prediction equations (Akalan et al., 2008). Validation of $V0_{2max}$ equations also tends to be underreported (Akalan et al., 2008).

While accuracy and precision are important measures to consider, the feasibility of delivering the submaximal test is also important to consider. This includes factors such as testing environment (i.e. indoor vs outdoor testing), testing parameters (i.e. heart rate, VO_2, or rating of perceived exertion), and required levels of exertion (Sartor et al., 2013). For example, a cycle test created by Akalan et al., (2008) reports an R-value of 0.867 compared to measured VO_{2max} ($p<0.0001$) and an error of 4.234 $ml \cdot kg^{-1} \cdot min^{-1}$ (Akalan et al., 2008), which are comparable to R-values and error rates of other submaximal prediction equations (Kline et al., 1987). However, when examining the measures required for the prediction equation, the feasibility of administering this test is called into question. First, to create an individualized testing protocol, participants were required to complete two separate cycle tests, the first test determining the rate of increase for wattage that is used in the second cycle test (Akalan et al., 2008). Second, the regression equation requires a k-value, or the regression rate constant for recovery heart rate following the second cycle test (Akalan et al., 2008). The two-test format can be an issue when time (i.e. testing duration) and fatigue are a concern. Additionally, not every administrator is going to have the ability to calculate a k-value to enter into the calculation. By comparison, the Rockport 1-mile walk test only requires the participant to walk one mile, and enter age, gender, body weight, completion time, and heart rate data into the regression equation (Kline et al., 1987). This is an example where precision and accuracy, while important, are negated by ease of administration.

There are a couple of limitations in the current body of literature describing methods to predict VO_{2max}. First is that despite the growing number of submaximal and non-exercise prediction equations available, very few have been validated in older adult populations as most equations were created for healthy younger adults (18-50 years of age). The recent review by

Smith, Evans, Parfitt, Eston, & Ferrar (2016) highlights only nine studies that report validated submaximal prediction equations appropriate for older adult populations (Smith, Evans, Parfitt, Eston, & Ferrar, 2016). As mentioned previously, certain tests have a decreased feasibility for older adults (i.e. running or some treadmill-based tests) and may not be appropriate for fitness assessment in this group. Second, while some studies (Akalan et al., 2008; Bennett, Parfitt, Davison, & Eston, 2016; Huggett, Connelly, & Overend, 2005; Kline et al., 1987; Smith et al., 2016) have reviewed or reported comparisons between different submaximal tests, the comparisons are limited due to inconsistent reporting. For example, some studies will report a correlation coefficient between the measured VO_{2max} and predicted VO_{2max} but will fail to report error of the estimate. Few studies have compared multiple submaximal prediction tests that are validated across a broad population.

Summary: Assessing and Estimating Maximal Oxygen Consumption

Maximal, "all-out" exercise protocols to measure VO_{2max} in older adults can be unsafe or impractical. Issues arise with balance and fall risk, as well as risk of adverse cardiovascular events. Additionally, it is questionable whether older adults can achieve true maximal levels for analysis. Submaximal tests are an appropriate and safe alternative to traditional VO_{2max} testing. Not only are they safer, but they generally require less expensive equipment. But interpretation of the results should be based on the reliability and accuracy of the test.

Prevalence of Physical Activity in Older Adult Populations

Despite the evidence promoting the benefits of routine PA, as discussed so far, regular PA participation is low in the US adult population. Current data reports only 20.2% of adults, or 1 out of 5, achieve the minimum recommendation of 150-minutes of moderate-intensity or 75-

minutes of vigorous-intensity PA per week (CDC, 2016). More sobering, a joint report from the US Department of Health and Human Services, CDC, and National Center for Chronic Disease Prevention and Health Promotion, Division of Nutrition, Physical Activity, and Obesity (2015), states that 23.7% of adults engage in *no* leisure-time PA (U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC), National Center for Chronic Disease Prevention and Health Promotion, Division of Nutrition, Physical Activity and Obesity, Atlanta, GA, 2015). Older adults, who are at an increased risk for developing CVD and experiencing functional declines, can especially benefit from regular PA. Like general national trends, however, older adults fall short in PA participation. Troiano et al., (2008) reports that adult males and females age 60-69 engage in an average of 16.7 and 12.4 minutes, respectively, of combined moderate and vigorous intensity PA (Troiano et al., 2008). Likewise, males and females age 70+ averaged 8.7 and 5.4 minutes, respectively, of combined moderate and vigorous intensity PA (Troiano et al., 2008). A review by Taylor et al., (2014) reports that 60% of US adults, aged 50 or greater, fail to achieve the recommended activity levels, and that PA participation continues to significantly decrease after 75 years of age (Taylor, 2014).

Barriers to PA

Barriers to PA will differ depending on the population, which means intervention approaches should be tailored to the population being studied. O'neill and Reid (1991) report that 87% of older adults have at least one barrier to exercise (O'Neill & Reid, 1991). Zaleski et al., (2016) expanded on these findings, and report the most common barriers to PA and exercise are low self-efficacy, fear of injury, lack of social support or isolation, and pain either from the activity itself or from medical conditions (Zaleski et al., 2016). Perceptions of exercise or barriers to exercise can be the deciding factor for an individual to engage in exercise. Schutzer &

Graves, (2004) reported that older adults perceive MPA to be too time consuming (Schutzer & Graves, 2004), suggesting perceived lack of time to be a barrier to engagement in active behaviors. Additionally, Schutzer et al., (2004) reported negative perceptions of exercise specific to older adults included sweating, labored breathing, muscle soreness, and, in some instances, it was considered "unladylike" (Schutzer & Graves, 2004). Taylor et al., (2014) further reported pain or ill health, and lack of social support to also be barriers to PA in older adults. It is necessary to target these barriers to improve PA engagement, especially when intervening in PA behavior (Taylor, 2014).

Theoretically Based Physical Activity Interventions

Behavioral theories help researchers predict human behavior and are important for participant retention (Wilcox et al., 2008). A review by Conn, Minor, Burks, Rantz, and Pomeroy (2003) reported that 70% of studies that were theory-based reported positive findings (i.e. PA initiation) compared to only 40% of studies that did not reference or utilize a theory (Conn, Minor, Burks, Rantz, & Pomeroy, 2003). A meta-analysis by Chase (2013) that focused specifically on older adult PA interventions expands on these findings and reported significantly greater effect sizes for theory-based interventions (d=.28) compared to interventions that were not theory-based (d=.05) (p<0.01) (Chase, 2013). Further, Chase (2013) reported a mean effect size of .18 (p<0.001) for two groups that had a post-test comparison. While this was not a large effect size, the authors went onto report that that this translated into 620 more steps per day, or 73 more minutes of PA per week, compared to the control group (Chase, 2013). Additionally, Chase (2013) reported that theory guided PA interventions had a significant impact on PA behaviors among community dwelling older adults (Chase, 2013).

The most commonly reported theories in older adult PA interventions are Social Cognitive Theory and the Theory of Planned Behavior (TPB) (van Stralen, De Vries, Mudde, Bolman, & Lechner, 2009; Wilcox, 2016). The Theory of Planned Behavior (TPB) describes the relationship between intention and behavior (i.e. intention to be physically active vs. engaging in PA) (Ajzen, 1991). The TPB is comprised of three main components: attitude toward the activity or behavior, subjective norm, and perceived behavioral control. These factors feed directly into behavioral intention, which then feeds into the behavior itself. Perceived behavioral control also can directly influence the behavior (Ajzen, 1991). A review article by Motalebi, Iranagh, Abdollahi, and Lim (2014) suggests that while intention to exercise decreases with increasing age, the "translation" of intention to behavior increases (Motalebi, Iranagh, Abdollahi, & Lim, 2014).

Social Cognitive Theory describes how an individual's personal, behavioral, and environmental factors interact with and influence each other (Bandura, 1988). There are five theoretical constructs of SCT: knowledge, perceived self-efficacy, outcome expectations, goal formation, and sociocultural factors. Independently, self-efficacy is an important component of PA engagement and exercise adoption and is the level of confidence an individual has in his or her ability to complete a specific activity or engage in a behavior (Bandura, 1988). There are four primary components that contribute to high levels of self-efficacy: mastery experience, social modeling, improved physical and emotional states, and verbal persuasion (Bandura, 1988). Mastery experience is especially important for older adults, as it has been reported that a key barrier to exercise engagement is lack of knowledge on how to safely engage in exercise (Higgins, Middleton, Winner, & Janelle, 2014). Chase (2013) suggests that older adults might benefit from a combination of cognitive and behavioral interventions (i.e. interventions that focus on education and counseling in addition to self-monitoring and goal setting) (Chase, 2013).

A third theoretical model that is closely related to both the TPB and self-efficacy is the Social Ecological Model (Bronfenbrenner, 1977), which describes five different levels of influence on an individual's behavior. The overarching/top level of this model is public policy, or the policies and laws related to the behavior. The next layer, community, describes how environmental factors such as design, space, or access influence PA engagement. Next is the organizational layer, or the organizations, schools, workplaces, etc., that an individual interacts with daily. After that is the interpersonal layer, which consists of family and friends, and the social network of an individual. The final layer is that of the individual, and consists of the knowledge, attitudes, and skills that person possesses (Bronfenbrenner, 1977). Interventions can target different layers within this model, with the understanding that the higher layers will influence the layers below it. Individually or in combination, these theoretical models can dramatically improve the success of PA initiation and adoption in older adults.

Often when behavior change theories are incorporated into interventions, they focus on teaching the participant strategies, skills, and techniques to adopt and maintain PA (Wilcox, 2016). These skills included self-monitoring, recording PA, goal setting, problem solving when facing barriers, and the means to identify and seek out needed social support (Wilcox, 2016). Similar to Wilcox (2016), a review by Van Stralen et al., (2009) sought to identify the determinants of PA behavior among older adults. Van Stralen and colleagues (2009) identified five primary areas that predicted PA initiation and maintenance: socio-demographic determinants, personal and behavior determinants, psychological determinants, social determinants, and physical environment determinants (van Stralen et al., 2009). Further, these determinants could be broken down into three psychosocial subcategories: pre-motivational, motivational, and post-motivational (de Vries, Mesters, Riet, Willems, & Reubsaet, 2006). These motivational factors correspond to different components of the TPB. For example, pre-motivational factors correspond with awareness-raising factors such as knowledge and risk perceptions. Motivational factors include attitude, self-efficacy, and social influence. Finally, post-motivational factors revolve around the translation of intention to action, also described as goal-setting and planning (de Vries et al., 2006).

Personal and behavioral determinants include age, marital status, and employment. Increased age was negatively associated with PA initiation, however being married and current employment were positively associated with PA initiation (van Stralen et al., 2009). Psychological determinants that were positively associated with PA initiation and maintenance were knowledge, self-efficacy or perceived behavioral control, outcome expectations and perceived benefits, enjoyment, and goal setting/planning or action control (self-monitoring and regulation) (van Stralen et al., 2009). Social determinants positively associated with PA initiation were social support, a sports partner, and good social network. Men also benefited from social models (van Stralen et al., 2009). Finally, positively associated physical environment determinants to PA were perceived neighborhood safety and access to facilities, as well as the intervention or program delivery format, specifically home-based (van Stralen et al., 2009). In considering these factors, PA interventions can be tailored more specifically to the older adult population, ideally translating into a greater intervention adherence.

When theoretical constructs are applied, intervention delivery methods can be altered to be more conducive to the targeted population. Geraedts, Zijlstra, Bulstra, Stevens, and Ziljstra, (2013) conducted a systematic review to determine if home-based PA are as effective as supervised, lab-based interventions in older adults. They found that PA programs with frequent remote feedback (i.e. more than one phone call per month) were just as effective as supervised programs (Geraedts, Zijlstra, Bulstra, Stevens, & Zijlstra, 2013). Interestingly, non-frequent telephone contact (i.e. one or fewer phone calls per month) was still more effective than no contact (i.e. in the case of a control group) and was just as effective as supervised interventions. These results are promising, especially when considering that most older adults prefer a home-based intervention approach rather than being required to report to a facility (Müller & Khoo, 2014).

Despite the positive evidence in support of behavioral theories, many studies lack theoretical foundations, as determined in a recent review by Wilcox (2016), who identified several gaps in the literature. First, interventions should not have a "one size fits all" approach but should acknowledge the diversity within the older adult population. Second, while group exercise classes provide social support and accountability, they might only appeal to those individuals who are actively seeking out such support and are already healthy and active. Finally, interventions do not have to be delivered solely in a face-to-face session, but rather can incorporate print-based or technology-based intervention methods (Wilcox, 2016).

Summary: Theoretically Based Physical Activity Interventions

Theoretical constructs are important for the successful adherence, completion, and translation of PA interventions. The older adult population is unique from other populations and presents unique barriers and motivators to engage in PA and exercise. Many PA interventions either overlook these unique barriers and motivators, and treat older adults the same as younger adults, or they exclude theoretical constructs all together. Laboratory-based experiments provide valuable information to expand the body of PA literature but are limited in their translation since they tend to be very controlled. Home-based or remotely mediated interventions allow for more realistic assessment of how the intervention fares in a “real world” setting and might be more appropriate for older adult populations, however protocol adherence can be lower. Utilizing behavioral theory to guide intervention methodology should be considered to improve protocol compliance and outcome measures.

<u>What’s Next?</u>

There are several “hot topic” PA interventions currently in the literature that have shown great promise in the laboratory setting, but have not been studied in-depth in home-based settings, prescribed to older adults, or used a theory-grounded framework. One such intervention is High Intensity Interval Training (HIT). As outlined in Part 2 of this lit review, HIT boasts many of the health and fitness benefits similar what has been previously described in this document despite the smaller exercise volume. Additionally, adaptations of HIT will be described that have been prescribed to clinical and older adult populations.

Part Two: High Intensity Interval Training and Older Adult Populations

<u>High Intensity Interval Training</u>

High Intensity Interval Training is defined as “brief, repeated bursts of relatively intense exercise… [and] periods of rest or low-intensity exercise,” (Gibala & McGee, 2008). An often-cited benefit of HIT is its potential time saving component, as the vigorous intensity of the exercise lends itself to shorter bouts of activity (Gibala & McGee, 2008). Additionally, due to the high intensity nature of the protocol, it can be prescribed fewer times per week. Compared to traditional, moderate intensity aerobic exercise ACSM guidelines (i.e. 150-minutes of moderate intensity aerobic exercise per week, or 30-minutes, 5 days per week vs. 75-minutes of vigorous intensity per week, or 20-minutes, 3 days per week (ACSM, 2013)), HIT generally comprises a fraction of the exercise volume. Additionally, HIT has been associated with a number of health benefits similar to those reported in the moderate intensity PA literature. This section will describe HIT protocols currently presented in the literature.

High Intensity Interval Training protocol prescriptions vary, ranging in intensity, number of intervals, interval to recovery time ratio, and modality. The most stringent protocol, known as Sprint Interval Training (SIT), comprises a series of 30-second, maximal or near-maximal (>90% VO_{2max}) sprints paired with 4-minutes of active recovery at a reduced intensity (Gibala et al., 2006). Traditionally, these SIT protocols have been completed on a cycle ergometer (Burgomaster et al., 2007; Burgomaster et al., 2008; Burgomaster, K. A., Hughes, Heigenhauser, Bradwell, & Gibala, 2005), but recent studies have introduced treadmill-based protocols to enhance translatability and access (Hazell, Hamilton, Olver, & Lemon, 2014; Macpherson, Hazell, Olver, Paterson, & Lemon, 2011; Rowley et al., 2017). Alternatively, several studies have adjusted the HIT protocol to one that is still vigorous intensity but does not adhere to the traditional maximal intensity SIT protocol. For the sake of this review, we will exclude SIT protocols and focus primarily on HIT protocols in human subjects, summarized in Table 1.

Population Breakdown

High Intensity Interval Training has been prescribed to a wide variety of populations, ranging from young, healthy populations to older, diseased populations. Within the scope of this 27-study review, four studies investigated the effects of HIT on healthy individuals who were either recreationally active or highly trained (Ciolac et al., 2010; Jakeman, Adamson, & Babraj, 2012; Little, Safdar, Wilkin, Tarnopolsky, & Gibala, 2010; Talanian, Galloway, Heigenhauser, Bonen, & Spriet, 2007). The majority of the studies (15 of 27) investigated the effects of HIT in overweight/obese individuals who were inactive but otherwise healthy (i.e. free of chronic disease) (Foster et al., 2015; Gillen, Percival, Ludzki, Tarnopolsky, & Gibala, 2013; Heisz, Tejada, Paolucci, & Muir, 2016; Heydari, Freund, & Boutcher, 2012; Hood, Little, Tarnopolsky, Myslik, & Gibala, 2011; Metcalfe, Babraj, Fawkner, & Vollaard, 2012; Nybo et al., 2010; Sawyer et al., 2016; Schjerve et al., 2008; Sijie, Hainai, Fengying, & Jianxiong, 2012; Tjonna et al., 2009; Trapp, Chisholm, Freund, & Boutcher, 2008; Tsekouras et al., 2008; Wallman, Plant, Rakimov, & Maiorana, 2009). Finally, the eight remaining studies investigated the effects of HIT in individuals with chronic disease (Boyne et al., 2016; Guimaraes et al., 2010; Little et al., 2011; Munk, Staal, Butt, Isaksen, & Larsen, 2009; Rognmo, Hetland, Helgerud, Hoff, & Slørdahl, 2004; Tjonna et al., 2008; Warburton et al., 2005; Wisloff et al., 2007). This included Type 2 Diabetes Mellitus, coronary artery disease patients, heart failure patients, and hypertensive patients. Additionally, these 23 studies spanned a wide range of ages, though the majority of studies (18 of 23) targeted adults aged 18 to 64 years old. Further, these studies tended to focus on the lower end of that range in the 20-40-year-old group. Five studies included individuals older than 65 years of age, but all of these studies focused on populations with chronic disease (Boyne et al., 2016; Little et al., 2010; Munk et al., 2009; Rognmo et al., 2004; Wisloff et al., 2007). Only one study targeted adolescents (Tjonna et al., 2009).

Table 2.1 HIT Protocols							
Author	**Study Duration**	**Sample Population**	**Modality**	**Session Frequency**	**Sprints/ Sprint Intensity**	**Rest Interval/ Rest Intensity**	**Control/Comparison Group(s)**
Little et al., 2010	2-wks	**Healthy young men** (21 ± 1 yr)	Cycle	3x/week	**10 x 60-s** ~90% HR_{max}	**75 s** 30 Watts	NA
Little et al., 2011	2-wks	**Patients with T2DM** (62.5 ± 7.6 yr)	Cycle	3x/week	**10 x 60-s** ~90% HR_{max}	**60 s** 50 Watts	NA
Gillen et al., 2013	6-wks	**OW/OB women** (27 ± 8 yr)	Cycle	3x/week	**10 x 60 s** ~90% HR_{max}	**60 s** 50 Watts	Fed vs Fasted
Metcalfe et al., 2012	6-wks	**Sedentary, otherwise healthy adults** (18-29 yr)	Cycle	3x/week	**2 x 10 s – 20 s** Maximal	**3:20 – 3:40 min:sec** 60 Watts	Sedentary control
Jakeman et al., 2012	2-wks	**Trained triathletes** (40 ± 9 yr)	Cycle	6 sessions/ 14 days	**10 x 6-s** Maximal	**60 s** Rest (Passive)	Maintain normal training routine
Trapp et al., 2008	15-wks	**Inactive, otherwise healthy women** (18-30 yr)	Cycle	3x/week	**8-s** 120 RPM	**12 s** 40 RPM	Control Steady state exercise
Heydari et al., 2012	12-wks	**OW adult males** (20-30 yr)	Cycle	3/week	**60 x 8-s** 80-90% HR_{peak}	**12 s** 40 RPM	Maintain current lifestyle
Talanian et al., 2007	2-wks	**Recreationally active women** (22 ± 1 yr)	Cycle	7 sessions/ 2 weeks	**10 x 4-min** 90% VO_{2peak}	**2-min** Rest (passive)	NA
Hood et al., 2011	2-wks	**Sedentary, otherwise healthy adults** (45 ± 5 yr)	Cycle	6 sessions/ 2 weeks	**10 x 60-s** 80-95% HRR	**60 s** 30 Watts	NA
Tsekouras et al., 2008	8-wks	**Sedentary young men** (20-40 yr)	Treadmill	3/week	**4 x 4-min** 90% VO_{2peak}	**4-min** 60% VO_{2peak}	Maintain current lifestyle
Hrmax: Maximal heart rate; RPM: Revolutions per minute; HRR: Heart Rate Reserve							

Table 2.1 Cont'd. HIT Protocols

Author	Study Duration	Sample Population	Modality	Session Frequency	Sprints/ Sprint Intensity	Rest Interval/ Rest Intensity	Control/Comparison Group(s)
Wallman et al., 2009	8-wks	**OW/OB adults** (18-64 yr)	Cycle	4x/week	**10 x 1-min** 90% VO_{2peak}	**2-min** 30% VO_{2peak}	Continuous aerobic training or Diet only
Rognmo et al., 2004	10-wks	**Coronary artery disease patients** (51-74 yr)	Treadmill (walking)	3x/week	**4 x 4-min** 80-90% VO_{2peak}	**3-min** 50-60% VO_{2peak}	Moderate intensity exercise
Moreira et al., 2008	12-wks	**OW, otherwise healthy adults** (40 ± 8 yr)	Cycle	3x/week	**20 x 2-min** 20% above anaerobic threshold	**1-min** Rest (passive)	Control group Endurance training group
Nybo et al., 2010	12-wks	**Untrained men** (20-43 yr)	Treadmill	3x/week	**5 x 2-min** 95% HR_{max}	**NR**	Control group Prolonged running group Strength training group
Schjerve et al., 2008	12-wks	**OW adults** (>20 yr)	Treadmill	3x/week	**4 x 4-min** 85-95% HR_{max}	**3-min** 50-60% HR_{max}	Continuous moderate-intensity Maximal strength training
Tjonna et al., 2009	12-wks	**OW/OB adolescents** (mean, 14 yr)	Treadmill	2x/week	**4 x 4-min** 90-95% HR_{max}	**3-min** 70% HR_{max}	Multidisciplinary approach
Wisloff et al., 2007	12-wks	**Heart failure patients** (75.5 ± 11 yr)	Treadmill (walking)	3x/week	**4 x 4-min** 90-95% HR_{peak}	**3-min** 50-75% HR_{max}	Control Continuous moderate-intensity
Ciolac et al., 2010	16-wks	**Healthy women** (20-30 yr)	Treadmill	3x/week	**13 x 1-min** 80-90% VO_{2max}	**2-min** 50-60% VO_{2max}	Control Continuous moderate-intensity
Guimaraes et al., 2010	16-wks	**Hypertensive patients** (36-58 yr)	Treadmill	2x/week	**13 x 1-min** 80% HRR	**2-min** 50% HRR	Sedentary control Continuous exercise training
Tjonna et al., 2008	16-wks	**Metabolic syndrome patients** (52.2 ± 3.7 yr)	Treadmill	3x/week	**4 x 4-min** 90% HR_{max}	**3-min** 70% HR_{max}	Control Continuous moderate-intensity

Hrmax: Maximal heart rate; RPM: Revolutions per minute; HRR: Heart Rate Reserve

Table 2.1 Cont'd. HIT Protocols

Author	Study Duration	Sample Population	Modality	Session Frequency	Sprints/ Sprint Intensity	Rest Interval/ Rest Intensity	Control/Comparison Group(s)
Warburton et al., 2005	16-wks	**Men with CAD** (56 ± 7 yr)	Treadmill/ Stairmaster/ Cycle	2x/week	**8 x 2-min** 90% HRR/VO_{2R}	**2-min** 40% HRR/VO_{2R}	Traditional moderate-intensity
Munk et al., 2009	24-wks	**Patients with CAD** (59.2 ± 9.5 yr)	Cycle	3x/week	**4 x 4-min** 80-90% HR_{max}	**3-min** 60-70% HR_{max}	Control
Sijie et al., 2012	12-wks	**OW Female University students** (19-20 yr)	Running (track)	5x/week	**5 x 3-min** 85% VO_{2max}	**3-min** 50% VO_{2max}	Moderate intensity continuous training
Sawyer et al., 2016	8-wks	**OW Adults** (18-55 yr)	Cycle	3x/week	**10 x 1-min** 90-95% HR_{max}	**1-min** ~25-50 W	Moderate intensity continuous training
Boyne et al., 2016	4-wks	**Ambulatory adults, 6 mos post-stroke** (35-90 yr)	Treadmill (walking)	3x/week	**30-s** "maximal"	**30-60 s** Rest (passive)	Moderate intensity continuous training
Foster et al., 2015	8-wks	**Sedentary, young adults** (18-28 yr)	Cycle	3x/week	**13 x 30-s** 100% $P_{aer}PO$ **8 x 20-s** 170% P_{aer}	**60-s** 90% VT **10-s** Unloaded pedaling	Moderate intensity continuous training
Heisz et al., 2016	6-wks	**Sedentary adults**	Cycle	3x/week	**10 x 1-min** 90-95% HR_{peak}	**1-min** 30% PPO	Moderate intensity continuous training

Hrmax: Maximal heart rate; RPM: Revolutions per minute; HRR: Heart Rate Reserve ; $P_{aer}PO$: Peak aerobic power output; VT: Ventilatory Threshold

Summary of HIT Protocols

Intervention duration ranged from 2-weeks (Hood et al., 2011; Jakeman et al., 2012; Little et al., 2010; Little et al., 2011; Talanian et al., 2007) to 6-months (Munk et al., 2009), with most studies falling between 6- and 16-weeks and the most common duration being 12-weeks. The most commonly reported prescription frequency was three times per week (i.e. three bouts of HIT three times per week), falling on a Monday, Wednesday, and Friday schedule. This falls in line with current exercise recommendations for vigorous intensity activity (American College of Sports Medicine, 2013), and adds to the appeal of a low volume exercise training program. Two studies reported participants completing six sessions over 2-weeks with a non-standardized number of days (1-2) separating training days (Hood et al., 2011; Jakeman et al., 2012), and one study reported seven HIT sessions over 2-weeks (Talanian et al., 2007). Only two studies reported more than three HIT sessions per week, Wallman et al., 2009 reporting four times per week (Wallman et al., 2009) and Sijie et al., 2012 reporting five times per week (Sijie et al., 2012), however the authors did not report why this frequency was prescribed. The modalities of these studies were split almost equally between cycle ergometers and treadmills. One study implemented mixed modalities, and split time between the treadmill, cycle ergometer, and stair climber (Warburton et al., 2005). Additionally, another study implemented a track for their running HIT protocol (Sijie et al., 2012). Branching out to other modalities outside of a treadmill or braked cycle ergometer increases the accessibility of HIT to the general public.

The number of sprints prescribed per HIT session varied the most between studies and was largely influenced by the duration and intensity of the sprints. The majority of studies reported between 4-13 sprints per exercise session. One study, that especially embraced the time saving spirit of HIT, prescribed only two sprints per session (Metcalfe et al., 2012). There were three studies that were major outliers, one that reported 20 sprints per session (Moreira et al., 2008) and two sessions that reported 60 sprints per session (Heydari et al., 2012; Trapp et al., 2008). Finally, two studies had extremely short duration sprints (8-sec) paired with a similarly short duration rest period (12-sec), allowing these protocols to last only 10-minutes total.

As stated previously, the duration of the sprint intervals was largely dependent upon the intensity of the sprint. The closer to maximal effort, the shorter sprint duration. Overall, most sprint intensities fell between 80-90% VO_{2max}/HR_{max}, which is considered a vigorous intensity. There were two studies that reported maximal intensities (Jakeman et al., 2012; Metcalfe et al., 2012), however these protocols differ from SIT because the sprint duration to rest/recovery prescription vary significantly from the standardized SIT protocol. In this same light, rest intervals varied in duration and intensity based on the intensity and duration of the prescribed sprint bout. Rest intervals ranged from 12-sec (Heydari et al., 2012; Trapp et al., 2008), paired with a short duration sprint, to 4-min (Tsekouras et al., 2008) which was a 1:1 sprint to recovery protocol. The intensities of these protocols ranged from passive rest (Jakeman et al., 2012; Moreira et al., 2008; Talanian et al., 2007) to a moderate intensity active recovery of 50-60% VO_{2peak} (Ciolac et al., 2010; Rognmo et al., 2004) or 70-75% HR_{max} (Munk et al., 2009; Tjonna et al., 2008; Tjonna et al., 2009; Wisloff et al., 2007).

Experimental Design

Methods of the reviewed HIT studies varied. Four studies reported no control or comparison group (Hood et al., 2011; Little et al., 2010; Little et al., 2011; Talanian et al., 2007). This was likely due in part to the short duration of the studies (2-weeks). Four studies reported a control group, where participants were instructed to maintain their usual routine, usually maintaining a sedentary lifestyle (Heydari et al., 2012; Metcalfe et al., 2012; Munk et al., 2009;

Tsekouras et al., 2008). Seven studies reported a control group and at least one other comparison group (Ciolac et al., 2010; Guimaraes et al., 2010; Moreira et al., 2008; Nybo et al., 2010; Tjonna et al., 2008; Trapp et al., 2008; Wisloff et al., 2007). Comparison groups generally consisted of a continuous, moderate intensity protocol. Nine studies reported only using a moderate intensity comparison group, but no true control (Boyne et al., 2016; Foster et al., 2015; Heisz et al., 2016; Rognmo et al., 2004; Sawyer et al., 2016; Schjerve et al., 2008; Sijie et al., 2012; Wallman et al., 2009; Warburton et al., 2005). One study reported a comparison group where participants were instructed to maintain their current level of training (Jakeman et al., 2012). This study differs from the studies that included a moderate intensity comparison protocol because the participants in both groups were highly trained athletes. Finally, one study examined the effects of diet (i.e. fasted vs. fed) on HIT performance (Gillen et al., 2013). This study was included primarily for the protocol however the dietary comparison excludes this study from further discussion.

Benefits of HIT

Improved VO_{2max} and Endurance Performance

It is widely recognized that HIT increases VO_{2max} despite the high intensity, low duration nature of the exercise. Table 2 summarizes improvements in VO_{2max} following HIT training. High Intensity Interval Training studies ranging 2-weeks to 6-months in duration report significant increases in VO_{2max}, often at comparable or greater levels than moderate intensity protocols. The percent change in VO_{2max} ranged from 8% (Sijie et al., 2012) to 46% (Wisloff et al., 2007) increase in VO_{2max}, with a mean percent increase of approximately 19%. It should be noted that three groups reported substantially higher percent increases compared to the rest of the studies, which is likely the result of the populations studied and reflective of a poor baseline VO_{2max}.

These studies report a 33%, 35%, and 46% increase in VO_{2max}, and studied obese adults, adults with metabolic syndrome, and heart failure patients, respectively (Schjerve et al., 2008; Tjonna et al., 2008; Wisloff et al., 2007). Remarkably, the heart failure participants in the Wisloff et al., (2007) study could complete the prescribed HIT protocol despite a clinically low average VO_{2max} value of 13.0 ± 1.6 $ml \cdot kg^{-1} \cdot min^{-1}$ (Wisloff et al., 2007). While these participants were still classified as "low fitness" at post-testing, they are a population that greatly benefits from an increase in VO_{2max}.

Not all studies measured VO_{2max}, but they did use time trials or time to fatigue to assess improvements in physical fitness and endurance performance. Three studies utilized these methods as a proxy for VO_{2max}, and all three reported significant improvements in performance. Little et al., 2010 reported an 11% and 9% decrease in time trial time at 50 kj and 750 kj of resistance, respectively (p=0.04; p=0.005). Similarly, Little et al., 2011 reported significant improvements in peak power output following two weeks of cycle training (pre: 113.36 ± 36 Watts, post: 124.37 ± 37 Watts, p=0.03). Finally, a study by Jakeman et al., (2012) that assessed both time trial performance and time to exhaustion reported improvements after only 2-weeks of cycle training. First, the 10-km time trial decreased from 851 ± 100 seconds to 768 ± 95 seconds (p=0.03). Next, the time to exhaustion was extended from 718 ± 74 seconds to 746 ± 91 seconds (p=.19). While this last measure was not statistically significant, it is encouraging to see changes in such a short period. It is believed that these aerobic improvements are due largely in part to improved peripheral oxygen exchange as supported by increases in oxidative enzyme activity in the Krebs cycle and electron transport chain (Gillen, 2016).

Table 2.2 $VO_{2max/peak}$ Improvements with HIT

Author	INT Baseline VO_{2max} (ml/kg/min)	INT Post VO_{2max} (ml/kg/min)	% Change	*P*-value
Metcalfe et al., 2012	36.3 ± 2.2 (men) 32.5 ± 1.5 (women)	41.6 ± 1.5 (men) 36.4 ± 1.3 (women)	↑ 15% (men) ↑ 12% (women)	<0.01 (group x time effect, both)
Trapp et al., 2008	28.8 ± 2.1	36.4 ± 2.5	↑ 26%	<0.05 (greater change than CON group)
Heydari et al., 2012	34.2 ± 1.0	39.4 ± 0.8	↑ 15%	<0.05 (greater change than CON group)
Talanian et al., 2007	36.3 ± 3.7	40.9 ± 3.2	↑ 13%	NR
Tsekouras et al., 2008	36.7 ± 2.7	43.9 ± 2.6	↑ 19%	<0.05
Rognmo et al., 2004	31.8 ± 9.3*	37.8 ± 12.4*	↑ 19%	<0.02
Nybo et al., 2010	36.3 ± 1.7	41.4 ± 2.2	↑ 14%	<0.05
Schjerve et al., 2008	23.6 ± 1.3	NR	↑ 33%	<0.001 (group x time effect)
Tjonna et al., 2009	32.3 ± 5.8	35.3 ± 0.8	↑ 9%	<0.01
Wisloff et al., 2007	13.0 ± 1.6*	19.0 ± 2.1*	↑ 46%	<0.01
Ciolac et al., 2010	29.3 ± 3.6*	33.9 ± 4.6*	↑ 16%	<0.001
Tjonna et al., 2008	33.6 ± 2.5	45.3 ± 3.3	↑ 35%	<0.01
Munk et al., 2009	23.2 ± 5.7*	27.1 ± 8*	↑ 17%	<0.01 (group x time effect)
Sijie et al., 2012	33.3 ± 3.9*	36.1 ± 3.1*	↑ 8%	<0.01
Sawyer et al., 2016	20.3 ± 4.9	24.4 ± 5.9	↑ 20%	<0.01
Boyne et al., 2016	16 ± 4.0*	19.4*	↑ 21%	=0.029
Foster et al., 2015	34.0 ± 6.5 (Group 1) 34.3 ± 9.1 (Group 2)	40.1 ± 6.8 (Group 1) 40.6 ± 8.7 (Group 2)	↑18% ↑18%	<0.05 (both groups)

Data presented as Mean ± SE, unless otherwise noted. *Mean ± SD. +SD not reported
P-values are significant from baseline, unless otherwise noted. CON: Control.

Improved Body Composition

Another benefit of HIT is improved body composition, which is presented in Table 3. The most commonly reported measures were body mass, body fat percentage, fat mass, and regional body composition. Duration of these studies ranged from 8- to 16-weeks. All eleven studies reported changes in body mass, with six studies reporting significant differences in post-testing body composition either compared to a control group or baseline (Trapp et al., 2008; Heydari et al., 2012; Moreira et al., 2008; Schjerve et al., 2008; Tjonna et al., 2008; Sijie et al., 2012). Significant decreases in body mass (kg) ranged from 1.2 kg (Moreira et al., 2008) to 6.2 kg (Sijie et al., 2012), with most studies reporting a decrease of ~2 kg.

Eight studies reported changes in total body fat percentage, of which six reported significant decreases in body fat percentage (Trapp et al., 2008; Moreira et al., 2008; Schjerve, et al., 2008; Tjonna et al., 2009; Sijie et al., 2012; Sawyer et al., 2016). The two studies that did not report significant changes in body composition had samples with relatively healthy body fat percentages (Tsekouras et al., 2008; Nybo et al., 2010). Decreases in body fat percentage ranged from 1% (Moreira et al., 2008; Tjonna et al., 2008; Sawyer et al., 2016) to 4% (Sijie et al., 2012). Like the changes in body mass, the study by Sijie et al., 2012 reported a greater change than the average change reported among the other studies (~2%). This could possibly be due to the frequency and modality of the HIT intervention, which was 5 days per week and track running, respectively. Running engages both upper and lower body muscle groups and is body weight dependent, resulting in an increased caloric expenditure compared to lower body cycling (Trapp et al., 2008; Moreira et al., 2008; Sawyer et al., 2016). The two other studies (Schjerve et al., 2008; Tjonna et al., 2009) prescribed HIT via a treadmill, but reported lesser decreases in body fat percentage (2.2% and 1%, respectively). This is likely due to the difference in weekly frequency, which was 2 times per week (Tjonna et al., 2009) and 3 times per week (Schjerve et al., 2008).

Three studies reported changes in regional body fat in addition to or in place of total body fat percentage. Heydari et al., (2012) did not measure total body fat percentage but did report significant reductions in abdominal fat (↓.14 kg, 6.6%, $p<0.05$) and in trunk fat (↓1.4 kg, 8.4%, $p<0.001$) after 12-weeks of cycle HIT. This is likely what attributed to the significant decrease in body mass. Similarly, Wallman et al., (2009) reported significant time effects for decreased android ($p=0.04$) and gynoid ($p=0.01$) body fat. Additionally, the HIT group experienced a greater loss of android fat compared to the continuous training group (7.9% vs 3.1% and 2.7%; moderate effect size of 0.7). Finally, Sawyer et al., (2016) reported a significant time effect ($p<0.01$) and group x time interaction ($p=0.03$) for gynoid body fat percentage.

Insulin Sensitivity

High Intensity Interval Training improves insulin sensitivity to a similar or even greater extent than traditional aerobic activity. A 2012 review by Kessler et al., reports that HIT improved insulin sensitivity in both healthy and diseased populations to a similar or greater extent than continuous, moderate intensity exercise (Kessler, Sisson, & Short, 2012). It is understood that improvements in insulin sensitivity are due to decreased body fat (Trapp et al., 2008) and increased levels of GLUT-4 (Little et al., 2010). Insulin sensitivity was most commonly assessed using HOMA methods (Trapp et al., 2008; Heydari et al., 2012; Hood et al., 2011; Tjonna et al., 2008; Ciolac et al., 2010; Tjonna et al., 2009; Sawyer et al., 2016), with other methods being glucose AUC (Little et al., 2011; Metcalfe et al., 2012) and Oral Glucose Tolerance Testing (OGTT) (Nybo et al., 2010). Six studies reported changes in fasting blood glucose, fasting insulin, and insulin sensitivity (Table 4). Only two studies reported no significant changes in any of these measures (Heydari et al., 2012; Sawyer et al., 2016), with the remaining studies reporting significant changes in at least one of the variables. Three of these studies report significant improvements in fasting blood glucose from baseline (Nybo et al., 2010; Tjonna et al., 2008; Tjonna et al., 2009). Five studies report significant improvements in insulin sensitivity from baseline (Hood et al., 2011; Nybo et al., 2010; Tjonna et al., 2008; Ciolac et al., 2010; Tjonna et al., 2009), with Tjonna et al., (2009) reporting significantly greater improvements in the HIT group compared to a moderate intensity comparison group and control group ($p<0.05$). Only three studies report significant improvements in fasting insulin levels (Hood et al., 2011; Ciolac et al., 2010; Tjonna et al., 2009). Study duration ranged from 2-weeks (Hood et al., 2011) to 16-weeks (Ciolac et al., 2010; Tjonna et al., 2008), with most studies lasting 12-weeks.

Four other studies, not reported in Table 4, report improvements in glucose control following HIT. Little et al., (2011) reports significant reductions in 24-hour average blood glucose levels following just two weeks of training (7.6 ± 1.0 to 6.6 ± 0.7 mmol/L, $p=0.01$), in healthy young men. Additionally, they report significantly lower 24-hour blood glucose AUC after training ($p=0.02$). Similarly, Metcalfe et al., (2012) reports a main time effect for women prescribed 12-weeks of HIT (671 ± 67 to 712 ± 76 mmol min l^{-1}, $p<0.05$), but men did not experience this change. However, men prescribed HIT did experience a significant 28% ($p<0.05$) increase in insulin sensitivity, not experienced in women. Trapp et al., (2008) reports similar

Table 2.3 Effects of High Intensity Interval Training (HIT) on Body Size and Composition

Author	Body Mass (kg)	FM (kg)	BF %	*P*-value (comparison)
Trapp et al., 2008	Pre: 63.3 ± 3.8 Post: 61.8 ± 3.6*	Pre: 22.2 ± 3.0 Post: 19.7 ± 2.6*+	Pre: 35.1 ± 2.7 Post: 32.4 ± 2.3*+	*p<0.05 (CON) +p<0.05 (MICT)
Heydari et al., 2012	Pre: 87.8 ± 2.7 Post: 86.3 ± 2.7*	Pre: 29.8 ± 1.6 Post: 27.8 ± 1.5*	NR	*p<0.05 (CON)
Tsekouras et al., 2008	Pre: 81.0 ± 5.6 Post: 79.3 ± 5.2	Pre: 15.2 ± 1.3 Post: 14.9 ± 1.4	Pre: 19.0 ± 1.8 Post: 19.2 ± 1.9	Non-significant within or between groups
Wallman et al., 2009	Pre: 90.5 ± 9.5 Post: 90.0 ± 9.8	Android FM (kg) Pre: 3.8 ± 0.4 Post: 3.5 ± 0.5 Gynoid FM (kg) Pre: 7.4 ± 1.6 Post: 7.1 ± 1.7	NR	Android: p= 0.04 (PRE) Gynoid: p=0.01 (PRE)
Moreira et al., 2008	Pre: 80.1 ± 14.2 Post: 78.9 ± 14.1*+	NR	Pre: 29.5 ± 7.6 Post: 28.9 ± 7.4*+	* p<0.05 (CON) + p<0.05 (PRE)
Nybo et al., 2010	Pre: 96.3 ± 3.8 Post: 94.9 ± 4.2	NR	Pre: 24.7 ± 1.5 Post: 24.2 ± 1.7	Non-significant
Schjerve et al., 2008	Pre: 114.0 ± 5.7 Post: ↓ 2.0%*	NR	Pre: 40.6 ± 1.4 Post: ↓ 2.2%*	*p<0.05 (PRE)
Tjonna et al., 2008	Pre: 91.8 ± 5.3 Post: 89.5 ± 4.9*	NR	NR	*p<0.05 (PRE)
Tjonna et al., 2009	Pre: 94.1 ± 23.3 Post: 94.4 ± 1.4	Pre: 34.5 ± 12.2 Post: 33.6 ± 1.1*	Pre: 40.6 ± 5.3 Post: 39.3 ± 0.5*	*p<0.01 (PRE)
Sijie et al., 2012	Pre: 73.7 ± 7.5 Post: 67.5 ± 7.0*+	NR	Pre: 40.57 ± 4.03 Post: 36.55 ± 4.32*+	*p<0.01 (PRE) +p<0.01 (MICT, CON)
Sawyer et al., 2016	Pre: 112.7 ± 26.6 Post: 112.6 ± 26.0	Pre: 51.5 ± 14.0 Post: 50.6 ± 14.1	Pre: 45.6 ± 5.3 Post: 44.8 ± 5.8*	*p=0.04

Summary of HIT literature reporting changes in body size and composition. *P*-values are representative of various comparisons, including compared to baseline (PRE) or change compared to control (CON) or moderate intensity continuous training (MICT) groups. Kg: Kilograms. FM: Fat Mass. BF%: Percent Body Fat. NR: Not reported.

Table 2.4 Effects of High Intensity Interval Training (HIT) on Insulin Resistance and Glucose Control

Author	Fasting Glucose	Insulin Sensitivity	Fasting Insulin	*p*-value (comparison)
Heydari et al., 2012	Pre: 4.86 ± 0.14 mmol/L Post: 4.97 ± 0.10 mmol/L	**HOMA-IR** Pre: 1.51 ± 0.15 Post: 1.47 ± 0.14	Pre: 6.98 ± 0.66 *M*u·Ml^{-1} Post: 6.72 ± 0.63 *M*u·Ml^{-1}	Non-significant within or between groups
Hood et al., 2011	Pre: 4.9 ± 0.3 mmol/L Post: 4.3 ± 0.5 mmol/L	**HOMA** ↑ 35%+	Pre: 8.1 ± 3.5 *M*iu·Ml^{-1} Post: 6.6 ± 2.9 *M*iu·Ml^{-1}*	*p<0.01 (PRE) +p<0.05 (PRE)
Nybo et al., 2010	Pre: 5.7 ± 0.2 Mm Post: 5.2 ± 0.1 Mm*	**OGTT** Pre: 6.1 ± 0.6 Mm Post: 5.1 ± 0.4 Mm*	Pre: 7.1 ± 1.1 *M*u·Ml^{-1} Post: 7.8 ± 2.2 *M*u·Ml^{-1}	*p<0.05 (PRE)
Tjonna et al., 2008	Pre: 6.9 ± 0.6 Mm Post: 6.6 ± 0.6 Mm*	**HOMA, %** Pre: 62.2 ± 8.0 Post: 77.2 ± 4.9*+	Pre: 111.2 ± 34.6 pmol/Ml Post: 113.2 ± 7.0 pmol/Ml	*p<0.05 (CON, MICT) + p<0.05 (PRE)
Ciolac et al., 2010	Pre: 83.3 ± 7.3 mg/100 ml Post: 83.8 ± 4.3 mg/100 ml	**HOMA** Pre: 1.53 ± 0.93 Post: 1.06 ± 0.88*	Pre: 7.9 ± 3.2 *M*u·Ml^{-1} Post: 5.1 ± 2.9 *M*u·Ml^{-1}*	*p<0.001 (PRE)
Tjonna et al., 2009	Pre: 5.2 ± 0.44 Mm Post: 4.9 ± 0.07 Mm*	**HOMA, %** Pre: 42.1 ± 26.3 Post: 66.0 ± 9.38*	Pre: 186.4 ± 134 Post: 132.1 ± 17.2*	*p<0.05 (PRE)
Sawyer et al., 2016	Pre: 91.7 ± 3.8 mg/Dl Post: 88.7 ± 6.7 mg/Dl	**HOMA-IR** Pre: 4.8 ± 1.7 Post: 4.2 ± 1.5	Pre: 21.3 ± 7.2 Mu/l Post: 19.1 ± 6.2 Mu/l	Non-significant within or between groups

Summary of HIT literature reporting changes in insulin resistance and glucose control. *P*-values are representative of various comparisons, including compared to baseline (PRE) or change compared to control (CON) groups.

Improvements in fasting insulin levels between a HIT group (↑31%) and moderate intensity comparison group (↑9%), however the HIT group was only significantly different from the control group ($p<0.05$). Finally, Moreira et al., (2008) reports significant reductions in fasting blood glucose compared to baseline and a control group ($p<0.05$), but do not report specific values.

Benefits of HIT: Summary

In summary, HIT provides the appropriate exercise stimulus to elicit significant improvements in fitness (VO_{2peak}) and health parameters (obesity and insulin sensitivity/glucose regulation). Older adults are at an increased risk for declining fitness, which negatively affects ADL's, mobility, and independence. Similarly, increased risks for obesity with increasing age leads to an increased risk for insulin insensitivity and poor blood glucose control. HIT could be a positive solution to attenuate these fitness and health changes characteristic of older adults.

Perceptions of HIT

An important component of exercise adherence is whether or a not a person enjoys the activity they are completing. While there has been some speculation as to the feasibility of populations outside of the young and healthy adopting HIT into a regular workout regimen, there is evidence to the contrary. Several studies have investigated the affective response to HIT training and report higher levels of enjoyment compared to traditional moderate intensity exercise. The first of such articles to be published was by Bartlett et al., (2011), who conducted a within subject comparison of exercise enjoyment immediately after an acute bout of moderate intensity continuous training and HIT in recreationally active, healthy young men. Despite a significantly higher rating of perceived exertion (RPE) during the HIT bout (p=0.015) compared to the moderate intensity bout, perceived enjoyment was higher (p=0.004).

A study in 2015 by Jung, Bourne, Beauchamp, Robinson, and Little (2015) compared 4-weeks of unsupervised HIT or moderate intensity continuous training in people with prediabetes. The authors reported similarly high RPE results in the HIT group as Bartlett et al., (2011), yet despite these high values, adherence was higher in the HIT group compared to the moderate intensity comparison group (89% vs 71%, p=0.05) (Jung, Bourne, Beauchamp, Robinson, & Little, 2015). A more recent study by Heisz et al., (2016), prescribed HIT and moderate intensity exercise to a sample of sedentary adults. Researchers collected weekly perceptions of enjoyment for both groups and reported a significant group-x-week interaction for the HIT group (p<0.05). Over the first four weeks perceived enjoyment was similarly high between the two groups, however in weeks five and six enjoyment was significantly higher in the HIT group (p<0.05). Similarly, a study by Little et al., (2011) investigated perceived enjoyment for both single sessions and multiple sessions (3 sessions per week) of HIT in older adult Type 2 Diabetics. Enjoyment was scored on a 9-point Likert scale, with '1' coinciding with "not enjoyable at all" and '9' coinciding with "very enjoyable". Both the single session and multiple session analysis reported high levels of enjoyment, with scores of 8.1 ± 1.0 and 7.9 ± 1.0 respectively.

There is some evidence to suggest that HIT training is not for everyone, as presented by Foster et al., (2015) who prescribed two different types of HIT and moderate intensity continuous training to sedentary, young adults. The HIT protocols are presented in Table 1., but briefly they entailed very short bursts of HIT intervals (20-30 seconds) at maximal and supramaximal intensities/power outputs, respectively, paired with very short duration rest intervals. Alternatively, the continuous training group was prescribed an intensity of 90%

ventilatory threshold. Training time was set to 20-minutes for all three protocols. Enjoyment was measured prior to, during, and after each training session, and was reported to decrease over the duration of the study for all three conditions and time measurements. Enjoyment, however, was reported to be highest in the steady state group over the course of the intervention. While a main premise of HIT is the vigorous nature of the exercise to allow for a shorter time commitment, the two previously mentioned HIT protocols surpass the "maximal" intensity threshold that is often criticized with SIT protocols. It *is* important to recognize that HIT is not for everyone, as mentioned above, however there is merit in the inclusion of HIT in exercise prescription for the people who will enjoy the protocol and would otherwise not engage in routine exercise. Of utmost importance, it is crucial to remember that HIT can be modified to a lesser intensity (while remaining vigorous in nature) that encourages participation.

Making 'HIT' Fit

In every exercise prescription, the main priority should be safe and appropriate progression, which includes the beginning phases of the program. Anytime an individual takes himself or herself to a physiological limit or high physical effort, proper screening is essential to decrease risk of a cardiovascular event. High Intensity Interval Training protocols must be set up properly and safely, and it is important for participants to have full understanding of the protocol prior to engaging in it. The benefit of HIT is that it is easily modifiable and does not need to be performed at an all-out, maximal effort. By adjusting the modality and intensity level, the reach of HIT can expand to clinical populations and older adults. To add to the translation factor of HIT, there are several methods that can be employed to make monitoring intensity more "user friendly". This includes using rate of perceived exertion, a subjective measure of intensity that correlates with heart rate (Borg, 1998), or the talk test, where an individual rates intensity based on how easy it is to talk during exercise (Reed & Pipe, 2016). These modifications make HIT more applicable and available to a broader range of individuals.

Numerous HIT studies have already targeted clinical populations (Little et al., 2011; Rognmo et al., 2004; Wisloff et al., 2007; Guimaraes et al., 2010; Tjonna et al., 2008; Warburton et al., 2005; Munk et al., 2009; Boyne et al., 2016) with very low functionality and baseline VO_{2max} values. HIT for these individuals looked very different compared to elite athletes who are usually sprinting or running maximally. Rather, these individuals were *walking* at an intensity that coincided with ~90% VO_{2max}. Herein lies the benefit of relative intensity protocols, making it appropriate for all levels of fitness. A study by Kelly, Murphy, Oja, Murtagh, and Foster, (2011) found that for most adults 50 years of age or older, walking at 3 mph falls under the vigorous intensity category (Kelly, Murphy, Oja, Murtagh, & Foster). With this in mind, a number of studies have investigated the effects of high intensity walking in older adult populations as a form of HIT. There have been other modalities investigated in older adults, such as water- (Handa et al., 2015) or cycle-based (Stockwell, McKean, & Burkett, 2012) interval training, however these modalities can potentially present barriers to older adults making walking a more feasible intervention modality.

High Intensity Walking (HIW)

To date, there are four publications describing HIW methods and results. The original paper by Nemoto et al., (2007) compared the effects of 5-months of HIW to moderate intensity continuous training and a control, in Japanese older adults (N=246, mean age 63±6 years). Primary outcome measures were improvements in thigh muscle strength, peak aerobic capacity, and blood pressure. The control group was instructed to maintain current PA habits (i.e. “sedentary”). The moderate intensity continuous training group was instructed to walk >8,000 steps per day, monitored by a pedometer, at an intensity corresponding to 50% VO_{2peak} a minimum of 4 days per week. Participants in this group checked in with researchers once a month to ensure protocol compliance.

The HIW group was divided into 5 different subgroups of 10-20 participants and was instructed to complete 5+ sets of 3-minute walking intervals that corresponded to 70-85% VO_{2peak} paired with 2- to 3-minutes of low intensity walking (~40% VO_{2peak}), at least 4 days per week. Intensity was established using a walking, submaximal prediction test as described by Iwashita et al., (2003). Maximal testing is not always feasible, especially in an elderly population, therefore this research team created a submaximal test that incorporated three different walking speeds and vertical displacement as assessed by accelerometry (Iwashita, 2003). Participants were fitted with a device that beeped to alert them to speed up or slow down, and intensity was monitored using a pedometer and triaxial accelerometer. Participants in this group also met with research staff every two-weeks to download data from the accelerometers and ensure that they were meeting the correct intensity levels. Post-testing showed that significant improvements were made in blood pressure readings and VO_{2peak}.

Since the article in 2007 there have been a handful of studies that have re-created studies similar to this methodology. Two studies from the same cohort have replicated these methods, prescribed to middle-aged and older adults, ranging in intervention duration from 4-months (Morikawa et al., 2011) to 22-months (Masuki et al., 2014). Like the results of Nemoto et al., (2007), these studies have reported significant increases in VO_{2peak} (Morikawa et al., 2011; Masuki, 2014). Additionally, these studies have reported extremely high adherence rates. Morikawa et al., (2011) reported 95% adherence to the HIW protocol, whereas Masuki et al., (2014) reported 70% adherence to the HIW protocol likely due to the long duration of the study.

These studies had extremely large sample sizes in the 600's, which also makes the adherence rates impressive.

Karstoft et al., (2013) slightly modified the Nemoto et al., (2007) protocol, and applied HIW to a group of Type 2 Diabetics (N=32, ~60 years of age) for a 4-month intervention duration. Like Nemoto et al., (2007), participants were assigned to a control, continuous walking, and HIW group to determine changes in blood lipid and glucose markers, body composition and anthropometrics, and VO_{2max}. Participants in the continuous walking group walked for 60-minutes at 55% HR_{max}. The HIW group alternated between 3-minutes at an intensity corresponding to 70% HR_{max} and 3-minutes "slow-walking", for 60-minutes. Both the continuous walking and HIW groups completed their respective protocols 5 days per week and were matched for energy expenditure. Post-testing resulted in significant increases in VO_{2max} (+4.4 ± 1.2 ml/kg/min (16.7%), $p<0.01$), decreases in body mass (-4.3 ± 1.2 kg, $p<0.001$) and body fat mass (-3.1 ± 0.7, $p<0.001$), and improved waist to hip ratio ($p<0.01$).

This high intensity walking protocol has been shown to be similarly effective in improving health and fitness measures in older adults, which is to be expected as many of these adaptations are intensity driven. The benefit of this walking protocol is that it is easy to administer, and the most basic components of the intervention are inexpensive (i.e. walking). One limitation of this protocol is the use of the beeping device, which could be cost prohibitive depending on the individual. There have been a few preliminary studies that have investigated the efficacy of a cellphone app, like the device used in these studies, to make the protocol more accessible (Ried-Larson et al., 2016; Nose, 2014). Similar to SIT, these initial studies create a structured foundation for high intensity walking protocols. Unlike SIT, however, the original protocol is not as specific, which could impact the translation of this intervention. A more controlled research methodology could shed light on how to best prescribe high intensity walking. Additionally, (to the best of our knowledge), there is yet to be a theoretically guided HIT intervention. Finally, HIW has the potential to fit into the "toolbox" of PA prescriptions for the older adult population. Further investigation is required to determine how HIW affects free-living levels of VPA.

CHAPTER THREE

Validation of a Series of Walking and Stepping Tests to Predict Maximal Oxygen Consumption in Adults Aged 18-79 Years

Abstract

INTRODUCTION: Field tests to estimate maximal oxygen consumption (VO_{2max}) are a practical, safe alternative to traditional testing methods. Previously published field tests and their accompanying estimation equations tend to account for as much as 80% of the variance in VO_{2max} with an error rate of ~4.5 $ml \cdot kg^{-1} \cdot min^{-1}$. These tests, however, are limited to very specific sample populations. The purpose of this study was to create and validate a series of walking and stepping field equations to predict VO_{2max} across a range of healthy 18-79-year-old adults. METHODS: One-hundred-sixty-two adults completed a graded exercise test to assess VO_{2max}. Five separate walking and three separate stepping tests of varying durations, number of stages, and intensities were completed. Estimation equations were created using hierarchal multiple regression. Covariates including age, gender, body mass, resting heart rate, distance, gait speed, stepping cadence, and recovery heart rate were entered into each model using a stepwise approach. Each full model had the same base model which consisted of age, gender, and body mass. Validity of each model was assessed using Jackknife cross-validation analysis, and percent bias and root mean square error (RMSE) were calculated. RESULTS: Base models accounted for ~72% of the total variance. Full model variance ranged from 79-83% and bias was minimal (<±1.0%) across models. Error for all models fell around 4.5 $ml \cdot kg^{-1} \cdot min^{-1}$. Stepping tests performed higher than walking tests by ~2.5% and displayed smaller RMSE. CONCLUSION: All eight models accounted for a large percentage of VO_{2max} variance (~81%) with an error of ~4.5 $ml \cdot kg^{-1} \cdot min^{-1}$. The variance and level of error of these models are comparable to previously

published equations. As all the models perform similarly, there is flexibility in the application of these tests to a more general population.

Introduction

Maximal oxygen consumption (VO_{2max}) is an important indicator of health and fitness. The standard method to assess VO_{2max} is by way of open circuit spirometry, a method of indirect calorimetry where air is inspired from the atmosphere and the expired air is analyzed for oxygen and carbon dioxide levels (Oxford University Press, 2007). A graded exercise test (GXT) is performed in conjunction with this method of gas exchange analysis to determine VO_{2max}. As the name implies, a GXT involves exercising at incremental levels of exertion until volitional fatigue. Despite the valuable information from VO_{2max} testing, it is not always a feasible option. The cost alone of the equipment required to complete these tests is high and testing often inaccessible to the general public. Economic factors aside, VO_{2max} testing is not always a safe option for certain populations, such as the elderly who are at a higher falls risk or those with an increased risk of experiencing an adverse cardiac event during vigorous exercise.

Submaximal testing, specifically in the form of a field test, is a cost effective, safer alternative to traditional maximal testing. There are several tests within the literature that vary in duration, modality, equipment requirements, testing environment, and targeted population. Treadmill and cycle tests are two popular testing modalities (Jette, Cambell, Mongeon, & Routhier, 1976; Coleman et al., 1976; Akalan et al., 2008), however the cost of acquiring and maintaining said equipment can also be a barrier to testing. Alternative, low cost options include over-ground walking/running (Kline et al., 1987; Ribisl & Kachadorian, 1969) or stepping tests (McArdle, Katch, Pechar, & Jacobson, 1972). These tests provide a safer testing alternative for high risk populations, such as older adults and can be completed in the field setting.

Over-ground running and walking tests and stepping tests are two popular modes of field test assessment. The Cooper 12-min run is a field test that was created on males age 17-52 years and was able to account for 81% of variance in VO_{2max}, however no error was reported (Cooper, 1968). Similarly, a one-mile walk test was created in males and females age 30-69 year and accounted for 77% of the variance of VO_{2max} with an error rate of 4.4 $ml \cdot kg^{-1} \cdot min^{-1}$ (Kline et al., 1987). A stepping test created on young women, age 18-22 years, yielded 56.3% of the variance in VO_{2max} with an associated error of 2.9 $ml \cdot kg^{-1} \cdot min^{-1}$ (McArdle et al., 1972). Error of the estimate can affect the ability to detect changes in VO_{2max} over time. Error estimates vary among submaximal prediction equations, but many equations possess an error of ~4.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (Kline et al., 1987; Akalan et al., 2008). Too large of an error can make it difficult to detect true change in a variable (i.e. VO_{2max}), which can complicate interpretation of results. In the case of the McCardle step test, which possesses a low error rate, the low error rate can be offset by the low R^2 indicating a tendency to perform inconsistently. Unfortunately, a limitation within this body of literature is a lack of reporting variance and error of VO_{2max} prediction equations simultaneously (Akalan et al., 2008). Validation of VO_{2max} equations also tends to be underreported (Akalan et al., 2008).

A second limitation surrounding these studies is that in their prediction of VO_{2max}, they tend to target homogenous groups of recreationally active young adults (McArdle et al., 1972; Coleman, 1976) or a narrow range of ages (Kline et al., 1987). There are only a few studies that have developed field tests across a broad age range (Jette et al., 1976; Billinger, Van Swearingen, McClain, Lentz, & Good, 2012). Further, the modality of the tests tends to reflect the age group for which the test was developed. For example, although the Cooper 12-minute run was developed on men age 17-52 years, running requires a certain level of fitness that is not feasible for many (Cooper, 1976). Similarly, walking a mile (Kline et al., 1987) is not appropriate for segments of the population, in addition to the fact that it is a long time-commitment. The development of different field tests is warranted to reach a broader audience. In comparing different methods to predict VO_{2max} with varied durations, modalities, and physiological data collection, the most effective method to predict VO_{2max} can be determined. Thus, the purpose of this study was to determine the most valid field-test to predict maximal oxygen consumption (VO_{2max}) between a series of different walking and stepping tests among a broad age range of adults.

Methods

Participants and Study Overview

This study had a cross-sectional design that spanned three days and two different locations. The first day took place within the University of Wisconsin-Milwaukee (UWM) Physical Activity and Health Research Laboratory. Participants completed demographic, anthropometric, and maximal oxygen consumption assessments. Days two and three took place at an on-campus facility with an indoor track to provide a controlled environment and comprised of walking and stepping tests respectively. One hundred and sixty-two individuals were recruited based on the following inclusion criteria: a.) between 18-79 years old, b.) ambulatory (i.e. free of any walking limitations, such as use of an assistive device or amputation), c.) able to walk on a treadmill, and d.) healthy as determined by a physical examination within the past three years. Individuals were excluded if they: a.) had a diagnosis of a cardiovascular, metabolic, or pulmonary condition, b.) were pregnant or nursing, and c.) had a history of severe arthritis or other orthopedic condition. Participant consent was obtained prior to enrolling in the study as approved by the University's Institutional Review Board.

Measures

Demographic and Anthropometric Assessment

Participants completed a health history questionnaire that assessed current health status and familial health history. Height was measured to the nearest quarter of an inch using a stadiometer (Detecto, Webb City, MO, USA), and weight was measured to the nearest quarter of a pound using a calibrated physician's scale (Detecto, Webb City, MO, USA), and were used to calculate body mass index (BMI). Resting blood pressure and heart rate were assessed using auscultation and palpitation, respectively, following standard procedures (Swain, 2014, pgs 326-329).

Maximal Exercise Test

A modified Balke treadmill protocol (ACSM, 2013) assessed maximal oxygen consumption (VO_{2max}). Participants wore a 3-way, non-rebreathing mouthpiece, nose clip, and head support (Hans-Rudolph) that were connected to a metabolic cart using a tube (TrueOne 2400, ParvoMedics, Sandy, UT, USA) to assess expired gas. Estimation of oxygen consumption using this metabolic cart has been previously validated against the traditional Douglas bag method (Basset et al., 2001). Heart rate and electrical activity were monitored using a 12-lead EKG (Case System, GE Healthcare, USA). Volitional fatigue or the following criteria had to be met to be considered a true max test: a plateau <2.1 ml/kg/min between two stages, a respiratory exchange ratio of 1.1 or greater, and a heart rate within 10 bpm of age-predicted maximal heart rate (220-age) (Howley, Bassett, & Welch, 1995).

Field Tests

During the field tests, participants were fitted with a heart rate monitor (Polar, Polar Electro Inc., Bethpage, NY, USA) to measure recovery heart rate. Tests were separated by a 5-minute seated recovery period. This was consistent for each field test.

Walking Tests

On day two of testing, participants completed a series of over-ground walking tests (Table 3.1). Distance (m) was measured using a Pittsburgh brand 10,000 ft/m distance wheel for each individual stage, or tests that were single-staged. Walking speed was calculated as distance covered divided by time ($m \cdot s^{-1}$). Recovery heart rate was recorded in 30-second increments for two-minutes immediately after each walk test (i.e 30-seconds post, 60-seconds post, etc).

Step Tests

The third day of testing consisted of a series of stepping tests (Table 3.2a). Stepping cadence was assigned based on age (Table 3.2b), to ensure that the test remained submaximal. Recovery heart rate was recorded in 30-second increments for two-minutes after each test.

Data Cleaning

Of the 162 participants recruited, five participants did not qualify for the study. Analysis was done on a test by test basis, meaning participants with a VO_{2max} value and full data set for the specific test being evaluated were included in each individual analysis.

Statistical Analysis

Statistical analysis was completed in SPSS Version 22 and SAS Version 9.4. Hierarchal multiple regression analysis (using stepwise selection) predicted VO_{2max}. The base model for each equation consisted of age, gender, and mass, and was entered as the first step of the model. Walking distance, speed, step cadence, step height, resting heart rate, and recovery heart rate variables were then added in subsequent steps to build each equation. For ramped walking tests, distance and speed were considered as well as total distance and average speed when building the equation. Main effects were only considered due to sample size limitations. The resulting model from hierarchical and selection process were tested for multicollinearity using variance inflation factor. If any problematic variables were identified, they were removed from the model. Variance (R^2), adjusted R^2, and root mean square error (RMSE) are reported for each test.

Each regression equation was cross-validated using the Jackknife analysis (leave one subject out) method (Friedman, Hastie, & Tibshirani 2001). Residual P-P plots were assessed for each jackknife validation to ensure the integrity of the analysis. Bias (+/-%) of the mean difference between each prediction equation and measured VO_{2max} and jackknife adjusted RMSE for each equation were assessed. Significance was set $p<0.05$.

Results

Participant Characteristics

Of the 157 participants, two-thirds of the sample was female (66%) and the average age was 49.4 ± 17.4 years (mean ± SD). Average VO_{2max} was 34.3 ± 10.1 $ml \cdot kg^{-1} \cdot min^{-1}$ and average BMI was 25.7 ± 4.3 $kg \cdot m^{-2}$. To ensure that the sub-samples were similar across tests, sub-sample participant characteristics were assessed and compared to the overall participant characteristics. Although the sample size varied, there were no differences between any of the sub-samples or between any sub-sample and the overall sample. Participant characteristics are presented in Table 3.3

Base Model

The base model for each regression equation included age (years), gender (male), and body mass (kg). While the specific values for the base model varied among tests, this model alone accounted for ~70% of the variance in VO_{2max} and the RMSE fell around 5.45 $ml \cdot kg^{-1} \cdot min^{-1}$. Age and body mass have a negative relationship with VO_{2max}, indicating that as age or body mass increase, VO_{2max} decreases. Male sex, alternatively, is associated with a higher VO_{2max}. This relationship was true across all base models, which are reported in Tables 3.4 and 3.5 with the walking and stepping equations, respectively.

Full Models

Estimation of VO_{2max} was strong for each test. The variance for the field test equation models varied from 79.7% to 83.5%, with Test 1 (the five-minute walking test) being the weakest predictor of VO_{2max}. Test 8 (the three stage, nine-minute step test using an 8-inch step) was the strongest predictor of VO_{2max}. Likewise, RMSE for these tests ranged from 4.138 $ml \cdot kg^{-1} \cdot min^{-1}$ to 4.656 $ml \cdot kg^{-1} \cdot min^{-1}$ for Test 8 and Test 1, respectively. By adding variables to the base models, the full models were able to account for approximately 10% more variance in VO_{2max}.

Walking Regression Equations

Walking regression results are presented in Table 3.4. Gait speed and heart rate variables were common among the walking equations. Gait speed, when significant, had a positive relationship with VO_{2max}, with a faster-selected gait speed being associated with a higher VO_{2max}. For the tests with multiple stages (Test 3-5), slower than usual gait speed was never a significant predictor. Heart rate variables varied from test to test and included resting heart rate and 30- or 60-second recovery heart rate. All heart rate variables had a negative relationship with VO_{2max}. Of the walking regression equations, Test 2 (Figure 3.1) was the strongest predictor of VO_{2max} with an R^2 of 0.829, Adjusted R^2 of 0.823, and a RMSE of 4.282 $ml \cdot kg^{-1} \cdot min^{-1}$.

Stepping Regression Equations

Stepping regression results are presented in Table 3.5. Thirty-second recovery heart rate was a significant predictor for each step test. Like the walking tests, heart rate variables were negatively related to VO_{2max}. Only one of the models included stepping cadence as a significant predictor of VO_{2max} (Test 8). Test 8 (Figure 3.2) was the strongest predictor of VO_{2max} with an R^2 of 0.835, Adjusted R^2 of 0.830, and a RMSE of 4.138 $ml \cdot kg^{-1} \cdot min^{-1}$.

Jackknife Validation Results

Results of the jackknife validation revealed that bias was relatively small for each test, with each model reporting a bias well within ± 1%. Once adjusted for bias, the variance for these models slightly decreased, ranging from 79.1% to 83.4%, for Test 1 and Test 8, respectively. Figure 3.X provides a visual representation of the relationship between estimated VO_{2max} using the jackknife adjustment, and measured VO_{2max}. Root mean square error ranged from 4.102 $ml \cdot kg^{-1} \cdot min^{-1}$ to 4.662 $ml \cdot kg^{-1} \cdot min^{-1}$, for Test 8 and Test 1, respectively. Jackknife results are presented in Table 3.5. Of the walking tests, Test 2 still accounted for the greatest variance in VO_{2max} with a Jackknife adjusted R^2 of 0.824 and RMSE of 4.287 $ml \cdot kg^{-1} \cdot min^{-1}$, and bias of -0.0000421% and 0.0000406%, respectively. Of the stepping tests, Test 8 accounted for the greatest variance in VO_{2max} with a Jackknife adjusted R^2 of 0.834 and RMSE of 4.102 $ml \cdot kg^{-1} \cdot min^{-1}$, and bias of -0.0000411% and 0.000104%, respectively.

Discussion

The purpose of this study was to determine the most valid field-test to predict maximal oxygen consumption (VO_{2max}) among a series of different walking and stepping tests. We found that among all the tests, a three-stage, 9-minute stepping test using an 8-inch step yielded the highest Jackknife validated R^2 (0.834) and lowest RMSE (4.102 $ml \cdot kg^{-1} \cdot min^{-1}$) while maintaining minimal bias, well within ±1%. Overall, the stepping tests performed higher than the walking tests. Among the walking tests, a two-minute test where participants were instructed to cover as much ground as possible yielded the highest Jackknife validated R^2 (0.824) and lowest RMSE (4.287 $ml \cdot kg^{-1} \cdot min^{-1}$), also maintaining a minimal bias within ±1%. Benefits to using field tests to estimate VO_{2max} is that they are relatively easy to administer (i.e. minimal equipment) and do not require the individual to work to maximal effort, opening up the possibility for fitness testing to a broader population.

When comparing tests based on modality, the models presented here held strong compared to other stepping and over ground walking tests. McArdle et al., (1972) investigated how well a 3-minute, single stage stepping test and recovery heart rate would predict VO_{2max} in females ~20 years of age. This test, also known as the Queen's College Step Test, required participants to maintain a cadence of 22 steps/min as they stepped up and down from a 16.25-inch step. McArdle et al., (1972) reported a variance of 56.3% (R^2=.563). Standard error was reported in $ml \cdot min^{-1}$, so cannot be compared to the error measurements presented here. While the step height and number of stages vary between this model and the models reported here, the primary difference is how recovery heart rate was measured. In the current study, a heart rate monitor was able to provide a real time heart rate measurement. Alternately, the McArdle test relied on a manual 15-second count of recovery heart rate starting 5-seconds after the completion of the test. This manual count introduces error into the heart rate reading, and likely results in a higher heart rate estimate that in turn results in a lower estimated VO_{2max}.

As mentioned previously, the Cooper 12-minute run and one-mile walk test report a variance of 77 and 81%, respectively (Cooper, 1976; Kline et al., 1987). The Cooper 12-minute run does not report standard error, thus limiting further comparison. The one-mile walk test reports an error of 5.0 $ml \cdot kg^{-1} \cdot min^{-1}$, with a variance of 77% (Kline et al., 1987). This group also performed a cross-validation analysis in a separate sample and reported a final variance of ~77% (R^2=77.4) and standard error of 4.4 $ml \cdot kg^{-1} \cdot min^{-1}$. The variance for both the one-mile walk and Cooper 12-minute test is similar to the variance we report within our tests. Additionally, the standard error of the one-mile walk test is close to our reported error, falling around 4.5 $ml \cdot kg^{-1} \cdot min^{-1}$. A benefit of the Cooper 12-minute run test is that the instructions are relatively simple (cover as much ground within the 12-minute time frame) and the equation only requires the distance to estimate VO_{2max} (Cooper, 1976). A major limitation of this test, though, is that it excludes the portion of the population based on the assumption that they can run. Additionally, the test was created on a largely homogenous group of physically fit men (Cooper, 1976). Alternatively, the one-mile walk test is a more appropriate assessment for the general public (walking rather than running) and encompasses a wider demographic (30-69-year-old men and women) (Kline et al., 1987). Still, a mile-long walk as fast as possible can be strenuous for many, and impractical for individuals with functional limitations. The walking tests we present here are appropriate for a wide range of individuals (age 18-79, men and women). Further, the longest test only takes nine-minutes and only requires the participant to exert themselves above a normal walking speed for three-minutes.

There are some considerations for interpreting the current findings. First, in considering feasibility and safety, the 9-minute stepping test, using an 8-inch step might not be appropriate for elderly or frail populations. Seeing as there was not much difference between the 9-minute stepping test using a 6-inch step and the 6-minute stepping test using a 6-inch step (both of these differed from the 9-minute stepping test using an 8-inch step by ~1% in variance and ~.1 $ml \cdot kg^{-1} \cdot min^{-1}$ in error), the shorter duration test with the shorter step could be a better option. Still, any form of stepping test could still perpetuate the risk for falls. The two-minute over ground walking test could be the best option for a quick estimation of VO_{2max} as it requires minimal equipment, is less strain on the participant, and is short in duration. Additionally, the instructions are simple (i.e. cover as much ground as possible in two-minutes), whereas the stepping tests ramp the cadence which could cause confusion. Compared to the stepping tests, the two-minute walking test accounts for a similar amount of variance in VO_{2max} as the stepping tests (~82%) and contains a similar level of error (~4.2 $ml \cdot kg^{-1} \cdot min^{-1}$).

There are some limitations to this study. First, the sample size was relatively small, which limited the analysis to only include main effects. Future studies should aim for a larger sample to allow for the investigation of interactions to potentially strengthen the model(s) and increase the R-squared value. Next, while these models are statistically sound, further investigation into the application of these measures should be investigated. In a clinical setting, for example, any of these tests should be acceptable for estimating VO_{2max}. Alternatively, it is unclear if these measures would be appropriate for measuring changes in VO_{2max} in an intervention setting.

In conclusion, this study generated VO_{2max} estimation equations from eight different stepping and over-ground walking field tests. A jackknife cross-validation assessment followed the creation of each equation to provide information on bias of each equation. Incorporating this bias, which was small, each equation accounted for ~80% of the variance for predicting VO_{2max} with an error of ~4.5 $ml \cdot kg^{-1} \cdot min\text{-}^{1}$. Compared to previously published field tests, the tests presented here are appropriate for a broad age range, are easy to administer, and are more appropriate for individuals with low fitness or functional limitations.

Chapter 3 References

Akalan, C., Robergs, R. A., & Kravitz, L. (2008). Prediction of VO2max from an individualized submaximal cycle ergometer protocol. *Journal of Exercise Physiology Online, 11*(2), 1-17.

Bassett Jr, D. R., Howley, E. T., Thompson, D. L., King, G. A., Strath, S. J., McLaughlin, J. E., & Parr, B. B. (2001). Validity of inspiratory and expiratory methods of measuring gas exchange with a computerized system. *Journal of Applied Physiology, 91*(1), 218-224.

Billinger, S. A., VAN Swearingen, E., McClain, M., Lentz, A. A., & Good, M. B. (2012). Recumbent stepper submaximal exercise test to predict peak oxygen uptake. *Medicine and Science in Sports and Exercise, 44*(8), 1539-1544. Doi:10.1249/MSS.0b013e31824f5be4 [doi]

Coleman, E. (1976). Validation of a submaximal test of maximal oxygen intake. *The Journal of sports medicine and physical fitness*, *16*(2), 106-111.

Cooper, K. H. (1968). A means of assessing maximal oxygen intake: Correlation between field and treadmill testing. *Jama, 203*(3), 201-204.

Friedman, J., Hastie, T., & Tibshirani, R. (2001). *The elements of statistical learning* Springer series in statistics New York.

Howley, E. T., Bassett, D. R., & Welch, H. G. (1995). Criteria for maximal oxygen uptake: Review and commentary. *Medicine and Science in Sports and Exercise, 27*(9), 1292-1301.

Jette, M., Campbell, J., Mongeon, J., & Routhier, R. (1976). The 69merican home fitness test as a predictor for aerobic capacity. *Canadian Medical Association Journal, 114*(8), 680-682.

Kline, C., Porcari, J. P., Hintermeister, R., Freedson, P. S., Ward, A., Mccarron, R. F., . . . Rippe, J. (1987). Estimation of from a one-mile track walk, gender, age and body weight. *Med.Sports Exerc, 19*, 253-259.

McArdle, W. D., Katch, F. I., Pechar, G. S., Jacobson, L., & Ruck, S. (1972). Reliability and interrelationships between maximal oxygen intake, physical work capacity and step-test scores in college women. *Medicine and Science in Sports, 4*(4), 182-186.

Oxford University Press. *Oxford Dictionary of Sports Science and Medicine, Online Version (2007)*. DOI: 10.1093/acref/9780198568506.001.0001.

Ribisl, P. M., & Kachadorian, W. A. (1969). Maximal oxygen intake prediction in young and middle-aged males. *The Journal of Sports Medicine and Physical Fitness, 9*(1), 17-22.

Table 3.1 Description of the Walking Tests

Test #	Name	Description
1	Walk at 1 or 1.5 mph	5-minute walk to a cadence of 60 bpm
2	2-minute walk*	Cover as much ground as possible within the time frame
3	6-minute walk* (3-minute stages)	Stage 1: < Stage 2: >
4	6-minute walk* (2-minute stages)	Stage 1: < Stage 2: = Stage 3: >
5	9-minute walk* (3-minute stages)	Stage 1: < Stage 2: = Stage 3: >

*Walking speeds were self-selected for these tests. < slower than normal speed, = normal speed, > faster than normal speed

Table 3.2a Description of the Step Tests		
Test #	Name	Description
6	6-minute step test (6-inch step)	Three-minute stages Cadence increased after Stage 1
7	9-minute step test (6-inch step)	Three-minute stages Cadence increased after Stage 1 and Stage 2
8	9-minute step test (8-inch step)	Three-minute stages Cadence increased after Stage 1 and Stage 2

Table 3.2b Stepping Cadence			
<40 years old	40-60 years old	>60 years old	Test/Stage Used
20 s/min = 80 bpm	15 s/min = 60 bpm	10 s/min = 40 bpm	Test 6/stage 1 Test 7/stage 1 Test 8/stage 1
25 s/min = 100 bpm	20 s/min = 80 bpm	15 s/min = 60 bpm	Test 6/stage 2 Test 7/stage 2 Test 8/stage 2
30 s/min = 120 bpm	25 s/min = 100 bpm	20 s/min = 80 bpm	Test 7/stage 3 Test 8/stage 3
s/min = steps per minute; bpm = beats per minute			

Table 3.3 Participant Characteristics	
Total Sample (N=157)	
% Female	66
Age (years)	48.9 ± 17.4
Height (cm)	171.1 ± 9.4
Body Mass (kg)	75.9 ± 16.5
BMI ($kg \cdot m^{-2}$)	25.7 ± 4.3
Resting Heart Rate (bpm)	60.3 ± 8.9
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	34.3 ± 10.1

Data presented as Mean ± SD.
Characteristics of participants within the total sample and of participants who had complete data.

Table 3.4 Regression Equations for the Walking Tests

		TEST 1 n= 149		TEST 2 n= 146		TEST 3 n= 147		TEST 4 n= 147		TEST 5 n= 149	
	Predictor	B	SE(B)	B	SE(B)	B	SE(B)	B	SE(B)	B	SE(B)
Base Model	*Constant*	**71.076**	2.592	**70.862**	2.610	**70.947**	2.610	**71.239**	2.603	**71.076**	2.592
	Age	**-0.398**	0.026	**-0.396**	1.066	**-0.399**	0.026	**-0.397**	0.026	**-0.398**	0.026
	Male	**10.163**	1.060	**10.198**	0.026	**10.208**	1.064	**10.082**	1.067	**10.163**	1.060
	Body Mass	**-0.290**	0.032	**-.289**	0.032	**-0.288**	0.032	**-0.291**	0.032	**-0.290**	0.032
	R-Square	0.717		0.717		0.720		0.717		0.717	
	R-Square (Adjusted)	0.712		0.711		0.714		0.711		0.712	
	RMSE	5.456		5.466		5.458		5.469		5.456	
Full Model	*Constant*	**79.666**	4.270	**51.366**	4.202	**60.952**	4.257	**63.783**	4.042	**72.290**	5.104
	Age	**-0.387**	0.022	**-0.319**	0.023	**-0.347**	0.023	**-0.357**	0.023	**-0.377**	0.023
	Male	**8.869**	0.928	**6.681**	0.925	**7.756**	0.934	**8.075**	0.948	**10.058**	0.922
	Body Mass	**-0.249**	0.028	**-0.193**	0.027	**-0.211**	0.028	**-0.214**	0.029	**-0.248**	0.028
	Gait Speed (Total)	**11.128**	4.921	**11.657**	1.446						
	Gait Speed (<Normal)										
	Gait Speed (Normal)							**10.478**	2.139	**7.261**	2.272
	Gait Speed (>Normal)					**11.029**	2.049				
	Resting Heart Rate (bpm)									**-0.257**	0.044
	Heart Rate Recovery (30 s)	**-0.248**	0.036			**-0.169**	0.023	**-0.151**	0.023		
	Heart Rate Recovery (60 s)			**-0.158**	0.021						
	R-Square	0.797		0.829		0.811		0.800		0.790	
	R-Square (Adjusted)	0.790		0.823		0.804		0.793		0.782	
	RMSE	4.656		4.282		4.517		4.627		4.739	

Individual regression results for the five, over ground walking tests. **Bolded** values are significant ($p<0.05$). RMSE= Root Mean Square Error.
Test 1: Walk at 1 or 1.5 mph (single stage), 5-minute walk, cadence = 60 bpm
Test 2: 2-minute walk (single stage), cover as much distance as possible
Test 3*: 6-minute walk (3-minute stages), stage 1: < walking speed, stage 2: > walking speed
Test 4*: 6-minute walk (2-minute stages), stage 1: < walking speed, stage 2: =walking speed, stage 3: > walking speed
Test 5*: 9-minute walk (3-minute stages), stage 1: < walking speed, stage 2: =walking speed, stage 3: > walking speed
*Self-selected walking speeds

Table 3.5 Regression Equations for the Step Tests

	Predictor	TEST 6 n= 148		TEST 7 n= 145		TEST 8 n= 141	
		B	SE(B)	B	SE(B)	B	SE(B)
Base Model	*Constant*	84.722	2.573	70.995	2.566	70.445	2.641
	Age	-0.433	0.026	-0.397	0.026	-0.401	0.026
	Male	10.293	1.053	10.141	1.060	9.952	1.091
	Body Mass	-0.290	0.032	-0.290	0.032	-0.277	0.033
	R-Square	0.722		0.722		0.720	
	R-Square (Adjusted)	0.716		0.716		0.713	
	RMSE	5.408		5.379		5.375	
Full Model	*Constant*	**84.722**	2.494	**83.841**	2.421	**84.569**	2.457
	Age	**-0.433**	0.021	**-0.446**	0.021	**-0.329**	0.06
	Male	**7.724**	0.869	**7.181**	0.886	**6.825**	0.886
	Body Mass	**-0.183**	0.027	**-0.178**	0.027	**-0.181**	0.027
	Stepping Cadence					**-2.696**	1.283
	Heart Rate Recovery (30 s)	**-0.211**	0.022	**-0.183**	0.019	**-0.168**	0.017
	R-Square	0.830		0.831		0.835	
	R-Square (Adjusted)	0.825		0.826		0.830	
	RMSE (Adjusted)	4.257		4.21		4.138	

Individual regression results for the three stepping tests. **Bolded** values are significant (p<0.05). RMSE= Root Mean Square Error.
Test 6: 6-minute step test (3-minute stages), cadence† increase after stage 1, 6-inch step
Test 7: 9-minute step test (3-minute stages), cadence† increase after stage 1 and 2, 6-inch step
Test 8: 9-minute step test (3-minute stages), cadence† increase after state 1 and 2, 8-inch step
†Cadence varied by age and test stage. Cadence was lower as age increased.

Table 3.6 Summary of Jackknife Validation Analysis

	TEST 1		TEST 2		TEST 3		TEST 4		TEST 5		TEST 6		TEST 7		TEST 8	
	B	%BIAS	B	%BIAS	B	%BIAS	B	%BIAS	B	%BIAS	B	%BIAS	B	%BIAS	B	%BIAS
Constant	79.50	-1.15 E-03	51.50	9.30 E-04	60.92	-1.14 E-03	63.59	-1.32 E-03	71.47	-5.57 E-03	84.62	-6.75 E-04	83.78	-4.38 E-04	84.57	1.91 E-06
Age	-0.39	4.33 E-06	-0.32	8.85 E-07	-0.35	9.10 E-06	-0.36	4.55 E-06	-0.38	-5.26 E-06	-0.43	5.91 E-06	-0.45	6.39 E-06	-0.33	1.93 E-05
Male	8.85	-1.52 E-04	6.66	-1.19 E-04	7.73	-3.51 E-04	8.05	-1.66 E-04	10.00	-4.18 E-04	7.74	8.77 E-05	7.18	2.61 E-05	6.83	4.85 E-05
Body Mass	-0.25	2.26 E-06	-0.19	3.20 E-06	-0.21	4.66 E-06	-0.21	2.32 E-06	-0.25	5.43 E-06	-0.18	-3.98 E-06	-0.18	-5.90 E-06	-0.18	-8.04 E-06
Gait Speed (Total)	11.28	1.03 E-03	11.59	-4.59 E-04												
Gait Speed (<Normal)																
Gait Speed (Normal)							10.53	3.74 E-04	7.49	1.55 E-03						
Gait Speed (>Normal)					11.01	-1.41 E-04										
Stepping Cadence															-2.74	-3.05 E-04
Resting Heart Rate (bpm)									-0.25	5.80 E-05						
Heart Rate Recovery (30 s)	-0.25	2.65 E-06			-0.17	5.84 E-07	-0.15	5.28 E-06			-0.21	7.30 E-06	-0.18	5.87 E-06	-0.17	2.24 E-06
Heart Rate Recovery (60 s)			-0.16	-2.92 E-06												
R-Square	0.791	-4.21 E-05	0.824	-3.64 E-05	0.805	-4.89 E-05	0.794	-4.56 E-05	0.782	-5.33 E-05	0.825	-3.06 E-05	0.826	-3.23 E-05	0.834	-4.11 E-05
RMSE	4.662	4.06 E-05	4.287	3.80 E-05	4.526	3.74 E-05	4.640	8.22 E-05	4.762	1.54 E-04	4.259	9.08 E-05	4.223	9.58 E-05	4.102	1.04 E-04

All data reflect Jackknife adjustment. Bias for each model was minimal (<±1%).

Walking Test Key:

Test 1: Walk at 1 or 1.5 mph (single stage), 5-minute walk, cadence = 60 bpm
Test 2: 2-minute walk (single stage), cover as much distance as possible
Test 3*: 6-minute walk (3-minute stages), stage 1: < walking speed, stage 2: > walking speed
Test 4*: 6-minute walk (2-minute stages), stage 1: < walking speed, stage 2: =walking speed, stage 3: > walking speed
Test 5*: 9-minute walk (3-minute stages), stage 1: < walking speed, stage 2: =walking speed, stage 3: > walking speed
*Self-selected walking speeds

Step Test Key:

Test 6: 6-minute step test (3-minute stages), cadence[†] increase after stage 1, 6-inch step
Test 7: 9-minute step test (3-minute stages), cadence[†] increase after stage 1 and 2, 6-inch step
Test 8: 9-minute step test (3-minute stages), cadence[†] increase after state 1 and 2, 8-inch step
[†]Cadence varied by age and test stage. Cadence was lower as age increased.

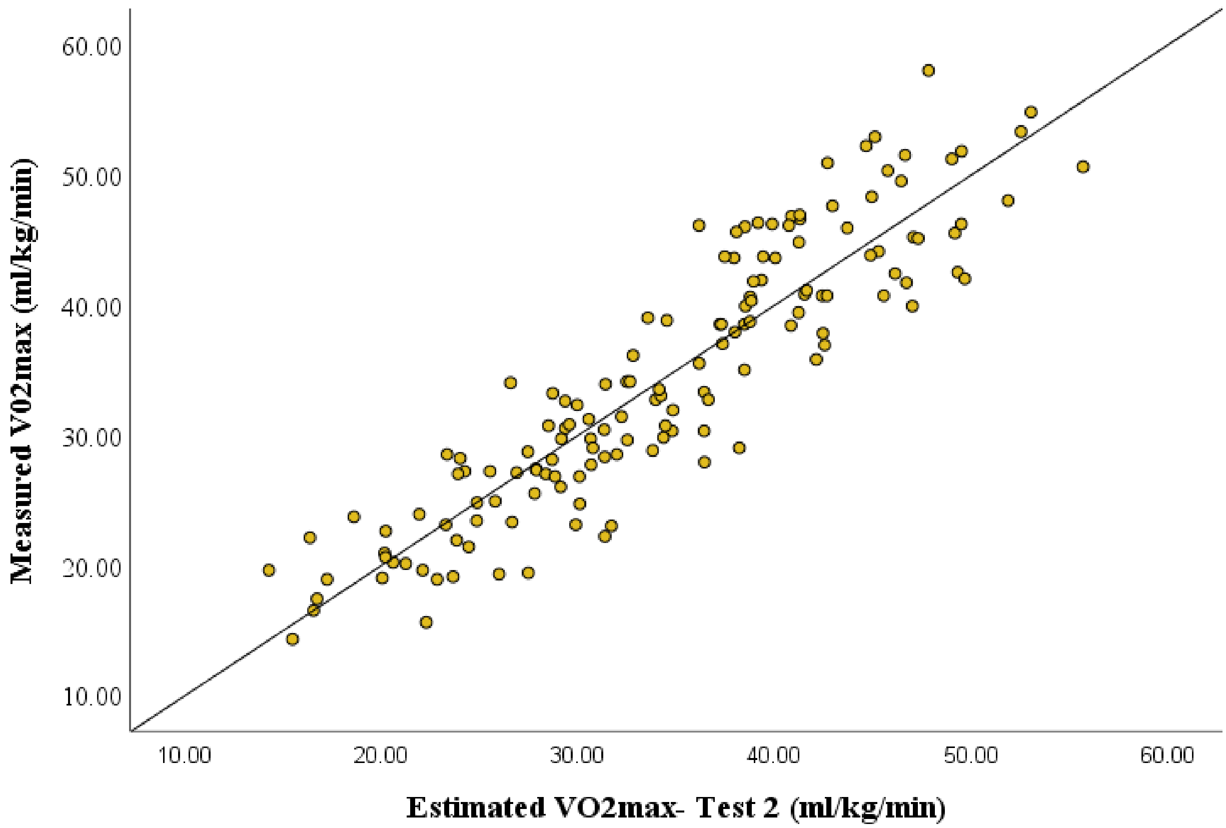


Figure 3.1 Comparison of estimated maximal oxygen consumption (VO_{2max}) using Test 2, a two-minute walking test, to measured VO_{2max}. Estimated VO_{2max} was calculated using the jackknife bias-adjusted equation. Bias was minimal, <0.01%. The bias-adjusted equation accounted for ~82% of the variance of VO_{2max} (R^2=0.824) and had a root mean square error of 4.287 $ml \cdot kg^{-1} \cdot min^{-1}$. This was the top performing model of all walking tests.

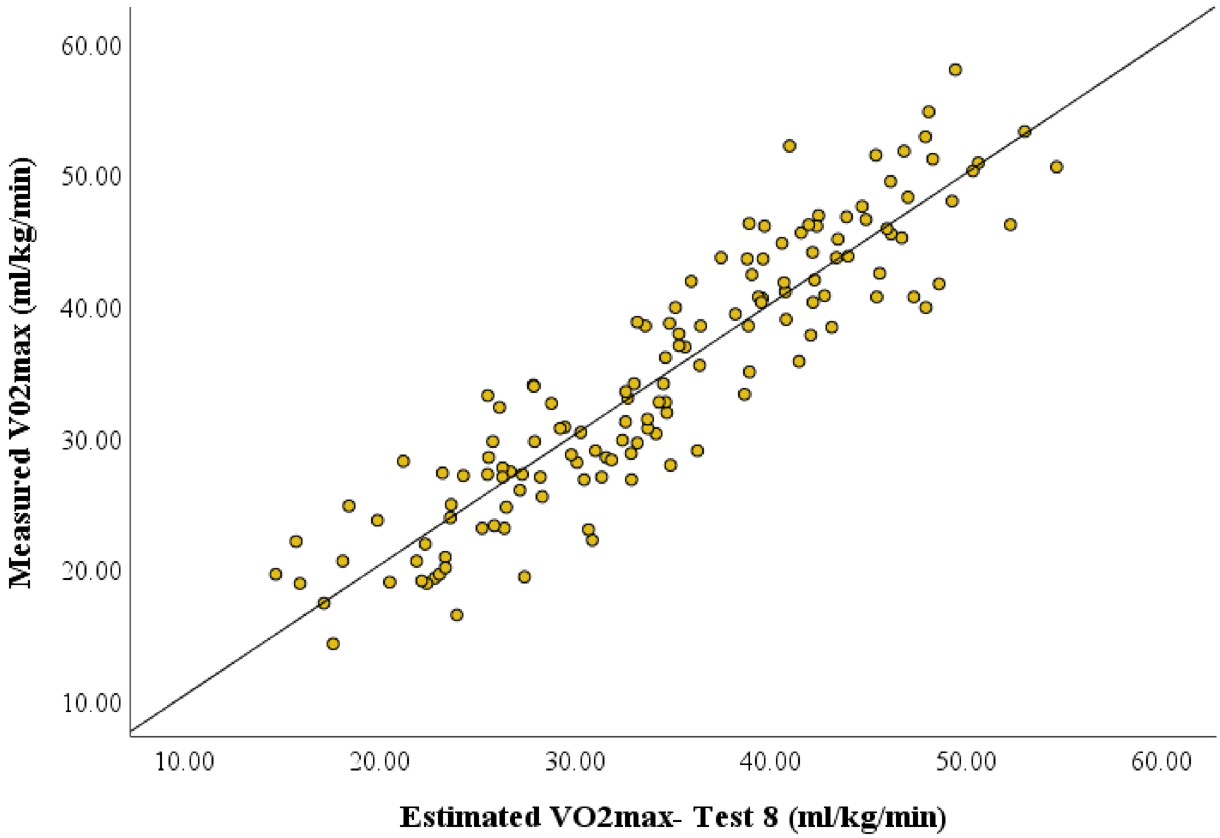


Figure 3.2 Comparison of estimated maximal oxygen consumption (VO_{2max}) using Test 8, 9-minute, 3-stage stepping test, to measured VO_{2max}. Estimated VO_{2max} was calculated using the jackknife bias-adjusted equation. Bias was minimal, <0.01%. The bias-adjusted equation accounted for ~83% of the variance of VO_{2max} (R^2=0.834) and had a root mean square error of 4.102 $ml \cdot kg^{-1} \cdot min^{-1}$. This was the top performing model of all walking tests.

CHAPTER FOUR

"Hit the Ground Walking": A Pilot Study Examining High Intensity Interval Walking in Older Adults

Abstract

INTRODUCTION: Regular physical activity (PA) and exercise is beneficial for preventing chronic disease and improving cardiorespiratory fitness. Despite these benefits, older adult PA engagement is low, compounded by unique barriers. High intensity interval walking (HIW) is a form of high intensity interval training (HIT) that is a low-volume, high intensity exercise protocol that reaps benefits similar to traditional training protocols. The purpose of this study was to determine if older adults' maximal oxygen consumption (VO_{2max}) increased following a theoretically guided, 4-week HIW intervention and a second purpose was to determine changes in PA levels. METHODS: Twenty-one older adults (60-85 years) were randomly assigned to the non-exercise control (CON) group (n=10) or the intervention (HIW) group (n=11). Participants completed baseline fitness testing and PA monitoring, an intervention/control period, and post-intervention testing and PA assessment. RESULTS: Eighteen older adults completed the study (CON, n=10; HIW, n=8). There were no significant changes in VO_{2max} for either group. PA did significantly improve for the HIW group, both from baseline ($p<0.05$) and compared to changes in the CON group ($p<0.05$). DISCUSSION: A 4-week HIW protocol appears to be effective to improve PA levels in older adults. Further studies with larger sample sizes are warranted to determine long-term changes in PA and if VO_{2max} does change.

Introduction

As the United States population continuously shifts and grows, the fastest growing portion of the population is that of the older adults (AoA, 2016). With this shifting landscape comes a wave of unique health concerns. Older adults exhibit a higher risk for chronic disease conditions, resulting in significantly higher health care costs compared to their younger counterparts (CDC, 2013). It is estimated that approximately 30% of the population, age 65 years or older, have some form of heart disease (Barret & Fiqueierdo, 2009). Higher rates of disease and co-morbidities contribute to a decline in independence and mobility (CDC, 2013; Cohen-Mansfield et al., 2013), thus diminishing quality of life. Unfortunately, this trend increases with each decade of life past 60 years of age (Mozaffarian, 2015). Physical activity (PA) and exercise, such as walking, is a low-cost option to help treat and prevent chronic disease. The benefits of PA and exercise are plentiful, and are linked to decreased incidence of cardiovascular disease (Sattelmair, 2011; Lee, 2003; Tanasescu, 2002; Franco, 2005), metabolic conditions such as Type 2 Diabetes (Jeon, 2007; Manson, 1991; DiPietro, 2006) or obesity (Litmann, 2005; Nicklas, 2009; Bell, 2010), and improved physical fitness (Huang, 2005; Bell, 2010; Kirwan, 1993; Nicklas, 2009).

Despite these benefits, PA engagement is low among United States adults. Taylor (2014) reports that 60% of United States adults age 50 years or older fail to meet recommended activity levels, and this trend continues significantly after age 75 years (Taylor, 2014). Older adults present unique barriers to PA engagement, which contribute to the low activity levels. O'neill and Reid (1991) report that 87% of older adults have at least one barrier to engaging in PA and exercise (O'neill & Reid, 1991), which include fear of injury, lack of knowledge, lack of social support, perceived lack of time, and pain (Zaleski, 2016; Taylor, 2014). Low self-efficacy

(Zaleski, 2016), in part stemming from these barriers, also contributes to decreased PA and exercise participation. Theoretical constructs, such as the Social Cognitive Theory which targets self-efficacy (Bandura, 1988), allow for tailoring to specific populations and are effective in promoting protocol adherence through mastery experiences (Wilcox, 2008; Chase, 2015). Theories in intervention studies, however, tend to be underutilized (Wilcox, 2016).

A current fitness trend, and the focus of many research interventions, is High Intensity Interval Training (HIT). Known to produce similar health benefits that are seen using conventional training methods, HIT is shown to improve CVD risk factors such as insulin sensitivity and glucose uptake (Tjonna, 2008; Tjonna, 2009, Ciolac, 2010). Additionally, HIT improves maximal oxygen consumption in both healthy and clinical populations (Rognmo, 2004; Wisloff, 2007; Tjonna, 2008; Munk, 2009; Boyne, 2016) despite the low exercise training volume. Maximal oxygen consumption has shown to improve by 13% in as little as two-weeks (Talanian et al., 2007) following HIT training. Similar results have been shown in other short-duration studies occurring within four (Schubert, Clarke, Seay, & Spain, 2017; Willoughby, Thomas, Schmale, Copeland, & Hazell, 2016) to six weeks (Metcalfe et al., 2012). This rapid improvement in VO_{2max} could be beneficial for older adults with low fitness who are interested in improving health and fitness parameters.

High intensity interval training is characterized by "brief, repeated bursts of relatively intense exercise… [alternate with] periods of rest or low-intensity exercise," (Gibala, 2008). Traditional HIT protocols comprise of three training sessions per week on a cycle ergometer or treadmill and consist of intervals lasting anywhere from 6-seconds (Jakeman, 2012) to 4-minutes (Wisloff, 2007; Tjonna, 2008). It is a highly adaptable training modality and can be adjusted based on the target population, though protocols typically consist of four to five intervals, three days per week. Additionally, the low exercise volume makes HIT an attractive alternative for adults who cite lack of time as a barrier to exercise (Taylor, 2014). High Intensity Interval Walking (HIW), originally introduced by Nemoto (2007), is a variation of the HIT protocol. Nemoto et al., (2007) designed the HIW protocol to contain five or more sets of three-minute walking intervals that correspond to 70-85% VO_{2peak} alternating with two- to three-minutes of recovery at a low intensity (~40% VO_{2peak}), a minimum of four days per week (Nemoto, 2007). This study, specifically, was conducted largely off-site and unsupervised. Similar to traditional HIT and traditional exercise modalities, HIW has shown to improve maximal oxygen consumption in older adults and people with Type 2 diabetes (Nemoto, 2007; Morikawa, 2011; Masuki, 2014; Karstoft, 2013). Further investigation of the translation of HIT or HIW to the community is warranted. To date, none of these protocols have paired theoretical constructs with unsupervised HIT or HIW.

The purpose of this study was to determine if older adults' maximal oxygen consumption increased following a theoretically guided, 4-week high intensity interval walking (HIW) intervention. It was hypothesized that older adults will experience improvements in VO_{2max} following the intervention. A secondary purpose of this study was to determine if older adults increased PA time spent in intensities similar to a normal or faster than normal walking speed following the same intervention. It was hypothesized that older adults will engage in more PA following the intervention than at baseline.

Methods

Study Design

This randomly controlled, theoretically guided, HIW intervention spanned 4-weeks. Prior to the intervention, participants who were allocated to the intervention group completed two training sessions to learn the HIW intervention protocol. Week 1 of the intervention consisted of two supervised sessions, with the third session having been conducted on their own, and weeks 2-4 were unsupervised. Various theoretical constructs were implemented over the course of the study to improve participant adherence. An overview of the study timeline is presented in Figure 4.1.

Participants

Twenty-one adults, age 60-85 years old, were recruited for this study. Inclusion criteria comprised: a) age 60-85 years, b) inactive (not meeting current ACSM aerobic exercise recommendations (<150 minutes of moderate intensity physical activity, or <75 minutes of vigorous intensity physical activity, per week), and c) have obtained primary care provider approval prior to enrollment. Exclusion criteria included use of any type of assistive walking device or lower limb amputation, uncontrolled cardiovascular (hypertension (i.e. a resting blood pressure greater than 160/100 mmHg), pulmonary, or metabolic disease, or use of medications that negatively affect balance or control heart rate. Participants were recruited from the local Milwaukee area via flyers, telephone, and word of mouth. There was a $10.00 compensation after baseline measures, and another $10.00 upon the successful completion of the intervention. Prior to the start of the study, participants provided written consent per the University of Wisconsin-Milwaukee institutional review board protocol.

Study Timeline

<u>Participant Randomization</u>

Upon providing consent, participants were assigned to the control group (CON) or intervention group (HIW) via block randomization. Blocks consisted of ten participants each, and participants were randomly assigned to either group as they enrolled.

Control Group

Participants allocated to the CON group completed baseline and post-testing measures and were instructed to maintain current physical activity habits. Upon completing the study, participants in the control group could receive the exercise protocol if they so desired.

Intervention Group

Participants allocated to the HIW group completed a two-day training following baseline measures. After the training, participants completed two additional supervised sessions during the first week of the intervention. The remainder of the intervention was unsupervised, after which participants completed post-testing measures.

Procedures

Training Sessions

Training sessions encompassed two separate visits. The purpose of the training sessions was to ensure that the participants were familiar with the protocol and to help promote adherence. Higgins et al., (2014) reported that lack of knowledge and mastery experiences are common barriers to PA engagement in older adults, and these training sessions were included to help promote knowledge and mastery of the protocol. First, Participants were fitted with a heart rate monitor (Polar USA, Lake Success, NY, USA) so that the researcher could provide feedback on training intensity. Next, the researcher provided a description of what a vigorous intensity would feel like and how to use a 10-point rating of perceived exertion (RPE) scale to gauge intensity. Based on total body feel, participants aimed for an RPE of '7' or '8', which coincides with a vigorous intensity (Borg, 1982) and 70-80% heart rate reserve (HRR). The Tanaka, Monahan, & Seals (2001) equation (HR_{max}= 208 – 0.7 x age) was used to estimate maximal heart rate (HR_{max}), which has been shown to be a better estimation tool for older adults compared to other methods (Tanaka, 2001). After providing the intensity description, the researcher taught the participants how to measure HR using radial artery palpitation (Swain, 2014, pg 326). To simplify the process, HR was measured for 15-seconds and a HR range that coincided with 70-80% HRR for the fast-walking intervals was assigned to each participant. For example, if an individual had a target HR range of 120-135, the 15-second range was 30-34 beats per 15 seconds.

Once participants mastered measuring resting HR, they alternated walking for one minute at the vigorous intensity and a self-selected recovery pace. The participant measured HR at the end of each minute, with the heart rate monitor providing confirmation of the measurement. Participants also practiced recording rating of perceived exertion and HR after each fast and slow interval. Self-monitoring, such as record keeping, has been shown to be effective for promoting exercise adherence in older adults (Wilcox et al., 2016). Participants continued to alternate between fast and slow walking minutes until they felt comfortable with the protocol, for up to three fast-slow intervals. At the end of the session participants recorded session-RPE, which is the overall rating of the exercise session using the same 1-10-point scale (Herman, Foster, Maher, Mikat, & Porcari, 2016; Foster et al., 2001). The second day of training was additional time to review the protocol and measuring techniques prior to the start of the exercise intervention. If the researcher deemed it necessary, a third training day was incorporated prior to the start of the intervention.

Intervention Protocol

Exercise sessions took place three days per week with at least one day of rest between sessions (i.e. a sequence of Monday, Wednesday, and Friday). During the first week of the study, participants reported to campus to complete two of the HIW sessions, separated by one unsupervised session. Sessions began with the participant measuring and recording resting heart rate. Next, participants completed a standardized five-minute warm up that consisted of three-minutes of walking at a self-selected walking speed and two-minutes of lower-limb stretches. The HIW protocol alternated between five, two-minute vigorous-intensity walking intervals and five, two-minute, self-paced recovery intervals. Fifteen-to-thirty seconds of the start and end of the recovery interval was passive, at which time participants will record HR and RPE. Participants had the option to use a free phone-app to alert them when each fast and slow interval was up, but each participant opted to use a traditional stopwatch to monitor their time. The remaining recovery time consisted of walking at a self-selected pace. Vigorous intensity exercise volume equated to 10-minutes, three days per week. Participants were encouraged to take extra time to warm up and cool down as needed. Session RPE and one-minute recovery HR were recorded at the end each session. The remaining intervention weeks were unsupervised, and away from campus. The intervention protocol is presented in Figure 4.2.

Finally, participants received weekly phone calls from the researcher to clarify any questions regarding the protocol and receive encouragement. Unsupervised interventions with regular phone calls (>1/month) have been shown to just as effective in promoting participant adherence as lab-based, supervised interventions (Geraedts et al., 2013). Social support for activity is important for older adults, and these phone calls served as a form of support.

Measures

All measures were assessed at baseline and within one week of the completion of the intervention (HIW group)/completion of the study (CON group).

Baseline Demographics and Anthropometrics

Participants provided demographic and health history questionnaire at baseline. Resting heart rate and blood pressure measures were assessed via manual palpitation and auscultation (American Diagnostic Corporation, Hauppauge, NY, USA), respectively, following standardized procedures (ACSM, 2014, pgs. 326-329). Height (cm) and mass (kg) were measured using a stadiometer and physician's scale (Detecto Weigh Beam Eye-Level, Webb City, MO, USA), following standardized procedures (Swain, 2014, pgs. 290-291), and body mass index (BMI) was calculated (kg/m^2).

Nine-Minute Walking Test

An over ground, nine-minute walking test was used to estimate maximal oxygen consumption (VO_{2max}). A GT3X+ accelerometer (Actigraph, Pensacola, FL, USA), placed on the right hip, collected activity data during the test. Frequency was set to 100 Hz and sampling rate was set to 1-second epochs. Participants walked continuously for nine-minutes and received prompts every three-minutes from the researcher to increase walking speed from self-selected slower than normal, normal, and faster than normal walking speeds. Distance (m) per stage was measured using a distance wheel, and gait speed ($m \cdot s^{-1}$) was calculated.

Physical Activity Monitoring

All participants completed seven-days of PA monitoring at baseline. Seven days was selected based on previous research by Hart, Swartz, Cashin, & Strath (2011), who determined that a minimum of five days of PA monitoring was necessary to capture typical PA behavior in older adults, ranging from sedentary to vigorous intensity activities. Participants received a GT3X+ accelerometer (Actigraph, Pensacola, FL, USA) to wear on the right hip, and maintained their usual activity behavior during baseline testing. Participants wore the monitor from the time they woke up to the time they went to bed at night and maintained a wear time log.

The GT3X+ accelerometer is a triaxial monitor, capable of storing 512 MB of data, or 40 days of data at 30 Hertz (Hz) (Strath et al., 2013). Monitors were initialized per manufacturer's instructions prior to leaving the lab after baseline testing. Frequency was set to 100 Hz, and sampling rate was set to 60-second epochs. Ten hours of wear was required to constitute a valid day. Non-wear time was defined as >60 minutes of consecutive zero counts (Choi, Matthews, & Buchowski, 2011). Activity monitoring took place again following post-testing measures.

<u>Self-Efficacy for Exercise Scale</u>

A nine-item scale assessed changes in self-efficacy (SE) for exercise (Resnick & Jenkins, 2000). The prompt read "How confident are you right now that you could exercise three times per week for 20 minutes if," and listed several conditions including the weather, feelings towards the program, stress, etc. The survey is scored out of a maximum of 90 points, with the higher score indicating higher levels of SE (Resnick & Jenkins, 2000). This survey was distributed at baseline and during post-testing measures for both groups, and immediately after the second in-person teaching session for the HIW group.

Statistical Analysis

<u>Estimation of Maximal Oxygen Consumption</u>

Maximal oxygen consumption was calculated using an equation that coincided with data from a ramped intensity, three-stage, nine-minute over ground walking test. Age (years), gender (male=1), mass (kg), resting heart rate (bpm), and gait speed ($m \cdot s^{-1}$) during the normal walking stage were covariates. This equation yielded an R^2 value of .78 and a root mean square error of 4.762 $ml \cdot kg^{-1} \cdot min^{-1}$, following validation.

$$VO_{2max} = 71.47 - 0.38*Age - 0.25*RHR + 10.00*MALE - 0.25*Mass + 7.49*Normal\ Gait\ Speed$$

Protocol Adherence

Adherence to the HIW protocol was assessed using the self-reported exercise HR data that coincided with each fast interval. If the participant was within one beat of the prescribed range, it qualified as hitting the target. There were 12 sessions over the course of the intervention, with five fast intervals per session. Adherence was calculated as a percentage out of 60 fast intervals.

Analysis

Changes in Physical Activity

Accelerometer data from the nine-minute walking test was used to create individualized intensity cut points that coincide with a slower than normal, normal, and faster than normal walking speeds. Data was converted from 1-second to 60-second averaging, which was then averaged across each three-minute walking stage. These individualized cut points were used to analyze differences in PA behaviors at baseline compared to post-intervention. Percent wear time (PWT) using valid wear time was calculated for each walking intensity.

Statistical Analysis

Statistical analysis was completed using IBM SPSS Statistical Software Version 22. Differences in baseline characteristics, including height, weight, estimated VO_{2max}, and accelerometer data, were assessed between groups using the non-parametric Mann-Whitney U test for two independent samples. Gender differences were assessed using the chi-square test. Difference scores from pre- to- post were calculated, and the Mann-Whitney U test for two independent samples assessed differences between groups for anthropometrics, VO_{2max}, and accelerometer data. Alpha was set to $p<0.05$.

Results

Participant Characteristics

Over the course of the study, there were three dropouts from the HIW group. One participant completed the intervention but did not respond when it was time to complete post-testing, another participant had to withdraw due to personal scheduling issues, and the third participant suffered a minor hamstring pull and ultimately dropped out due to unrelated health reasons. A CONSORT flow diagram of recruitment and enrollment is presented in Figure 4.3.

Baseline characteristics are reported in Table 4.1. There were no significant differences between the two groups at baseline. Groups had a similar percentage of females (~65%), age (~71 years), and BMI (~28 $kg \cdot m^{-2}$). VO_{2max} was not significantly different between groups, but it should be noted that there was an outlier in the CON group that had a noticeably lower estimated VO_{2max} relative to the rest of the group.

Anthropometrics

There were no significant changes within group over time, but diastolic blood pressure did approach significance for the HIW group (p=0.066). Change in body mass (pre-to-post) was significantly different between groups (p=0.016). Although it was not significant, differences in change in BMI (p=0.055) and RHR (p=0.068) between groups were approaching significance. There were no other significant differences over time between groups.

Estimated VO_{2max}

The median estimated VO_{2max} (median (minimum, maximum)) slightly decreased for the CON group (baseline: 18.0 (11.6, 22.6) $ml \cdot kg^{-1} \cdot min^{-1}$; post: 17.1 (9.1-23.1) $ml \cdot kg^{-1} \cdot min^{-1}$) and remained stable for the HIW group (baseline: 20.7 (12.7-32.8) $ml \cdot kg^{-1} \cdot min^{-1}$; post: 20.8 (13.2-30.4) $ml \cdot kg^{-1} \cdot min^{-1}$). These changes were not significant (CON: p=0.208, effect size (ES) -0.44;

HIW: *p*=0.386, ES -0.27). There was no significant difference in change over time between groups (*p*=0.237, ES 0.29), either. Despite this insignificance, further investigation of the results showed that seven of the ten HIW participants experienced an improvement in VO_{2max}, compared to three of the eight CON who saw an improvement in VO_{2max} (Figure 4.4).

Physical Activity

At baseline there were no significant differences in PWT across walking intensity cut points between groups (*p*>0.05). Both groups had seven days of valid wear-time, consisting of 12+ hours per day, at baseline and post-intervention (*p*>0.05 between groups). Physical activity profile changed significantly, from baseline to post-testing, in most categories for the HIW group. Median change of PWT for normal walking speed intensity (0.99%, ES -0.89), faster than normal walking speed intensity (0.98%, ES -0.89) and combined normal and faster than normal walking speed intensities (1.89%, ES -0.89) all significantly increased at post-testing (*p*=0.008 for all changes). Change in sedentary intensity PWT (2.77%) and minutes coinciding with slower than normal walking intensity (-4.06%) were not significant (*p*>0.05). The CON group did not experience significant changes in PA profile except for a significant decrease in median PWT spent in faster than normal walking speed intensity (-0.05%, *p*=0.028). These changes are presented in Table 4.3. Compared to the CON group, HIW changes PWT in intensities coinciding with normal walking speed (*p*=0.001, ES -0.78), faster than normal walking speed (*p*<0.001, ES -0.83), and combined normal and faster than normal walking speed (*p*<0.001, ES -0.84) intensities were all significantly different from the CON group. Changes in PWT spent in different PA intensities are presented in Figure 4.5.

Median activity counts relative to wear time increased significantly from baseline (231.6 counts/wear time) to post-intervention (290.4 counts/wear time) for the HIW group (*p*=0.008, ES

-0.89), but not the CON group (207.1 counts/wear time at baseline to 190.8 counts/wear time post-intervention, p=0.398, ES -0.32). The median change in total activity counts was significantly greater in the HIW group than the CON group (p=0.001, ES -0.79). There were no significant differences in total activity counts at baseline.

Self-Efficacy for Exercise

Median scores for the Self-efficacy for Exercise survey significantly improved in the HIW group by 8 points (p=0.022, ES -0.73) but not in the CON group who experienced a decrease of -11.5 points (p=0.400, ES -0.29). Additionally, there was a significant difference in change over time between groups (p=0.012, ES -0.59). The HIW group did not display any significant changes between baseline and the second teaching day (p=0.123) or the second teaching day and post-testing (p=0.400).

Protocol Adherence

Participants completed an exercise session every day that was prescribed to them. However, protocol adherence was extremely bimodal, with participants either meeting 70-100% of the range or 0-50%. The median adherence was 73.3% and the average was 53%. Fifty percent of the HIW group adhered to 70% of the sessions.

Discussion

The purpose of this study was to determine the effects of a 4-week, theoretically guided HIW intervention on estimated VO_2 and physical activity levels in older adults. Compared to a non-exercise CON group, the HIW group did not see significant changes in VO_{2max} compared to baseline. Time spent in different PA intensities did change significantly for the HIW group compared to baseline and compared to the CON group.

Adherence

Adherence to the HIW protocol was extremely bimodal for participants in the intervention group, with a median adherence of 73.3% and average adherence of 53%. This was lower than other unsupervised HIW protocols that reported 90-95% compliance (Karstoft et al., 2013, Morikawa et al., 2011). A distinct difference between these studies and the current study is that they used an accelerometer that alerted participants when they had reached their prescribed intensity and objectively monitored exercise intensity. The present study relied on self-reported heart rate data following each walking interval. Participants received instructions to measure heart rate as quickly as possible after each interval (within the first 15-30 seconds of completion). However, participants did report some difficulty in finding and/or counting their heart rate immediately after the fast walking interval. This could have resulted in a lower reported heart rate. Multiple pre-intervention training sessions were provided to prevent this, and in certain cases additional training days were required prior to allowing participants to go off on their own. In the future, a simple way to address this issue would be to administer a heart rate monitor to each participant.

The HIW group experienced the only dropouts over the course of the study, due to personal reasons. There were no major adverse events to the exercise protocol, although there was one incidence of a self-reported minor hamstring strain. When the event occurred, the participant was instructed to rest and stretch as necessary. However, the participant's return to the study was delayed because they did not abide by these instructions and the healing time was extended. Eventually, the individual had to withdraw due to unrelated health issues. A proper warm up was stressed by the research team at every supervised session, and additional time for warm up was encouraged if the participant or researcher deemed it necessary. Still, a longer warm up and baseline assessment of hamstring flexibility could be beneficial for this population.

Aim 1- Maximal Oxygen Consumption

Although 70% of participants in the HIW experienced an improvement in VO_{2max}, this finding was not significant and is confounded by a low ES for change from baseline to post (-0.27), and for change over 4-weeks compared to the CON group (0.29). Previous traditional HIT and modified HIW studies have shown significant improvements in VO_{2max} of 3 $ml \cdot kg^{-1} \cdot min^{-1}$ in as few as four-to-eight weeks (Boyne et al., 2016, Tsekourus et al., 2008) and 4 $ml \cdot kg^{-1} \cdot min^{-1}$ after four-months (Karstoft et al., 2013, Morikawa et al., 2011). In most cases (Boyne et al., 2016 Tsekourus et al., 2008, Karstoft et al., 2013), the gold standard assessment (e.g. open circuit spirometry) was used to assess changes in VO_{2max}, allowing for a more specific measurement and assessment of changes in VO_{2max}. The current study utilized a predictive field test to estimate VO_{2max} at baseline and post. This protocol was selected to substitute traditional measurement methods to enhance participant safety, however interpretation of results is limited due to the larger error associated with the equation (4.762 $ml \cdot kg^{-1} \cdot min^{-1}$). One study (Morikawa et al., 2011) did utilize a field test estimation method to predict VO_{2max} that had a 10% error rate. Likely significance was discovered due to the very large sample size (N=666).

Error of the equation aside, another possible issue with the method used to estimate VO_{2max} was participant motivation. The VO_{2max} protocol requires participants to walk at a self-selected pace for each stage (less than normal, normal, and faster than normal). Normal gait speed was a major predictor of VO_{2max} and depending on how the participant interpreted a "usual" or "normal" walking pace on a given day could severely impact their results. For example, there was one outlier for the HIW group whose performance, at baseline, far surpassed the rest of the participant pool (~33 $ml \cdot kg^{-1} \cdot min^{-1}$). However, during the post-test, this participant walked ~100 meters fewer during the normal walking speed stage, resulting in a decrease of ~6 $ml \cdot kg^{-1} \cdot min^{-1}$. Interestingly, this participant still outperformed the rest of the field during the follow up visit.

Aim 2- Physical Activity

Generally, physical activity profiles changed significantly for the HIW group, but not the CON group. Both normal and faster than normal PWT intensities increased ~1%, resulting in an increase of ~2% for the combined normal and faster than normal PWT intensity, from baseline to post-testing. This roughly equates to a 170-minute daily increase in time spent at an intensity level coinciding with a combined normal and faster than normal PWT. There were no significant changes in sedentary and slower than normal PWT. It is difficult to interpret these changes, however, as they are not grounded in any established intensity (i.e. moderate or vigorous intensity). Although tempting to link slower than normal walking intensity to light intensity PA, normal walking intensity to moderate intensity PA, and faster than normal walking intensity to vigorous intensity PA, it would be unrealistic to assume that older adults increased their daily combined moderate and vigorous intensity PA by almost 2 hours. For future reference, physiological data, such as heart rate, should be collected at each stage of the nine-minute walk test to truly delineate changes in PA. Total counts relative to wear time did significantly increase, though, from baseline to post-intervention for the HIW group, which was not seen in the CON group and yielded a large ES for differences in changes between groups (-0.79). This indicates that the intervention influenced daily activity.

Self-Efficacy

The current intervention methods were created utilizing behavioral theory. An emphasis was placed on training the HIW group how to properly complete the exercise protocol, including how to measure and report HR and RPE after each interval. Self-efficacy, which is a component of Social Cognitive Theory, was assessed for changes across the intervention, at baseline and post-testing. Additionally, SE was measured after the HIW group completed the pre-protocol training. The HIW experienced a significant improvement in SE from baseline to post-testing, which was not seen in the CON group. Interestingly, SE did not change significantly from baseline to immediately following the pre-protocol training, or from the pre-protocol training to post-testing. A primary contributing factor likely stems from mastery of the exercise protocol. Self-efficacy is defined as one's belief or confidence that they can complete a task or achieve a goal (Bandura, 1988), and mastery influences SE. After the pre-training protocol, the HIW participants had only completed two "training" sessions. Across four-weeks of the exercise intervention, however, the HIW participants completed twelve total training sessions, reinforcing the exercise protocol and promoting mastery (Taylor, 2015). Another factor that could have contributed to improvements in SE for the HIW group was recording HR and RPE data. Self-monitoring is linked to high SE and in recording their own data, participants received immediate feedback on their exercise performance.

Limitations of the Study

There were some limitations to this study, the first being a small sample size which makes it harder to interpret changes in VO_{2max}. Recruitment for the study was slow, and which can be attributed to two reasons. The first is that much of the study took place during the winter months, making it difficult to walk outside and drive to the study site to receive training (there were several instances where people declined to participate based on that fact). The second is that the time between the initial screening and the baseline visit could take up to a month due to requiring primary care provider approval. Typically, participants requested forms to be delivered through the mail which took several days if they were immediately attentive to the release form. Additionally, primary care provider return rate was delayed in many instances. Consequently, some participants lost interest or declined to participate due to the extended timeline. Second, the VO_{2max} estimation equation had a large error rate, making it less sensitive to small changes in VO_{2max} in a sample this small. These limitations, however, came about as an intentional decision to ensure participant safety. A submaximal walking field test to predict VO_{2max} was used to avoid the participant having to work to a maximal effort and prevent any adverse events. In retrospect, the primary care provider step was likely an unnecessary precaution. The screening and exclusion criteria ensured that anyone at risk for a cardiac event would be screened out and unable to participate. It is likely that removing this step would have resulted in a higher sample size allowing for a more favorable VO_{2max} outcome.

Feasibility of the Study & Future Recommendations

This feasibility pilot study is useful for guiding future HIW intervention protocols. Implementing a pre-protocol training appears to be beneficial in teaching older adults how to complete and record data for a HIW protocol. To simplify the HR measurement and confirm that participants are hitting their target HR, a heart rate monitor is recommended. Due to the method to estimate VO_{2max}, low effect size (0.29) for change between groups, and low sample size, it is hard to truly interpret changes resulting from the HIW protocol. A more sensitive measure would be useful to gauge small, but clinical, changes in VO_{2max}. Additionally, a more streamlined approach for screening and recruitment should be implemented.

This pilot study showed that 4-weeks of HIW training is a feasible method to increase PA and SE for exercise. The analysis of changes in PA from baseline to post-testing and comparison of changes between groups yielded large ES. The overall ES between groups for change in normal and faster than normal PWT was -0.83. Similarly, the ES between groups for change in total activity counts was -0.89. Improved SE likely contributed to increased levels of PA following the intervention. Future unsupervised HIW protocols will benefit from a designated pre-protocol training period to promote antecedents to SE (such as mastery) which will improve protocol adherence. It would also be helpful to assess baseline exercise preparedness using, for example, the transtheoretical model to assess stages of change. Further, additional assessments surrounding changes in pain could provide additional information as to the benefits of this exercise protocol. Several participants commented that they felt reduced stiffness or lower leg pain, but these were not recorded in an official capacity. Follow up several months later would also shed important light as to the efficacy of this exercise protocol and the skills acquired during the training sessions influencing overall PA.

In conclusion, this study successfully elicited changes in PA profile and self-efficacy for exercise. More sensitive measures of VO_{2max} are needed to definitively determine the impact of this protocol on physical fitness. This protocol appears to be safe for older adults to complete if a comprehensive warm up is required prior to starting each training session. The recommendations based on the findings from this study will be beneficial in creating future HIW intervention methodology targeting older adults.

Chapter 4 References

Administration on Aging (AoA). (2016). Profile of older Americans: 2015. Retrieved from https://aoa.acl.gov/Aging_Statistics/Profile/2015/3.aspx

American College of Sports Medicine. (2013). *ACSM's guidelines for exercise testing and prescription* Lippincott Williams & Wilkins.

Bandura, A. (1988). Organisational applications of social cognitive theory. *Australian Journal of Management, 13*(2), 275-302.

Barrett, L., & Fiqueiredo, C. (2009). Beyond 50.09: Chronic care: A call to action for health reform, AARP. *Public Policy Institute, Washington, DC.*

Bell, G. J., Harber, V., Murray, T., Courneya, K. S., & Rodgers, W. (2010). A comparison of fitness training to a pedometer-based walking program matched for total energy cost. *Journal of Physical Activity and Health, 7*(2), 203-213.

Boyne, P., Dunning, K., Carl, D., Gerson, M., Khoury, J., Rockwell, B., . . . McCarthy, M. (2016). High-intensity interval training and moderate-intensity continuous training in ambulatory chronic stroke: Feasibility study. *Physical Therapy, 96*(10), 1533-1544.

Centers for Disease Control and Prevention. (2013). The state of aging and health in America 2013. *Atlanta, GA: Centers for Disease Control and Prevention, US Department of Health and Human Services.*

Chase, J. A. (2013). Physical activity interventions among older adults: A literature review. *Research and Theory for Nursing Practice, 27*(1), 53-80.

Choi, L., Liu, Z., Matthews, C. E., & Buchowski, M. S. (2011). Validation of accelerometer wear and nonwear time classification algorithm. *Medicine and Science in Sports and Exercise, 43*(2), 357-364. Doi:10.1249/MSS.0b013e3181ed61a3 [doi]

Ciolac, E. G., Bocchi, E. A., Bortolotto, L. A., Carvalho, V. O., Greve, J. M., & Guimarães, G. V. (2010). Effects of high-intensity aerobic interval training vs. moderate exercise on hemodynamic, metabolic and neuro-humoral abnormalities of young normotensive women at high familial risk for hypertension. *Hypertension Research, 33*(8), 836-843.

Cohen-Mansfield, J., Shmotkin, D., Blumstein, Z., Shorek, A., Eyal, N., & Hazan, H. (2013). The old, old-old, and the oldest old: Continuation or distinct categories? An examination of the relationship between age and changes in health, function, and wellbeing. *The International Journal of Aging and Human Development, 77*(1), 37-57.

DiPietro, L., Dziura, J., Yeckel, C. W., & Neufer, P. D. (2006). Exercise and improved insulin sensitivity in older women: Evidence of the enduring benefits of higher intensity training. *Journal of Applied Physiology, 100*(1), 142-149.

Franco, O. H., de Laet, C., Peeters, A., Jonker, J., Mackenbach, J., & Nusselder, W. (2005). Effects of physical activity on life expectancy with cardiovascular disease. *Archives of Internal Medicine, 165*(20), 2355-2360.

Gibala, M. J., & McGee, S. L. (2008). Metabolic adaptations to short-term high-intensity interval training: A little pain for a lot of gain? *Exercise and Sport Sciences Reviews, 36*(2), 58-63. Doi:10.1097/JES.0b013e318168ec1f [doi]

Hart, T. L., Swartz, A. M., Cashin, S. E., & Strath, S. J. (2011). How many days of monitoring predict physical activity and sedentary 100merican in older adults? *International Journal of Behavioral Nutrition and Physical Activity, 8*(1), 62.

Huang, G., Gibson, C. A., Tran, Z. V., & Osness, W. H. (2005). Controlled endurance exercise training and VO2max changes in older adults: A meta-analysis. *Preventive Cardiology, 8*(4), 217-225.

Jakeman, J., Adamson, S., & Babraj, J. (2012). Extremely short duration high-intensity training substantially improves endurance performance in triathletes. *Applied Physiology, Nutrition, and Metabolism, 37*(5), 976-981.

Jeon, C. Y., Lokken, R. P., Hu, F. B., & van Dam, R. M. (2007). Physical activity of moderate intensity and risk of type 2 diabetes: A systematic review. *Diabetes Care, 30*(3), 744-752. Doi:30/3/744 [pii]

Karstoft, K., Winding, K., Knudsen, S. H., Nielsen, J. S., Thomsen, C., Pedersen, B. K., & Solomon, T. P. (2013). The effects of free-living interval-walking training on glycemic control, body composition, and physical fitness in type 2 diabetic patients: A randomized, controlled trial. *Diabetes Care, 36*(2), 228-236. Doi:10.2337/dc12-0658 [doi]

Kirwan, J. P., Kohrt, W. M., Wojta, D. M., Bourey, R. E., & Holloszy, J. O. (1993). Endurance exercise training reduces glucose-stimulated insulin levels in 60-to 70-year-old men and women. *Journal of Gerontology, 48*(3), M84-M90.

Lee, I. M., Sesso, H. D., Oguma, Y., & Paffenbarger, R. S.,Jr. (2003). Relative intensity of physical activity and risk of coronary heart disease. *Circulation, 107*(8), 1110-1116.

Littman, A., Kristal, A., & White, E. (2005). Effects of physical activity intensity, frequency, and activity type on 10-y weight change in middle-aged men and women. *International Journal of Obesity, 29*(5), 524-533.

Manson, J. E., Stampfer, M., Colditz, G., Willett, W., Rosner, B., Hennekens, C., . . . Krolewski, A. (1991). Physical activity and incidence of non-insulin-dependent diabetes mellitus in women. *The Lancet, 338*(8770), 774-778.

Masuki, S., Mori, M., Tabara, Y., Sakurai, A., Hashimoto, S., Morikawa, M., . . . Higuchi, K. (2014). The factors affecting adherence to a long-term interval walking training program in middle-aged and older people. *Journal of Applied Physiology, 118*(5), 595-603.

Metcalfe, R. S., Babraj, J. A., Fawkner, S. G., & Vollaard, N. B. (2012). Towards the minimal amount of exercise for improving metabolic health: Beneficial effects of reduced-exertion high-intensity interval training. *European Journal of Applied Physiology, 112*(7), 2767-2775.

Morikawa, M., Okazaki, K., Masuki, S., Kamijo, Y., Yamazaki, T., Gen-no, H., & Nose, H. (2011). Physical fitness and indices of lifestyle-related diseases before and after interval walking training in middle-aged and older males and females. *British Journal of Sports Medicine, 45*(3), 216-224. Doi:10.1136/bjsm.2009.064816 [doi]

Mozaffarian, D., Benjamin, E. J., Go, A. S., Arnett, D. K., Blaha, M. J., Cushman, M., . . . American Heart Association Statistics Committee and Stroke Statistics Subcommittee. (2015). Heart disease and stroke statistics—2015 update: A report from the 102merican heart association. *Circulation, 131*(4), e29-322. Doi:10.1161/CIR.0000000000000152 [doi]

Munk, P. S., Staal, E. M., Butt, N., Isaksen, K., & Larsen, A. I. (2009). High-intensity interval training may reduce in-stent restenosis following percutaneous coronary intervention with stent implantation: A randomized controlled trial evaluating the relationship to endothelial function and inflammation. *American Heart Journal, 158*(5), 734-741.

Nemoto, K., Gen-no, H., Masuki, S., Okazaki, K., & Nose, H. (2007). Effects of high-intensity interval walking training on physical fitness and blood pressure in middle-aged and older people. Paper presented at the *Mayo Clinic Proceedings, , 82*(7) 803-811.

Nicklas, B. J., Wang, X., You, T., Lyles, M. F., Demons, J., Easter, L., . . . Carr, J. J. (2009). Effect of exercise intensity on abdominal fat loss during calorie restriction in overweight and obese postmenopausal women: A randomized, controlled trial. *The American Journal of Clinical Nutrition, 89*(4), 1043-1052. Doi:10.3945/ajcn.2008.26938 [doi]

O'Neill, K., & Reid, G. (1991). Perceived barriers to physical activity by older adults. *Canadian Journal of Public Health = Revue Canadienne De Sante Publique, 82*(6), 392-396.

Resnick, B., & Jenkins, L. S. (2000). Testing the reliability and validity of the self-efficacy for exercise scale. *Nursing Research, 49*(3), 154-159.

Rognmo, Ø., Hetland, E., Helgerud, J., Hoff, J., & Slørdahl, S. A. (2004). High intensity aerobic interval exercise is superior to moderate intensity exercise for increasing aerobic capacity in patients with coronary artery disease. *European Journal of Cardiovascular Prevention & Rehabilitation, 11*(3), 216-222.

Sattelmair, J., Pertman, J., Ding, E. L., Kohl, H. W.,3rd, Haskell, W., & Lee, I. M. (2011). Dose response between physical activity and risk of coronary heart disease: A meta-analysis. *Circulation, 124*(7), 789-795. Doi:10.1161/CIRCULATIONAHA.110.010710 [doi]

Schubert, M. M., Clarke, H. E., Seay, R. F., & Spain, K. K. (2017). Impact of 4 weeks of interval training on resting metabolic rate, fitness, and health-related outcomes. *Applied Physiology, Nutrition, and Metabolism*, *42*(10), 1073-1081.

Strath, S. J., Kaminsky, L. A., Ainsworth, B. E., Ekelund, U., Freedson, P. S., Gary, R. A., . . . American Heart Association Physical Activity Committee of the Council on Lifestyle and Cardiometabolic Health and Cardiovascular, Exercise, Cardiac Rehabilitation and Prevention Committee of the Council on Clinical Cardiology, and Council. (2013). Guide to the assessment of physical activity: Clinical and research applications: A scientific statement from the 103merican heart association. *Circulation, 128*(20), 2259-2279. Doi:10.1161/01.cir.0000435708.67487.da [doi]

Swain, D. P., Brawner, C. A., & American College of Sports Medicine. (2014). *ACSM's resource manual for guidelines for exercise testing and prescription* Wolters Kluwer Health/Lippincott Williams & Wilkins.

Talanian, J. L., Galloway, S. D., Heigenhauser, G. J., Bonen, A., & Spriet, L. L. (2007). Two weeks of high-intensity aerobic interval training increases the capacity for fat oxidation during exercise in women. *Journal of Applied Physiology (Bethesda, Md.: 1985), 102*(4), 1439-1447. Doi:01098.2006 [pii]

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology, 37*(1), 153-156.

Tanasescu, M., Leitzmann, M. F., Rimm, E. B., Willett, W. C., Stampfer, M. J., & Hu, F. B. (2002). Exercise type and intensity in relation to coronary heart disease in men. *Jama, 288*(16), 1994-2000.

Taylor, D. (2014). Physical activity is medicine for older adults. *Postgraduate Medical Journal, 90*(1059), 26-32. Doi:10.1136/postgradmedj-2012-131366 [doi]

Tjonna, A. E., Lee, S. J., Rognmo, O., Stolen, T. O., Bye, A., Haram, P. M., . . . Wisloff, U. (2008). Aerobic interval training versus continuous moderate exercise as a treatment for the metabolic syndrome: A pilot study. *Circulation, 118*(4), 346-354. Doi:10.1161/CIRCULATIONAHA.108.772822 [doi]

Tjonna, A. E., Stolen, T. O., Bye, A., Volden, M., Slordahl, S. A., Odegard, R., . . . Wisloff, U. (2009). Aerobic interval training reduces cardiovascular risk factors more than a multitreatment approach in overweight adolescents. *Clinical Science (London, England : 1979), 116*(4), 317-326. Doi:10.1042/CS20080249 [doi]

Tsekouras, Y. E., Magkos, F., Kellas, Y., Basioukas, K. N., Kavouras, S. A., & Sidossis, L. S. (2008). High-intensity interval aerobic training reduces hepatic very low-density lipoprotein-triglyceride secretion rate in men. *American Journal of Physiology.Endocrinology and Metabolism, 295*(4), E851-8. Doi:10.1152/ajpendo.90545.2008 [doi]

Wilcox, S. (2016). Behavioral interventions and physical activity in older adults: Gains and gaps. *Kinesiology Review, 5*(1), 57-64.

Wilcox, S., Dowda, M., Leviton, L. C., Bartlett-Prescott, J., Bazzarre, T., Campbell-Voytal, K., . . . Dunn, A. L. (2008). Active for life: Final results from the translation of two physical activity programs. *American Journal of Preventive Medicine, 35*(4), 340-351.

Willoughby, T. N., Thomas, M. P., Schmale, M. S., Copeland, J. L., & Hazell, T. J. (2016). Four weeks of running sprint interval training improves cardiorespiratory fitness in young and middle-aged adults. *Journal of sports sciences*, *34*(13), 1207-1214.

Wisloff, U., Stoylen, A., Loennechen, J. P., Bruvold, M., Rognmo, O., Haram, P. M., . . . Skjaerpe, T. (2007). Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients: A randomized study. *Circulation, 115*(24), 3086-3094. Doi:CIRCULATIONAHA.106.675041 [pii]

Zaleski, A. L., Taylor, B. A., Panza, G. A., Wu, Y., Pescatello, L. S., Thompson, P. D., & Fernandez, A. B. (2016). Coming of age: Considerations in the prescription of exercise for older adults. *Methodist DeBakey Cardiovascular Journal, 12*(2), 98-104. Doi:10.14797/mdcj-12-2-98 [doi]

Table 4.1 Baseline Characteristics			
	CON (n=8)	HIW (n=10)	*p*
Female (%)	62.5	70.0	0.750
Age (years)	72.3 ± 6.6	71.4 ± 4.6	0.595
Height (cm)	170.9 ± 8.3	167.1 ± 10.7	0.645
Mass (kg)	83.8 ± 16.9	76.5 ± 11.1	0.161
BMI ($kg \cdot m^{-2}$)	28.5 ± 4.4	27.3 ± 3.4	0.414
Estimated VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	17.4 ± 4.6	21.4 ± 5.5	0.238

Comparison of baseline participant characteristics between groups. There were no significant differences. Data are presented as Mean ± SD. CON= Control Group, HIW= High Intensity Interval Walking Group.

Table 4.2 Anthropometrics

	CON Group (n=8)		HIW Group (n=10)		
	Pre	Post	Pre	Post	*p*
Mass (kg)	88.1 (57.9, 101.9)	88.6 (58.6, 105.1)	76.4 (55.4, 89.6)	76.6 (55, 88)	**0.016**
BMI ($kg \cdot m^{-2}$)	29.4 (20.6, 34.3)	29.7 (20.9, 34.4)	27.2 (18.9, 32.7)	27.3 (19.0, 32.6)	0.055
RHR (bpm)	69.0 (60, 81)	72.0 (61.0, 84.0)	64.0 (57.0, 84.0)	61.0 (51.0, 83.0)	0.068
SBP (mmHg)	124.5 (120, 143)	125.5 (109, 131)	121.0 (113, 140)	115.5 (100, 144)	0.829
DBP (mmHg)	80.5 (63, 90)	80.0 (64, 90)	79.0 (69, 90)	70.0 (61.0, 88.0)	0.101

Changes in anthropometric measures from pre to post, and comparison in changes across time between groups. **Bolded** *P*-values indicate difference over time between groups. There were no significant changes over time within groups. Data presented as Median (Min, Max). BMI= Body Mass Index, RHR= Resting Heart Rate, SBP= Systolic Blood Pressure, DBP= Diastolic Blood Pressure

Table 4.3 Percent Wear Time								
	CON (n=7)				HIW (n=9)			
	Baseline (%)	Post (%)	*P*	ES	Baseline (%)	Post (%)	*P*	ES
Sedentary	64.7	63.3	.499	-0.26	59.3	65.6	.953	-0.02
<Normal	31.1	32.5	.237	-0.45	34.2	28.2	.173	-0.45
Normal*	4.8	4.2	.128	-0.57	3.7	4.4	**.008**	-0.89
>Normal*	0.2	0.2	.063	-0.70	0.4	1.5	**.008**	-0.89
Normal/ >Normal*	5.9	5.2	.128	-0.57	4.4	6.2	**.008**	-0.89

Comparison of change in percent wear time across different intensity cut points. The HIW group significantly increased time spent at normal, >normal, and combined normal/>normal intensities (p=0.008 for all). *Indicates significant difference in change between groups (p<0.01). Effect size between groups for normal, >normal, and combined normal/>normal intensities was -0.78, -0.78, and -0.83, respectively.

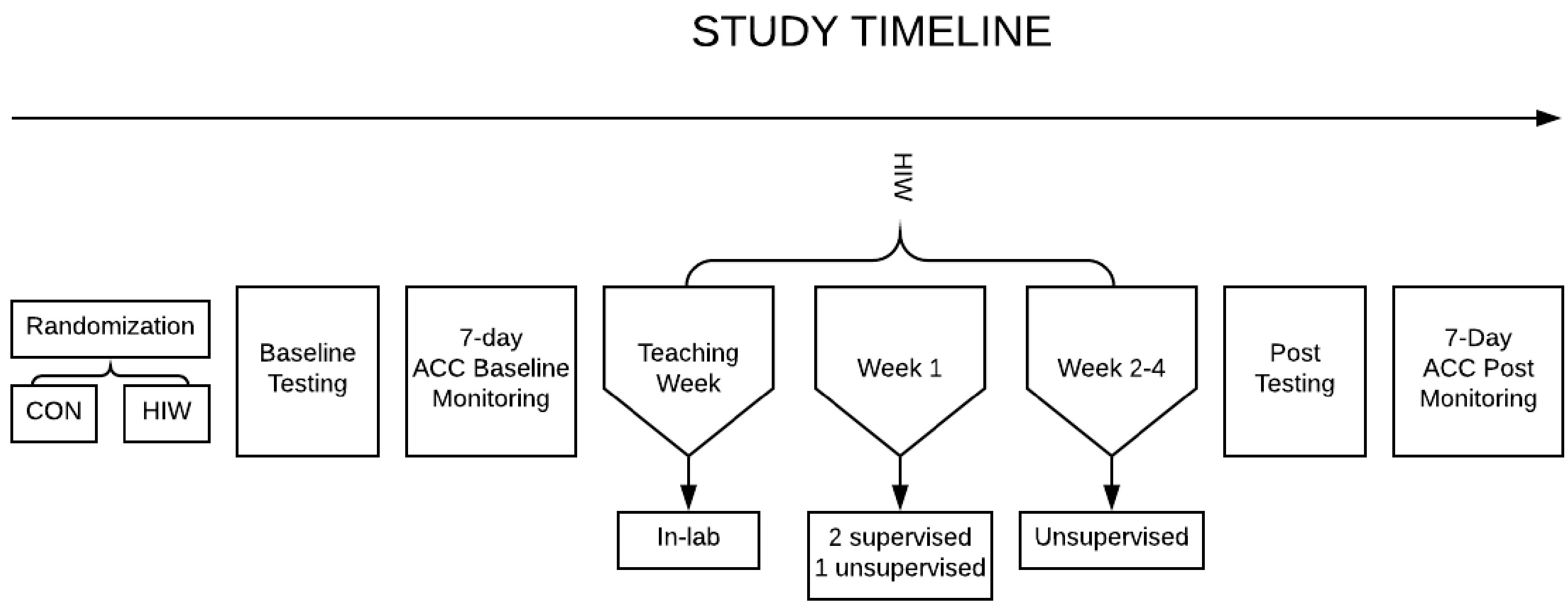


Figure 4.1 Timeline of the "HIT the Ground Walking" study. Participants received a $10 gift card after 7-day ACC baseline monitoring and after 7-day ACC post monitoring. CON= Control; HIW= High Intensity Interval Walking; ACC= Accelerometer.

High Intensity Interval Walking Protocol

	70-80% HRR		70-80% HRR		70-80% HRR		70-80% HRR		70-80% HRR	
		SS Pace		SS Pace		SS Pace		SS Pace		SS Pace
Warm Up (5-min)	INT1	Rec1	INT2	Rec2	INT3	Rec3	INT4	Rec4	INT5	Rec5

Figure 4.2. Visual representation of the high intensity walking protocol. Each interval was 2-minutes in duration, excluding the final recovery interval which was 3-minutes. INT= Fast interval; Rec= Recovery interval; HRR= Heart rate reserve; SS= Self-selected.

CONSORT Flow Diagram

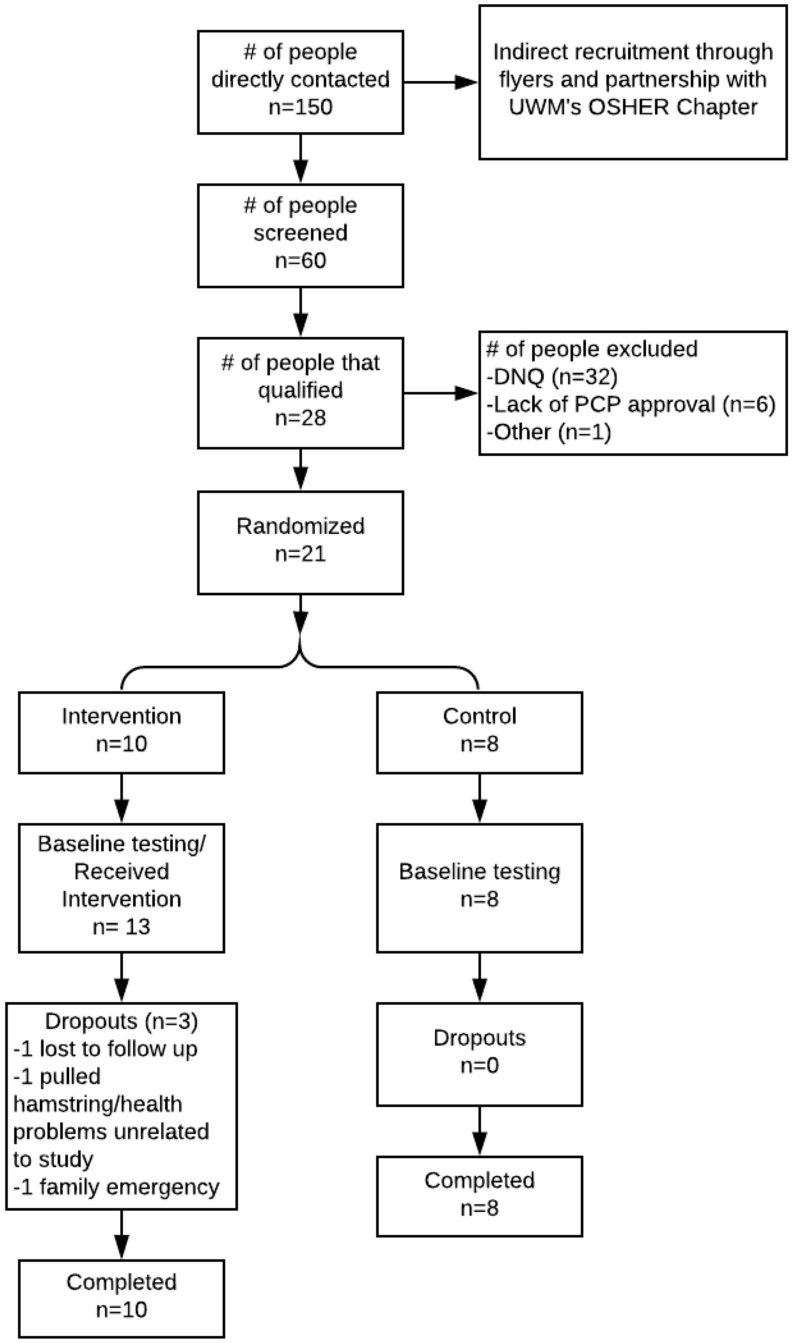


Figure 4.3. CONSORT diagram to show recruitment, enrollment, randomization, and completion of the study.

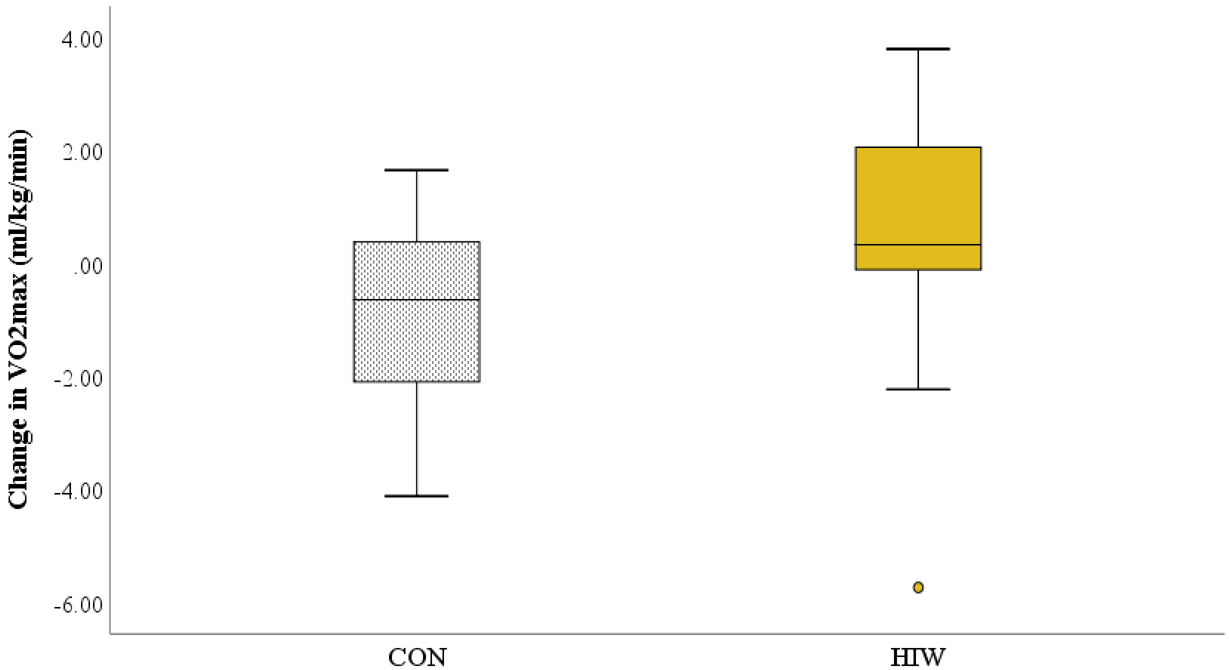


Figure 4.4 Median changes in VO_{2max} between the Control (CON) and High Intensity Interval Walking (HIW) groups. Data presented as Median (25^{th}, 75^{th} quartile). The CON group experienced a 0.9 $ml \cdot kg^{-1} \cdot min^{-1}$ non-significant decrease in VO_{2max} (p=0.208). The HIW group experienced a 0.1 $ml \cdot kg^{-1} \cdot min^{-1}$ non-significant increase in VO_{2max} (p=0.386). Change was not significantly different between groups (p=0.237).

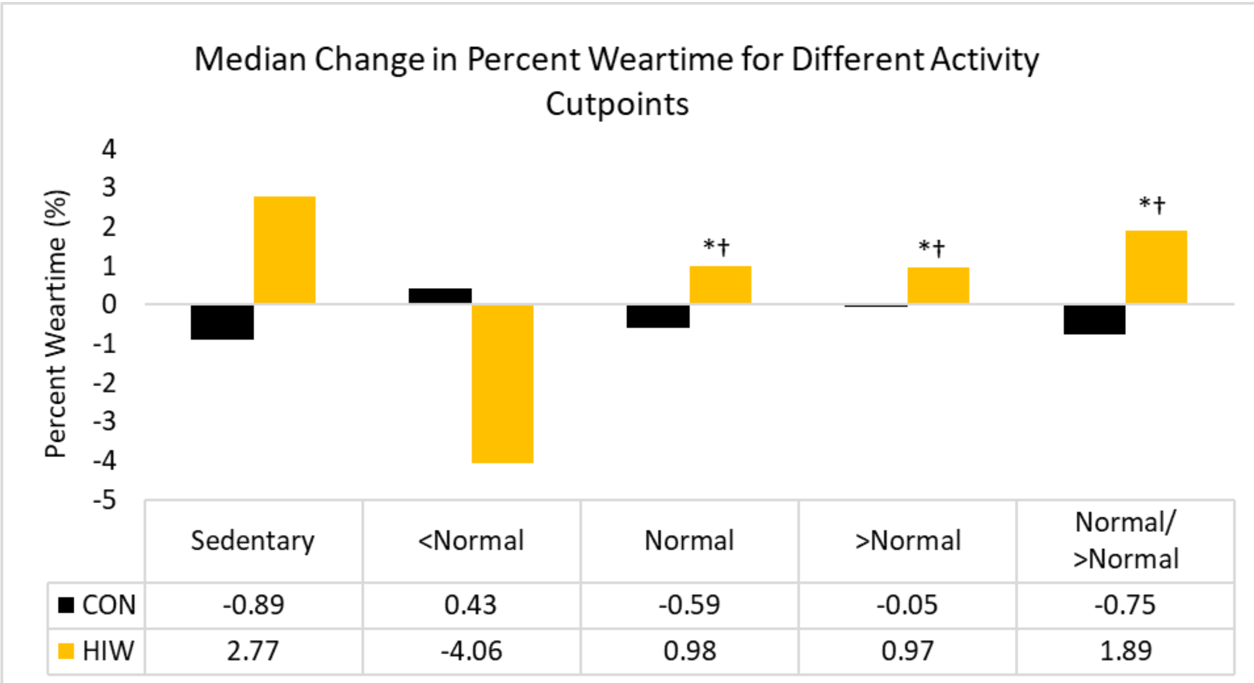


Figure 4.5 Median changes in percent wear time that coincide with sedentary, slower than normal walking speed, normal walking speed, faster than normal walking speed, and combined faster than normal walking speed from baseline to post-intervention (4-weeks). CON= Control Group, HIW= High Intensity Interval Walking Group. *Significant difference from CON group (*p*<0.01). †Significant from baseline (HIW group only).

CHAPTER FIVE

Conclusion

The older adult population within the United States is the most rapidly growing segment of the total population. Incidence of chronic disease increases with older age, so likely as the demographic landscape continues to shift the health of the nation will shift as well. This places an unprecedented burden on the healthcare system as there are more people to care for than ever before. Now, more than ever, preventative measures are needed to decrease chronic disease rates. Regular PA and exercise are cost-effective solutions to this quandary. In fact, routine PA is linked to decreased incidence of cardiovascular disease and metabolic conditions, such as Type 2 diabetes mellitus and obesity. Physical fitness is also improved which is important for older adults maintaining independence. Despite these benefits, though, activity engagement is low in adult and older adult populations.

Physical activity interventions are being developed in response to low activity levels. For interventions to be successful, it is important to gauge and address barriers to PA and exercise that are unique to the population being studied. Adults in general cite lack of time as the primary barrier to exercise, and older adults cite lack of knowledge or understanding for how to safely engage in exercise as a barrier as well. While traditional, moderate-intensity PA is known to improve health parameters and physical fitness, a greater exercise volume and thus time commitment is required to complete this mode of exercise. A proposed solution to this is HIT training, which is a high intensity, low-volume exercise protocol that alternates high intensity sprint bouts with lower intensity recovery bouts. High intensity interval training has been shown to elicit health and fitness benefits similar to continuous, moderate-intensity training. Further, HIT training has been shown to be more enjoyable than traditional training, affecting protocol adherence. Despite these benefits, traditional HIT training involving maximal or near maximal running or cycling sprints could be too much for older adults from a safety and/or feasibility standpoint. A more appropriate alternative to traditional HIT training is HIW training. This method follows a similar format to traditional HIT, but the fast intervals are a brisk walk rather than a sprint. High intensity interval walking has shown to elicit similar results to traditional HIT, including improved physical fitness.

Study 1

Maximal oxygen consumption is the primary measure for assessing cardiorespiratory fitness. Traditional methods to assess VO_{2max}, however, are not always a safe or feasible option for older adult populations. Field tests to estimate VO_{2max} are a safer alternative as they do not require a maximal effort from the participant. The first study of this dissertation project sought to develop and validate different walking and stepping field tests to predict VO_{2max} across a broad range of ages (18-79 years). Across all eight tests (five walking and three stepping), bias-adjusted variance hovered around 80% and error of ~4.5 $ml \cdot kg^{1} \cdot min^{-1}$. These results are similar to previously reported field tests. All of the equations had a base model that consisted of age, gender, and body mass. The base model alone accounted for about 72% of variance and had an error of ~5.4 $ml \cdot kg^{-1} \cdot min^{-1}$. Additional covariates for the tests included resting heart rate, recovery heart rate, distance covered, gait speed, step height, and stepping cadence, entered in subsequent stages.

Of the walking tests, the highest performer was a two-minute walking test where participants cover as much distance as possible. This test yielded a bias-adjusted variance of 82.4% and an error of 4.3 $ml \cdot kg^{-1} \cdot min^{-1}$. The stepping tests accounted for a greater amount of variance in VO_{2max} and had a lower error rate compared to the walking tests. Of the three stepping tests, a three-stage, 9-minute step test using an 8-inch step elicited the best results. Bias-adjusted variance was 83.4% and error was 4.1 $ml \cdot kg^{-1} \cdot min^{-1}$.

Study 2

Older adults are not meeting the recommended exercise guidelines and cite unique barriers to PA and exercise, including a lack of knowledge. The purpose of this study was to pilot a four-week HIW protocol in older adults and gauge changes in VO_{2max} and physical activity levels. Adherence to the protocol was lower than previously published studies, but it is potentially the result of underreported exercise HR. Maximal oxygen consumption did not significantly change for either group, but analysis did show that 7/10 participants did improve VO_{2max}. Physical activity profiles did improve significantly for the HIW group from baseline to post-testing and compared to changes in the CON group. The effect size for these changes were large (~.9) and are likely attributed to positive changes in SE, which improved significantly in the HIW group.

Recommendations Based on Findings

Findings from these studies will benefit future fitness testing options and guide future intervention methodology. A strength of the field tests developed in Study 1 is that they are appropriate for a broad population. Each test has been validated for adults up to 79 years of age. Additionally, since the difference in variance and error small between tests, there is flexibility in terms of which test is used to estimate VO_{2max}. Further work is needed to continue to reduce the error of models estimating VO_{2max} to improve the prediction accuracy. In doing this, fitness testing measures will become increasingly available to broad populations where maximal testing is not feasible.

The results from Study 2 will help guide future HIW and PA interventions. Strengths of the study include theory-guided methodology, which addresses barriers to PA that are unique to the older adult population. Incorporating pre-protocol training sessions to instruct participants how to complete the protocol appear to be effective in promoting mastery. A simple recommendation to replace manual HR palpitation with a HR monitor will allow for a more complete understanding of protocol adherence. Fitness levels did not improve significantly for the HIW group, so future studies should utilize more precise measurement methods to assess potentially clinically significant improvements in VO_{2max}. Physical activity levels did improve significantly for the HIW group and compared to the CON group, suggesting that this intervention method is effective for increasing PA engagement. Future studies should incorporate long-term follow up assessment to determine if changes in PA are acute or are long lasting.

Conclusion

With increased age comes increased incidence of chronic disease and decreased PA participation, despite the benefits of PA for promoting improvements in health and fitness. A safe and feasible alternative to traditional fitness assessment methods are submaximal field tests, such as walking or stepping tests. The flexibility of these tests allows for broader populations, such as older adults, to safely estimate fitness levels. Older adults have unique barriers to exercise and PA, which should be addressed when intervening. A theoretically guided, HIW protocol is effective for increasing PA levels and improving SE for exercise. Future studies should continue to improve submaximal methods to assess fitness and should continue to incorporate theory into HIW interventions to improve PA participation in older adults.

References

Administration on Aging (AoA). (2016). Profile of older Americans: 2015. Retrieved from https://aoa.acl.gov/Aging_Statistics/Profile/2015/3.aspx

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179-211.

Akalan, C., Robergs, R. A., & Kravitz, L. (2008). Prediction of VO2max from an individualized submaximal cycle ergometer protocol. *Journal of Exercise Physiology Online, 11*(2), 1-17.

American College of Sports Medicine. (2013). *ACSM's guidelines for exercise testing and prescription* Lippincott Williams & Wilkins.

American College of Sports Medicine, Chodzko-Zajko, W. J., Proctor, D. N., Fiatarone Singh, M. A., Minson, C. T., Nigg, C. R., . . . Skinner, J. S. (2009). American college of sports medicine position stand. Exercise and physical activity for older adults. *Medicine and Science in Sports and Exercise, 41*(7), 1510-1530. Doi:10.1249/MSS.0b013e3181a0c95c [doi]

Avery, L., Flynn, D., van Wersch, A., Sniehotta, F. F., & Trenell, M. I. (2012). Changing physical activity behavior in type 2 diabetes: A systematic review and meta-analysis of behavioral interventions. *Diabetes Care, 35*(12), 2681-2689. Doi:10.2337/dc11-2452 [doi]

Bandura, A. (1988). Organisational applications of social cognitive theory. *Australian Journal of Management, 13*(2), 275-302.

Barrett, L., & Fiqueiredo, C. (2009). Beyond 50.09: Chronic care: A call to action for health reform, AARP. *Public Policy Institute, Washington, DC,*

Bartlett, J. D., Close, G. L., MacLaren, D. P., Gregson, W., Drust, B., & Morton, J. P. (2011). High-intensity interval running is perceived to be more enjoyable than moderate-intensity continuous exercise: Implications for exercise adherence. *Journal of Sports Sciences, 29*(6), 547-553.

Bassett Jr, D. R., Howley, E. T., Thompson, D. L., King, G. A., Strath, S. J., McLaughlin, J. E., & Parr, B. B. (2001). Validity of inspiratory and expiratory methods of measuring gas exchange with a computerized system. *Journal of Applied Physiology, 91*(1), 218-224.

Bauer, U. E., Briss, P. A., Goodman, R. A., & Bowman, B. A. (2014). Prevention of chronic disease in the 21st century: Elimination of the leading preventable causes of premature death and disability in the USA. *The Lancet, 384*(9937), 45-52.

Bell, G. J., Harber, V., Murray, T., Courneya, K. S., & Rodgers, W. (2010). A comparison of fitness training to a pedometer-based walking program matched for total energy cost. *Journal of Physical Activity and Health, 7*(2), 203-213.

Bennett, H., Parfitt, G., Davison, K., & Eston, R. (2016). Validity of submaximal step tests to estimate maximal oxygen uptake in healthy adults. *Sports Medicine, 46*(5), 737-750.

Billinger, S. A., VAN Swearingen, E., McClain, M., Lentz, A. A., & Good, M. B. (2012). Recumbent stepper submaximal exercise test to predict peak oxygen uptake. *Medicine and*

Science in Sports and Exercise, 44(8), 1539-1544. Doi:10.1249/MSS.0b013e31824f5be4 [doi]

Borg, G. (1998). The Borg RPE scale. *Borg's Perceived Exertion and Pain Scales*, pg. 29-38.

Boyne, P., Dunning, K., Carl, D., Gerson, M., Khoury, J., Rockwell, B., . . . McCarthy, M. (2016). High-intensity interval training and moderate-intensity continuous training in ambulatory chronic stroke: Feasibility study. *Physical Therapy, 96*(10), 1533-1544.

Braith, R. W., Pollock, M. L., Lowenthal, D. T., Graves, J. E., & Limacher, M. C. (1994). Moderate-and high-intensity exercise lowers blood pressure in normotensive subjects 60 to 79 years of age. *The American Journal of Cardiology, 73*(15), 1124-1128.

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist, 32*(7), 513.

Burgomaster, K. A., Cermak, N. M., Phillips, S. M., Benton, C. R., Bonen, A., & Gibala, M. J. (2007). Divergent response of metabolite transport proteins in human skeletal muscle after sprint interval training and detraining. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 292*(5), R1970-R1976.

Burgomaster, K. A., Howarth, K. R., Phillips, S. M., Rakobowchuk, M., MacDonald, M. J., McGee, S. L., & Gibala, M. J. (2008). Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. *The Journal of Physiology, 586*(1), 151-160.

Burgomaster, K. A., Hughes, S. C., Heigenhauser, G. J., Bradwell, S. N., & Gibala, M. J. (2005). Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. *Journal of Applied Physiology (Bethesda, Md.: 1985), 98*(6), 1985-1990. Doi:01095.2004 [pii]

Centers for Disease Control and Prevention. (2013). The state of aging and health in America 2013. *Atlanta, GA: Centers for Disease Control and Prevention, US Department of Health and Human Services,*

Centers for Disease Control and Prevention. (2015). Glossary of terms. Retrieved from https://www.cdc.gov/physicalactivity/basics/glossary/index.htm

Centers for Disease Control and Prevention (2016).

Centers for Disease Control and Prevention. (2017). National diabetes statistic report, 2017.

Chase, J. A. (2013). Physical activity interventions among older adults: A literature review. *Research and Theory for Nursing Practice, 27*(1), 53-80.

Choi, L., Liu, Z., Matthews, C. E., & Buchowski, M. S. (2011). Validation of accelerometer wear and nonwear time classification algorithm. *Medicine and Science in Sports and Exercise, 43*(2), 357-364. Doi:10.1249/MSS.0b013e3181ed61a3 [doi]

Church, T. S., Gill, T. M., Newman, A. B., Blair, S. N., Earnest, C. P., & Pahor, M. (2008). Maximal fitness testing in sedentary elderly at substantial risk of disability: LIFE-P study experience. *Journal of Aging and Physical Activity, 16*(4), 408-415.

Ciolac, E. G., Bocchi, E. A., Bortolotto, L. A., Carvalho, V. O., Greve, J. M., & Guimarães, G. V. (2010). Effects of high-intensity aerobic interval training vs. moderate exercise on hemodynamic, metabolic and neuro-humoral abnormalities of young normotensive women at high familial risk for hypertension. *Hypertension Research, 33*(8), 836-843.

Cohen-Mansfield, J., Shmotkin, D., Blumstein, Z., Shorek, A., Eyal, N., & Hazan, H. (2013). The old, old-old, and the oldest old: Continuation or distinct categories? An examination of the relationship between age and changes in health, function, and wellbeing. *The International Journal of Aging and Human Development, 77*(1), 37-57.

Coleman, E. (1976). Validation of a submaximal test of maximal oxygen intake. *The Journal of sports medicine and physical fitness*, *16*(2), 106-111.

Conn, V. S., Minor, M. A., Burks, K. J., Rantz, M. J., & Pomeroy, S. H. (2003). Integrative review of physical activity intervention research with aging adults. *Journal of the American Geriatrics Society, 51*(8), 1159-1168.

Cooper, K. H. (1968). A means of assessing maximal oxygen intake: Correlation between field and treadmill testing. *Jama, 203*(3), 201-204.

De Vries, H., Mesters, I., Riet, J. V., Willems, K., & Reubsaet, A. (2006). Motives of 123merica adolescents for using sunscreen: The role of action plans. *Cancer Epidemiology, Biomarkers & Prevention : A Publication of the American Association for Cancer Research, Cosponsored by the American Society of Preventive Oncology, 15*(7), 1360-1366. Doi:15/7/1360 [pii]

DiPietro, L., Dziura, J., Yeckel, C. W., & Neufer, P. D. (2006). Exercise and improved insulin sensitivity in older women: Evidence of the enduring benefits of higher intensity training. *Journal of Applied Physiology, 100*(1), 142-149.

Finucane, F., Sharp, S., Purslow, L., Horton, K., Horton, J., Savage, D., . . . Sleigh, A. (2010). The effects of aerobic exercise on metabolic risk, insulin sensitivity and intrahepatic lipid in healthy older people from the 124merican124d124re cohort study: A 124merican124d controlled trial. *Diabetologia, 53*(4), 624-631.

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., . . . Dodge, C. (2001). A new approach to monitoring exercise training. *The Journal of Strength & Conditioning Research, 15*(1), 109-115.

Foster, C., Farland, C. V., Guidotti, F., Harbin, M., Roberts, B., Schuette, J., . . . Porcari, J. P. (2015). The effects of high intensity interval training vs steady state training on aerobic and anaerobic capacity. *Journal of Sports Science & Medicine, 14*(4), 747-755.

Franco, O. H., de Laet, C., Peeters, A., Jonker, J., Mackenbach, J., & Nusselder, W. (2005). Effects of physical activity on life expectancy with cardiovascular disease. *Archives of Internal Medicine, 165*(20), 2355-2360.

Friedman, J., Hastie, T., & Tibshirani, R. (2001). *The elements of statistical learning* Springer series in statistics New York.

Geraedts, H., Zijlstra, A., Bulstra, S. K., Stevens, M., & Zijlstra, W. (2013). Effects of remote feedback in home-based physical activity interventions for older adults: A systematic review. *Patient Education and Counseling, 91*(1), 14-24.

Gibala, M. J., Little, J. P., Van Essen, M., Wilkin, G. P., Burgomaster, K. A., Safdar, A., . . . Tarnopolsky, M. A. (2006). Short-term sprint interval versus traditional endurance training: Similar initial adaptations in human skeletal muscle and exercise performance. *The Journal of Physiology, 575*(3), 901-911.

Gibala, M. J., & McGee, S. L. (2008). Metabolic adaptations to short-term high-intensity interval training: A little pain for a lot of gain? *Exercise and Sport Sciences Reviews, 36*(2), 58-63. Doi:10.1097/JES.0b013e318168ec1f [doi]

Gillen, J. B., Percival, M. E., Ludzki, A., Tarnopolsky, M. A., & Gibala, M. (2013). Interval training in the fed or fasted state improves body composition and muscle oxidative capacity in overweight women. *Obesity, 21*(11), 2249-2255.

Guimaraes, G. V., Ciolac, E. G., Carvalho, V. O., D'Avila, V. M., Bortolotto, L. A., & Bocchi, E. A. (2010). Effects of continuous vs. interval exercise training on blood pressure and arterial stiffness in treated hypertension. *Hypertension Research, 33*(6), 627-632.

Hagberg, J. M. (1987). Effect of training on the decline of VO2max with aging. *Federation Proceedings, 46*(5), 1830-1833.

Handa, S., Masuki, S., Ohshio, T., Kamijo, Y., Takamata, A., & Nose, H. (2016). Target intensity and interval walking training in water to enhance physical fitness in middle-aged and older women: A 126merican126d controlled study. *European Journal of Applied Physiology, 116*(1), 203-215.

Hart, T. L., Swartz, A. M., Cashin, S. E., & Strath, S. J. (2011). How many days of monitoring predict physical activity and sedentary 126merican in older adults? *International Journal of Behavioral Nutrition and Physical Activity, 8*(1), 62.

Haskell, W. L., Lee, I., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., . . . Bauman, A. (2007). Physical activity and public health: Updated recommendation for adults from the 126merican college of sports medicine and the 126merican heart association. *Circulation, 116*(9), 1081.

Hazell, T. J., Hamilton, C. D., Olver, T. D., & Lemon, P. W. (2014). Running sprint interval training induces fat loss in women. *Applied Physiology, Nutrition, and Metabolism, 39*(8), 944-950.

Heisz, J. J., Tejada, M. G. M., Paolucci, E. M., & Muir, C. (2016). Enjoyment for high-intensity interval exercise increases during the first six weeks of training: Implications for promoting exercise adherence in sedentary adults. *PloS One, 11*(12), e0168534.

Herman, L., Foster, C., Maher, M., Mikat, R., & Porcari, J. (2006). Validity and reliability of the session RPE method for monitoring exercise training intensity. *South African Journal of Sports Medicine, 18*(1), 14-17.

Heydari, M., Freund, J., & Boutcher, S. H. (2012). The effect of high-intensity intermittent exercise on body composition of overweight young males. *Journal of Obesity, 2012*

Higgins, T. J., Middleton, K. R., Winner, L., & Janelle, C. M. (2014). Physical activity interventions differentially affect exercise task and barrier self-efficacy: A meta-analysis. *Health Psychology, 33*(8), 891.

Hood, M. S., Little, J. P., Tarnopolsky, M. A., Myslik, F., & Gibala, M. J. (2011). Low-volume interval training improves muscle oxidative capacity in sedentary adults. *Medicine and Science in Sports and Exercise, 43*(10), 1849-1856. Doi:10.1249/MSS.0b013e3182199834 [doi]

Howley, E. T., Bassett, D. R., & Welch, H. G. (1995). Criteria for maximal oxygen uptake: Review and commentary. *Medicine and Science in Sports and Exercise, 27*(9), 1292-1301.

Huang, G., Gibson, C. A., Tran, Z. V., & Osness, W. H. (2005). Controlled endurance exercise training and VO2max changes in older adults: A meta-analysis. *Preventive Cardiology, 8*(4), 217-225.

Huggett, D. L., Connelly, D. M., & Overend, T. J. (2005). Maximal aerobic capacity testing of older adults: A critical review. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 60*(1), 57-66.

Iwashita, S., Takeno, Y., Okazaki, K., Itoh, J., Kamijo, Y., Masuki, S., . . . Nose, H. (2003). Triaxial accelerometry to evaluate walking efficiency in older subjects. *Medicine and Science in Sports and Exercise, 35*(10), 1766-1772. Doi:10.1249/01.MSS.0000089350.54959.CB [doi]

Jakeman, J., Adamson, S., & Babraj, J. (2012). Extremely short duration high-intensity training substantially improves endurance performance in triathletes. *Applied Physiology, Nutrition, and Metabolism, 37*(5), 976-981.

Jeon, C. Y., Lokken, R. P., Hu, F. B., & van Dam, R. M. (2007). Physical activity of moderate intensity and risk of type 2 diabetes: A systematic review. *Diabetes Care, 30*(3), 744-752. Doi:30/3/744 [pii]

Jessup, J. V., Lowenthal, D. T., Pollock, M. L., & Turner, T. (1998). The effects of endurance exercise training on ambulatory blood pressure in normotensive older adults. *Geriatric Nephrology and Urology, 8*(2), 103-109.

Jette, M., Campbell, J., Mongeon, J., & Routhier, R. (1976). The 128merican home fitness test as a predictor for aerobic capacity. *Canadian Medical Association Journal, 114*(8), 680-682.

Jung, M. E., Bourne, J. E., Beauchamp, M. R., Robinson, E., & Little, J. P. (2015). High-intensity interval training as an efficacious alternative to moderate-intensity continuous training for adults with prediabetes. *Journal of Diabetes Research, 2015*, 191595. Doi:10.1155/2015/191595 [doi]

Karstoft, K., Winding, K., Knudsen, S. H., Nielsen, J. S., Thomsen, C., Pedersen, B. K., & Solomon, T. P. (2013). The effects of free-living interval-walking training on glycemic control, body composition, and physical fitness in type 2 diabetic patients: A randomized, controlled trial. *Diabetes Care, 36*(2), 228-236. Doi:10.2337/dc12-0658 [doi]

Kelly, P., Murphy, M., Oja, P., Murtagh, E. M., & Foster, C. (2011). Estimates of the number of people in 129merica who attain or exceed vigorous intensity exercise by walking at 3 mph. *Journal of Sports Sciences, 29*(15), 1629-1634.

Kemi, O. J., & Wisloff, U. (2010). High-intensity aerobic exercise training improves the heart in health and disease. *Journal of Cardiopulmonary Rehabilitation and Prevention, 30*(1), 2-11. Doi:10.1097/HCR.0b013e3181c56b89 [doi]

Kessler, H. S., Sisson, S. B., & Short, K. R. (2012). The potential for high-intensity interval training to reduce cardiometabolic disease risk. *Sports Medicine, 42*(6), 489-509.

Kirwan, J. P., Kohrt, W. M., Wojta, D. M., Bourey, R. E., & Holloszy, J. O. (1993). Endurance exercise training reduces glucose-stimulated insulin levels in 60-to 70-year-old men and women. *Journal of Gerontology, 48*(3), M84-M90.

Kline, C., Porcari, J. P., Hintermeister, R., Freedson, P. S., Ward, A., Mccarron, R. F., . . . Rippe, J. (1987). Estimation of from a one-mile track walk, gender, age and body weight. *Med.Sports Exerc, 19*, 253-259.

Kodama, S., Saito, K., Tanaka, S., Maki, M., Yachi, Y., Asumi, M., . . . Ohashi, Y. (2009). Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: A meta-analysis. *Jama, 301*(19), 2024-2035.

Larose, J., Sigal, R. J., Khandwala, F., Prud'homme, D., Boulé, N., & Kenny, G. P. (2011). Associations between physical fitness and HbA1c in type 2 diabetes mellitus. *Diabetologia, 54*(1), 93-102.

Lee, L., Arthur, A., & Avis, M. (2007). Evaluating a community-based walking intervention for hypertensive older people in 130meric: A randomized controlled trial. *Preventive Medicine, 44*(2), 160-166.

Lee, I. M., Sesso, H. D., Oguma, Y., & Paffenbarger, R. S.,Jr. (2003). Relative intensity of physical activity and risk of coronary heart disease. *Circulation, 107*(8), 1110-1116.

Little, J. P., Gillen, J. B., Percival, M. E., Safdar, A., Tarnopolsky, M. A., Punthakee, Z., . . . Gibala, M. J. (2011). Low-volume high-intensity interval training reduces hyperglycemia and increases muscle mitochondrial capacity in patients with type 2 diabetes. *Journal of Applied Physiology, 111*(6), 1554-1560.

Little, J. P., Safdar, A., Wilkin, G. P., Tarnopolsky, M. A., & Gibala, M. J. (2010). A practical model of low-volume high-intensity interval training induces mitochondrial biogenesis in human skeletal muscle: Potential mechanisms. *The Journal of Physiology, 588*(6), 1011-1022.

Littman, A., Kristal, A., & White, E. (2005). Effects of physical activity intensity, frequency, and activity type on 10-y weight change in middle-aged men and women. *International Journal of Obesity, 29*(5), 524-533.

Macpherson, R. E., Hazell, T. J., Olver, T. D., Paterson, D. H., & Lemon, P. W. (2011). Run sprint interval training improves aerobic performance but not maximal cardiac output. *Medicine and Science in Sports and Exercise, 43*(1), 115-122. Doi:10.1249/MSS.0b013e3181e5eacd [doi]

Manson, J. E., Greenland, P., LaCroix, A. Z., Stefanick, M. L., Mouton, C. P., Oberman, A., . . . Siscovick, D. S. (2002). Walking compared with vigorous exercise for the prevention of cardiovascular events in women. *New England Journal of Medicine, 347*(10), 716-725.

Manson, J. E., Stampfer, M., Colditz, G., Willett, W., Rosner, B., Hennekens, C., . . . Krolewski, A. (1991). Physical activity and incidence of non-insulin-dependent diabetes mellitus in women. *The Lancet, 338*(8770), 774-778.

Martin, D., & Kauwell, G. P. (1990). Continuous assistive-passive exercise and cycle ergometer training in sedentary women. *Medicine and Science in Sports and Exercise, 22*(4), 523-527.

Masuki, S., Mori, M., Tabara, Y., Sakurai, A., Hashimoto, S., Morikawa, M., . . . Higuchi, K. (2014). The factors affecting adherence to a long-term interval walking training program in middle-aged and older people. *Journal of Applied Physiology, 118*(5), 595-603.

McArdle, W. D., Katch, F. I., Pechar, G. S., Jacobson, L., & Ruck, S. (1972). Reliability and interrelationships between maximal oxygen intake, physical work capacity and step-test scores in college women. *Medicine and Science in Sports, 4*(4), 182-186.

McLaughlin, J., King, G., Howley, E., Bassett Jr, D., & Ainsworth, B. (2001). Validation of the COSMED K4 b2 portable metabolic system. *International Journal of Sports Medicine, 22*(04), 280-284.

Metcalfe, R. S., Babraj, J. A., Fawkner, S. G., & Vollaard, N. B. (2012). Towards the minimal amount of exercise for improving metabolic health: Beneficial effects of reduced-exertion high-intensity interval training. *European Journal of Applied Physiology, 112*(7), 2767-2775.

Moreira, M. M., Souza, Helder Porto Carozo de, Schwingel, P. A., Sá, Cloud Kennedy Couto de, & Zoppi, C. C. (2008). Effects of aerobic and anaerobic exercise on cardiac risk variables in overweight adults. *Arquivos Brasileiros De Cardiologia, 91*(4), 219-226.

Morikawa, M., Okazaki, K., Masuki, S., Kamijo, Y., Yamazaki, T., Gen-no, H., & Nose, H. (2011). Physical fitness and indices of lifestyle-related diseases before and after interval walking training in middle-aged and older males and females. *British Journal of Sports Medicine, 45*(3), 216-224. Doi:10.1136/bjsm.2009.064816 [doi]

Morris, J. N., Heady, J., Raffle, P., Roberts, C., & Parks, J. (1953). Coronary heart-disease and physical activity of work. *The Lancet, 262*(6796), 1111-1120.

Morton, R. D., West, D. J., Stephens, J. W., Bain, S. C., & Bracken, R. M. (2010). Heart rate prescribed walking training improves cardiorespiratory fitness but not glycaemic control in people with type 2 diabetes. *Journal of Sports Sciences, 28*(1), 93-99.

Motalebi, S. A., Iranagh, J. A., Abdollahi, A., & Lim, W. K. (2014). Applying of theory of planned behavior to promote physical activity and exercise behavior among older adults. *Journal of Physical Education and Sport, 14*(4), 562.

Mozaffarian, D., Benjamin, E. J., Go, A. S., Arnett, D. K., Blaha, M. J., Cushman, M., . . . American Heart Association Statistics Committee and Stroke Statistics Subcommittee.

(2015). Heart disease and stroke statistics—2015 update: A report from the 133merican heart association. *Circulation, 131*(4), e29-322. Doi:10.1161/CIR.0000000000000152 [doi]

Müller, A. M., & Khoo, S. (2014). Non-face-to-face physical activity interventions in older adults: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 11*(1), 35.

Munk, P. S., Staal, E. M., Butt, N., Isaksen, K., & Larsen, A. I. (2009). High-intensity interval training may reduce in-stent restenosis following percutaneous coronary intervention with stent implantation: A randomized controlled trial evaluating the relationship to endothelial function and inflammation. *American Heart Journal, 158*(5), 734-741.

Nemoto, K., Gen-no, H., Masuki, S., Okazaki, K., & Nose, H. (2007). Effects of high-intensity interval walking training on physical fitness and blood pressure in middle-aged and older people. Paper presented at the *Mayo Clinic Proceedings, , 82*(7) 803-811.

Nicklas, B. J., Wang, X., You, T., Lyles, M. F., Demons, J., Easter, L., . . . Carr, J. J. (2009). Effect of exercise intensity on abdominal fat loss during calorie restriction in overweight and obese postmenopausal women: A randomized, controlled trial. *The American Journal of Clinical Nutrition, 89*(4), 1043-1052. Doi:10.3945/ajcn.2008.26938 [doi]

Nose, H. (2014). Interval walking training for middle-aged and older people: Methods and evidence. *IEICE Transactions on Communications, 97*(3), 534-539.

Nybo, L., Sundstrup, E., Jakobsen, M. D., Mohr, M., Hornstrup, T., Simonsen, L., . . . Krustrup, P. (2010). High-intensity training versus traditional exercise interventions for promoting health. *Medicine and Science in Sports and Exercise, 42*(10), 1951-1958. Doi:10.1249/MSS.0b013e3181d99203 [doi]

Ogden, C. L., Carroll, M. D., Fryar, C. D., & Flegal, K. M. (2015). *Prevalence of obesity among adults and youth: United states, 2011-2014* US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics.

Ogilvie, D., Foster, C. E., Rothnie, H., Cavill, N., Hamilton, V., Fitzsimons, C. F., . . . Scottish Physical Activity Research Collaboration. (2007). Interventions to promote walking: Systematic review. *BMJ (Clinical Research Ed.), 334*(7605), 1204. Doi:bmj.39198.722720.BE [pii]

O'Neill, K., & Reid, G. (1991). Perceived barriers to physical activity by older adults. *Canadian Journal of Public Health = Revue Canadienne De Sante Publique, 82*(6), 392-396.

Oxford University Press. *Oxford Dictionary of Sports Science and Medicine, Online Version (2007)*. DOI: 10.1093/acref/9780198568506.001.0001.

Reed, J. L., & Pipe, A. L. (2016). Practical approaches to prescribing physical activity and monitoring exercise intensity. *Canadian Journal of Cardiology, 32*(4), 514-522.

Resnick, B., & Jenkins, L. S. (2000). Testing the reliability and validity of the self-efficacy for exercise scale. *Nursing Research, 49*(3), 154-159.

Ribisl, P. M., & Kachadorian, W. A. (1969). Maximal oxygen intake prediction in young and middle-aged males. *The Journal of Sports Medicine and Physical Fitness, 9*(1), 17-22.

Ried-Larsen, M., Thomsen, R. W., Berencsi, K., Brinkløv, C. F., Brøns, C., Valentiner, L. S., . . . Pedersen, B. K. (2016). Implementation of interval walking training in patients with type 2 diabetes in 135merica: Rationale, design, and baseline characteristics. *Clinical Epidemiology, 8*, 201.

Rognmo, Ø., Hetland, E., Helgerud, J., Hoff, J., & Slørdahl, S. A. (2004). High intensity aerobic interval exercise is superior to moderate intensity exercise for increasing aerobic capacity in patients with coronary artery disease. *European Journal of Cardiovascular Prevention & Rehabilitation, 11*(3), 216-222.

Rothman, A. J. (2000). Toward a theory-based analysis of behavioral maintenance. *Health Psychology, 19*(1S), 64.

Rowley, T. W., Espinoza, J. L., Akers, J. D., Wenos, D. L., & Edwards, E. S. (2017). Effects of run sprint interval training on healthy, inactive, overweight/obese women: A pilot study. *Facets, 2*(1), 53-67.

Sartor, F., Vernillo, G., De Morree, H. M., Bonomi, A. G., La Torre, A., Kubis, H., & Veicsteinas, A. (2013). Estimation of maximal oxygen uptake via submaximal exercise testing in sports, clinical, and home settings. *Sports Medicine, 43*(9), 865-873.

Sattelmair, J., Pertman, J., Ding, E. L., Kohl, H. W.,3rd, Haskell, W., & Lee, I. M. (2011). Dose response between physical activity and risk of coronary heart disease: A meta-analysis. *Circulation, 124*(7), 789-795. Doi:10.1161/CIRCULATIONAHA.110.010710 [doi]

Sawyer, B. J., Tucker, W. J., Bhammar, D. M., Ryder, J. R., Sweazea, K. L., & Gaesser, G. A. (2016). Effects of high-intensity interval training and moderate-intensity continuous training on endothelial function and cardiometabolic risk markers in obese adults. *Journal of Applied Physiology (Bethesda, Md.: 1985), 121*(1), 279-288. Doi:10.1152/japplphysiol.00024.2016 [doi]

Schjerve, I. E., Tyldum, G. A., Tjonna, A. E., Stolen, T., Loennechen, J. P., Hansen, H. E., . . . Wisloff, U. (2008). Both aerobic endurance and strength training programmes improve cardiovascular health in obese adults. *Clinical Science (London, England : 1979), 115*(9), 283-293. Doi:10.1042/CS20070332 [doi]

Schubert, M. M., Clarke, H. E., Seay, R. F., & Spain, K. K. (2017). Impact of 4 weeks of interval training on resting metabolic rate, fitness, and health-related outcomes. *Applied Physiology, Nutrition, and Metabolism*, *42*(10), 1073-1081.Schutzer, K. A., & Graves, B. S. (2004). Barriers and motivations to exercise in older adults. *Preventive Medicine, 39*(5), 1056-1061.

Sijie, T., Hainai, Y., Fengying, Y., & Jianxiong, W. (2012). High intensity interval exercise training in overweight young women. *The Journal of Sports Medicine and Physical Fitness, 52*(3), 255-262. Doi:r40123553 [pii]

Simonsick, E. M., Fan, E., & Fleg, J. L. (2006). Estimating cardiorespiratory fitness in well-functioning older adults: Treadmill validation of the long distance corridor walk. *Journal of the American Geriatrics Society, 54*(1), 127-132.

Smith, A. E., Evans, H., Parfitt, G., Eston, R., & Ferrar, K. (2016). Submaximal Exercise–Based equations to predict maximal oxygen uptake in older adults: A systematic review. *Archives of Physical Medicine and Rehabilitation, 97*(6), 1003-1012.

Soares-Miranda, L., Siscovick, D. S., Psaty, B. M., Longstreth, W. T.,Jr, & Mozaffarian, D. (2016). Physical activity and risk of coronary heart disease and stroke in older adults: The cardiovascular health study. *Circulation, 133*(2), 147-155. Doi:10.1161/CIRCULATIONAHA.115.018323 [doi]

Stewart, A. L., Verboncoeur, C. J., McLellan, B. Y., Gillis, D. E., Rush, S., Mills, K. M., . . . Bortz, W. M. (2001). Physical activity outcomes of CHAMPS II: A physical activity promotion program for older adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 56*(8), M465-M470.

Stewart, K. J., Bacher, A. C., Turner, K., Lim, J. G., Hees, P. S., Shapiro, E. P., . . . Ouyang, P. (2005). Exercise and risk factors associated with metabolic syndrome in older adults. *American Journal of Preventive Medicine, 28*(1), 9-18.

Stockwell, T. B., McKean, M. R., & Burkett, B. J. (2012). Response to constant and interval exercise protocols in the elderly. *Journal of Exercise Physiology Online, 15*(2)

Strath, S. J., Kaminsky, L. A., Ainsworth, B. E., Ekelund, U., Freedson, P. S., Gary, R. A., . . . American Heart Association Physical Activity Committee of the Council on Lifestyle and Cardiometabolic Health and Cardiovascular, Exercise, Cardiac Rehabilitation and Prevention Committee of the Council on Clinical Cardiology, and Council. (2013). Guide to the assessment of physical activity: Clinical and research applications: A scientific statement from the 138merican heart association. *Circulation, 128*(20), 2259-2279. Doi:10.1161/01.cir.0000435708.67487.da [doi]

Swain, D. P., Brawner, C. A., & American College of Sports Medicine. (2014). *ACSM's resource manual for guidelines for exercise testing and prescription* Wolters Kluwer Health/Lippincott Williams & Wilkins.

Swain, D. P., & Franklin, B. A. (2006). Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise. *The American Journal of Cardiology, 97*(1), 141-147.

Tak, E., Kuiper, R., Chorus, A., & Hopman-Rock, M. (2013). Prevention of onset and progression of basic ADL disability by physical activity in community dwelling older adults: A meta-analysis. *Ageing Research Reviews, 12*(1), 329-338.

Talanian, J. L., Galloway, S. D., Heigenhauser, G. J., Bonen, A., & Spriet, L. L. (2007). Two weeks of high-intensity aerobic interval training increases the capacity for fat oxidation during exercise in women. *Journal of Applied Physiology (Bethesda, Md.: 1985), 102*(4), 1439-1447. Doi:01098.2006 [pii]

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology, 37*(1), 153-156.

Tanasescu, M., Leitzmann, M. F., Rimm, E. B., Willett, W. C., Stampfer, M. J., & Hu, F. B. (2002). Exercise type and intensity in relation to coronary heart disease in men. *Jama, 288*(16), 1994-2000.

Taylor, D. (2014). Physical activity is medicine for older adults. *Postgraduate Medical Journal, 90*(1059), 26-32. Doi:10.1136/postgradmedj-2012-131366 [doi]

Tjonna, A. E., Lee, S. J., Rognmo, O., Stolen, T. O., Bye, A., Haram, P. M., . . . Wisloff, U. (2008). Aerobic interval training versus continuous moderate exercise as a treatment for the metabolic syndrome: A pilot study. *Circulation, 118*(4), 346-354. Doi:10.1161/CIRCULATIONAHA.108.772822 [doi]

Tjonna, A. E., Stolen, T. O., Bye, A., Volden, M., Slordahl, S. A., Odegard, R., . . . Wisloff, U. (2009). Aerobic interval training reduces cardiovascular risk factors more than a multitreatment approach in overweight adolescents. *Clinical Science (London, England : 1979), 116*(4), 317-326. Doi:10.1042/CS20080249 [doi]

Trapp, E. G., Chisholm, D. J., Freund, J., & Boutcher, S. H. (2008). The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women. *International Journal of Obesity, 32*(4), 684-691.

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the united states measured by accelerometer. *Medicine and Science in Sports and Exercise, 40*(1), 181.

Tsekouras, Y. E., Magkos, F., Kellas, Y., Basioukas, K. N., Kavouras, S. A., & Sidossis, L. S. (2008). High-intensity interval aerobic training reduces hepatic very low-density lipoprotein-triglyceride secretion rate in men. *American Journal of Physiology.Endocrinology and Metabolism, 295*(4), E851-8. Doi:10.1152/ajpendo.90545.2008 [doi]

U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC), National Center for Chronic Disease Prevention and Health Promotion, Division of Nutrition, Physical Activity and Obesity, Atlanta, GA. (2015). Nutrition, physical activity and obesity data, trends and maps web site. . Retrieved from http://www.cdc.gov/nccdphp/DNPAO/index.html

van Stralen, M. M., De Vries, H., Mudde, A. N., Bolman, C., & Lechner, L. (2009). Determinants of initiation and maintenance of physical activity among older adults: A literature review. *Health Psychology Review, 3*(2), 147-207.

Wallman, K., Plant, L. A., Rakimov, B., & Maiorana, A. J. (2009). The effects of two modes of exercise on aerobic fitness and fat mass in an overweight population. *Research in Sports Medicine, 17*(3), 156-170.

Warburton, D. E., McKenzie, D. C., Haykowsky, M. J., Taylor, A., Shoemaker, P., Ignaszewski, A. P., & Chan, S. Y. (2005). Effectiveness of high-intensity interval training for the rehabilitation of patients with coronary artery disease. *The American Journal of Cardiology, 95*(9), 1080-1084.

Wilcox, S. (2016). Behavioral interventions and physical activity in older adults: Gains and gaps. *Kinesiology Review, 5*(1), 57-64.

Wilcox, S., Dowda, M., Leviton, L. C., Bartlett-Prescott, J., Bazzarre, T., Campbell-Voytal, K., . . . Dunn, A. L. (2008). Active for life: Final results from the translation of two physical activity programs. *American Journal of Preventive Medicine, 35*(4), 340-351.

Willoughby, T. N., Thomas, M. P., Schmale, M. S., Copeland, J. L., & Hazell, T. J. (2016). Four weeks of running sprint interval training improves cardiorespiratory fitness in young and middle-aged adults. *Journal of sports sciences*, *34*(13), 1207-1214.

Wisloff, U., Stoylen, A., Loennechen, J. P., Bruvold, M., Rognmo, O., Haram, P. M., . . . Skjaerpe, T. (2007). Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients: A randomized study. *Circulation, 115*(24), 3086-3094. Doi:CIRCULATIONAHA.106.675041 [pii]

Zaleski, A. L., Taylor, B. A., Panza, G. A., Wu, Y., Pescatello, L. S., Thompson, P. D., & Fernandez, A. B. (2016). Coming of age: Considerations in the prescription of exercise for older adults. *Methodist DeBakey Cardiovascular Journal, 12*(2), 98-104. Doi:10.14797/mdcj-12-2-98 [doi]

Self-efficacy For Exercise (SEE) Scale

How confident are you right now that you could exercise three times per week for 20 minutes if:

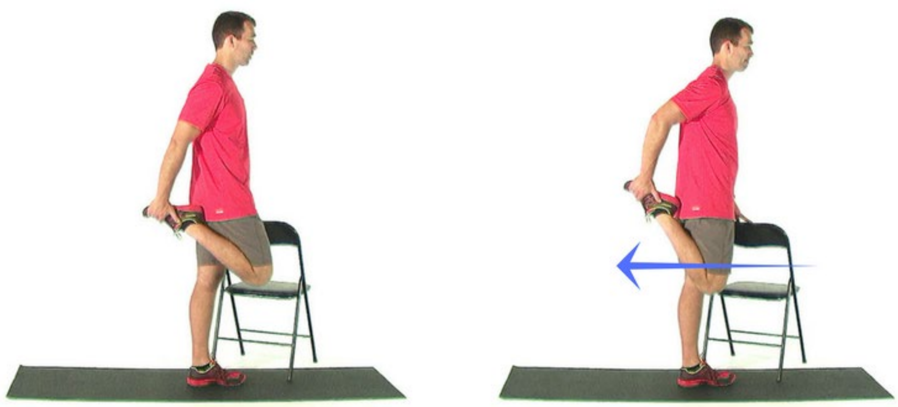
	Not Confident										Very Confident
1. The weather was bothering you	0	1	2	3	4	5	6	7	8	9	10
2. You were bored by the program or activity	0	1	2	3	4	5	6	7	8	9	10
3. You felt pain when exercising	0	1	2	3	4	5	6	7	8	9	10
4. You had to exercise alone	0	1	2	3	4	5	6	7	8	9	10
5. You did not enjoy it	0	1	2	3	4	5	6	7	8	9	10
6. You were too busy with other activities	0	1	2	3	4	5	6	7	8	9	10
7. You felt tired	0	1	2	3	4	5	6	7	8	9	10
8. You felt stressed	0	1	2	3	4	5	6	7	8	9	10
9. You felt depressed	0	1	2	3	4	5	6	7	8	9	10

APPENDIX B: HIGH INTENSITY INTERVAL WALKING WARM UP INSTRUCTIONS

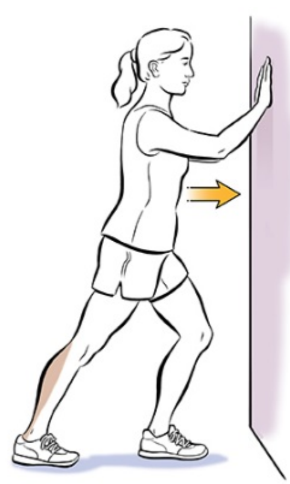
Five-Minute Warm Up

1. Walk for three minutes at a comfortable pace. If you were carrying on a conversation, you would be able to speak with relative ease.
2. Hold each stretch for 20-seconds on each leg. Repeat if necessary.
3. Hamstring Stretch

4. Quad Stretch



5. Calf Stretch



APPENDIX C: HIGH INTENSITY INTERVAL WALKING TRAINING PROTOCOL

Training Protocol Session 1	
Participant ID:	Date:
Estimated Maximal Heart Rate • 207-(__________ age in years x 0.7) = _________ Heart Rate Range • HR 1= ______ Max HR - ______ RHR = ________x 0.7 = _________ + RHR = _______bpm • HR 2= ______ Max HR - ______ RHR = ________x 0.8 = _________ + RHR = _______bpm	
Heart Rate Range	
15-Second HR Range	
Time Keeping Method (circle one): Wrist watch Stop watch Cell phone Smart Phone App	
Training Script: "I am going to ask you to walk at a high intensity. When I say 'high intensity', you should walk at a fast-enough pace where your heart rate and breathing frequency increase noticeably. You should only be able to speak a few words before you must pause to take another breath. You will also be asked to use the Rating of Perceived Exertion scale to help determine your walking intensity. The scale ranges from 0 to 10, with '0' coinciding with resting activities, such as sitting or lying down, and '10' coinciding with you working as hard as you can. For this activity, I want you to aim for a '7' or '8' on this scale. Keep in mind when you are using this scale that it is reflecting a total body feeling, not just (for example) how tired your legs are."	
1. Put HR monitor on participant 2. Record the participant's resting HR a. ____________ bpm 3. Complete standardized warm-up (see warm-up sheet) 4. Explain RPE scale (participants want to be at a 7 or 8) 5. Teach participant how to measure their HR a. Show participant where to place index and middle finger on radial artery of wrist b. Help participant count HR for 15 seconds c. Have participant practice several times 6. Have participant start walking quickly a. Using HR watch, tell participant to speed up or slow down to hit the HR target b. Participant should walk quickly for 2 minutes at a time c. Have participant stop walking at the end of the walking bout and measure HR d. Repeat this up to 2-3 more times as necessary 7. At end of training session, have participant cool down for 3 minutes at a self-selected walking speed	

Training Protocol Session 2	
Participant ID:	Date:
Heart Rate Range	
15-Second HR Range	

Time Keeping Method (circle one):

Wrist watch Stop watch Cell phone Smart Phone App

1. Put HR monitor on participant
2. Record the participant's resting HR
    a. _____________ bpm
3. Complete standardized warm-up (see warm-up sheet)
4. Review RPE and HR measurement with participant
    a. RPE should be at a 7 or 8
    b. Have participant demonstrate measuring resting HR
    c. Have participant practice several times as necessary
5. Have participant start walking quickly
    a. Using HR watch, tell participant to speed up or slow down to hit the HR target
    b. Participant should walk quickly for 2 minutes at a time
    c. Have participant stop walking at the end of the walking bout and measure HR
    d. Repeat this up to 2-3 more times as necessary
6. At end of training session, have participant cool down for 3 minutes at a self-selected walking speed

APPENDIX D: RATING OF PERCEIVED EXERTION (RPE) SCALE

rating	description
0	NOTHING AT ALL
0.5	VERY, VERY LIGHT
1	VERY LIGHT
2	FAIRLY LIGHT
3	MODERATE
4	SOMEWHAT HARD
5	HARD
6	
7	VERY HARD
8	
9	
10	VERY VERY HARD (MAXIMAL)

APPENDIX E: HIGH INTENSITY INTERVAL WALKING TRAINING DATA COLLECTION SHEET

<table>
<tr><th colspan="9">High Intensity Walking Log: Week ____</th></tr>
<tr><th colspan="9">Target Heart Rate Zone: ________ to ________ beats per 15 seconds</th></tr>
<tr><th colspan="3">Day 1</th><th colspan="3">Day 2</th><th colspan="3">Day 3</th></tr>
<tr><th colspan="3">Date ____/____/____</th><th colspan="3">Date ____/____/____</th><th colspan="3">Date ____/____/____</th></tr>
<tr><td>Resting HR</td><td colspan="2">______ x 4 = ______</td><td>Resting HR</td><td colspan="2">______ x 4 = ______</td><td>Resting HR</td><td colspan="2">______ x 4 = ______</td></tr>
<tr><td>5-min warm up</td><td colspan="2">_____ Yes</td><td>5-min warm up</td><td colspan="2">_____ Yes</td><td>5-min warm up</td><td colspan="2">_____ Yes</td></tr>
<tr><td></td><td>HR</td><td>RPE</td><td></td><td>HR</td><td>RPE</td><td></td><td>HR</td><td>RPE</td></tr>
<tr><td>Interval 1 (2-min)</td><td></td><td></td><td>Interval 1 (2-min)</td><td></td><td></td><td>Interval 1 (2-min)</td><td></td><td></td></tr>
<tr><td>Recovery 1 (2-min)</td><td></td><td></td><td>Recovery 1 (2-min)</td><td></td><td></td><td>Recovery 1 (2-min)</td><td></td><td></td></tr>
<tr><td>Interval 2 (2-min)</td><td></td><td></td><td>Interval 2 (2-min)</td><td></td><td></td><td>Interval 2 (2-min)</td><td></td><td></td></tr>
<tr><td>Recovery 2 (2-min)</td><td></td><td></td><td>Recovery 2 (2-min)</td><td></td><td></td><td>Recovery 2 (2-min)</td><td></td><td></td></tr>
<tr><td>Interval 3 (2-min)</td><td></td><td></td><td>Interval 3 (2-min)</td><td></td><td></td><td>Interval 3 (2-min)</td><td></td><td></td></tr>
<tr><td>Recovery 3 (2-min)</td><td></td><td></td><td>Recovery 3 (2-min)</td><td></td><td></td><td>Recovery 3 (2-min)</td><td></td><td></td></tr>
<tr><td>Interval 4 (2-min)</td><td></td><td></td><td>Interval 4 (2-min)</td><td></td><td></td><td>Interval 4 (2-min)</td><td></td><td></td></tr>
<tr><td>Recovery 4 (2-min)</td><td></td><td></td><td>Recovery 4 (2-min)</td><td></td><td></td><td>Recovery 4 (2-min)</td><td></td><td></td></tr>
<tr><td>Interval 5 (2-min)</td><td></td><td></td><td>Interval 5 (2-min)</td><td></td><td></td><td>Interval 5 (2-min)</td><td></td><td></td></tr>
<tr><td>Recovery 5 (2-min)</td><td></td><td></td><td>Recovery 5 (2-min)</td><td></td><td></td><td>Recovery 5 (2-min)</td><td></td><td></td></tr>
<tr><td>Session RPE</td><td colspan="2"></td><td>Session RPE</td><td colspan="2"></td><td>Session RPE</td><td colspan="2"></td></tr>
<tr><td>Recovery HR (1-min post)</td><td colspan="2"></td><td>Recovery HR (1-min post)</td><td colspan="2"></td><td>Recovery HR (1-min post)</td><td colspan="2"></td></tr>
</table>

CURRICULUM VITAE

Taylor W. Rowley, (Nee- Taylor Wenos)

1. GENERAL INFORMATION

1.1. Formal Education

1.1.1. Doctor of Philosophy (Ph.D. Graduation in May 2020). The University of Wisconsin-Milwaukee, Department of Kinesiology, Milwaukee, WI. Concentration: Exercise Physiology. Cognate: Healthy Aging and Behavior Change.

1.1.1.1. Dissertation Title: "Prescribing Vigorous Intensity Exercise to Older Adults"

1.1.2. Master of Science (M.S.). (2014). James Madison University, Harrisonburg, VA. Concentration: Clinical Exercise Physiology.

1.1.2.1. Thesis Title: "Run Sprint Interval Training Perceived as Highly Enjoyable despite High Session RPE in Sedentary, Overweight/Obese Women"

1.1.3. Bachelor of Science (B.S.). (2010). Roanoke College, Salem, VA. Concentration: Health and Human Performance.

1.2. Academic and Professional Positions Held

1.2.1. 2019-present, Assistant Professor of Kinesiology, Exercise Science. Department of Kinesiology, College of Health and Human Services, Saginaw Valley State University, Saginaw, MI.

1.2.2. 2018-2019, Laboratory Manager. Physical Activity and Health Research Laboratory, Department of Kinesiology, College of Health Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI.

1.2.3. 2016-2019, Adhoc Instructor. Department of Kinesiology, College of Health Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI.

1.2.4. 2014-2019, Teaching Assistant. Department of Kinesiology, College of Health Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI.

1.2.5. 2012-2014, Teaching Assistant. Department of Kinesiology, College of Health and Behavioral Sciences, James Madison University, Harrisonburg, VA.

1.2.6. 2010-2013, Health Fitness Specialist/Personal Trainer. Sentara-RMH Wellness Center, Harrisonburg, VA.

1.3. Significant Continuing Education

1.3.1. Online/Blended Teaching Certificate (expected Fall 2019). Center for Excellence in Teaching and Learning. The University of Wisconsin-Milwaukee, Milwaukee, WI.

1.3.2. Graduate Certificate in Applied Gerontology (2017). The University of Wisconsin-Milwaukee, Department of Kinesiology, Milwaukee, WI.

1.3.3. Collaborative Institutional Training Initiative: Good Clinical Practice (2017)

1.3.4. Collaborative Institutional Training Initiative: Human Subject Research (2017)

1.3.5. Learner-Centered Course Design (2015). Center for Excellence in Teaching and Learning. The University of Wisconsin-Milwaukee, Milwaukee, WI.

1.3.6. American College of Sports Medicine certified Health Fitness Specialist (2010-2016).

2. RESEARCH AND SCHOLARSHIP

2.1. Articles and Papers Published or in Review for Publication

2.1.1. **Rowley, T.W.**, Lenz, E.K., Swartz, A.M., Miller, N.E., Maeda, H., & Strath, S.J. (2019- reprint). Efficacy of an Individually Tailored, Internet-Mediated Physical Activity Intervention in Older Adults: A Randomized Controlled Trial. *Journal of Applied Gerontology: Special Issue- Intervention Studies in Applied Gerontology*. DOI: **10.1177/0733464817735396**

2.1.2. **Rowley, T.W.**, Cho, C., Swartz, A.M., Staudenmayer, J., Hyngstrom, A., Keenan, K.G., Welch, W.A., & Strath, S.J. (2019). Energy Cost of Slow and Normal Gait Speeds in Low and Normally Functioning Adults. *American Journal of Physical Medicine & Rehabilitation.* DOI: **10.1097/PHM.0000000000001228**

2.1.3. Strath, S. J., & **Rowley, T.W.** (2018). Wearables for Promoting Physical Activity. *Clinical Chemistry*, *64 (1) 64-71*. DOI: **10.1373/clinchem.2017.273532**

2.1.4. **Rowley, T.W.**, Lenz, E.K., Swartz, A.M., Miller, N.E., Maeda, H., & Strath, S.J. (2017). Efficacy of an Individually Tailored, Internet-Mediated Physical Activity Intervention in Older Adults: A Randomized Controlled Trial. *Journal of Applied Gerontology*. DOI: **10.1177/0733464817735396**

2.1.5. **Rowley, T.W.**, Espinoza, J.L., Akers, J.D., Wenos, D.L., & Edwards, E.S. (2017). Run Sprint Interval Training on Healthy Sedentary, Overweight/Obese Women: A Pilot Study. *FACETS 2: 53-67.* DOI: **10.1139/facets-2016-0004**

2.1.6. Lerma, N. L., Swartz, A. M., **Rowley, T. W.**, Maeda, H., & Strath, S. J. (2016). Increasing the Energy Expenditure of Seated Activities in Older Adults with a Portable Elliptical Device. *Journal of Aging and Physical Activity*, 25(1), 99-104. DOI: **10.1123/japa.2015-0277**

2.2. Research Grants and Scholarships Received

2.2.1. Saginaw Valley State University, Faculty Research Grant
3-credit Hour Release Time (requested/pending)

2.2.2. University of Wisconsin-Milwaukee, College of Health Sciences Doctoral Research Grant.
Prescribing High Intensity Interval Walking to Older Adults.
$1,731.00, 7/1/2017-6/30/2019

2.2.3. University of Wisconsin-Milwaukee, Helen Bader Gerontology Scholarship
$2,000.00, 7/1/2016-6/30/2017

2.2.4. University of Wisconsin-Milwaukee, Helen Bader Gerontology Scholarship
$6,000.00, 7/1/2015-6/30/2016

2.3. International and National Research Presentations

2.3.1. **Rowley, T.W.**, Cho, C., Swartz, A.M., Strath, S.J. *A Comparison of Step Tests to Predict Maximal Oxygen Consumption*. American College of Sports Medicine. National Meeting. Submitted.

2.3.2. Strath, S.J., **Rowley, T.W.**, Swartz, A.M., Hyngstrom, A., Keenan, K.G., Staudenmayer, J. *Validity of a Hip-Mounted Accelerometer to Estimate Structured Activity Energy Cost in Adults With and Without Functional Limitations*. International Conference on Ambulatory Monitoring of Physical Activity and Movement. Annual Meeting, July 2019.

2.3.3. **Rowley, T.W.**, Cho, C., Swartz, A.M., Strath, S.J. *A Validated Model to Predict Maximal Oxygen Consumption Using a 9-Minute Walk Test.* American College of Sports Medicine. National Meeting. June 1, 2018. Poster Presentation, Board #35.

2.3.4. Jahanian, O., **Rowley, T.W.**, Strath, S.J., Silver-Thorn, B., Slavens, B.A. *Impact of Geared Wheels on Energy Expenditure During Manual Wheelchair Mobility.* American Society of Biomechanics. Annual Meeting. August 9, 2017. Poster Presentation, Board #247A.

2.3.5. **Rowley, T.W.**, Cho, C., Swartz, A.M., Miller, N.E., Strath, S.J. *Predicting Maximal Oxygen Uptake in Adults Using a Walk Test.* American College of Sports Medicine. National Meeting. June 1, 2017. Poster Presentation, Board #235.

2.3.6. Strath, S.J., Swartz, A.M., Hyngstrom, A.S., Keenan, K.G., **Rowley, T.W.**, Miller, N.M., Welch, W.A., Cho, C.C., Staudenmayer, J. *Validity of Accelerometer Methods to Estimate Activity Energy Cost in Adults With and Without Functional Limitations*. American College of Sports Medicine. National Meeting. June 3, 2016. Slide Presentation.

2.3.7. **Rowley, T.W.,** Swartz, A.M., Staudenmayer, J., Keenan, K., Welch, W.A., Cho, C.C., Strath, S.J. *Energy Cost of Slow and Normal Gait Speed in Adults With and Without Lower-body Impairments.* American College of Sports Medicine. National Meeting. June 2, 2016. Poster Presentation, Board #68.

2.3.8. Lerma, N.L., Swartz, A.M., **Rowley, T.W.**, Maeda, H., Strath, S.J. *Increasing the Energy Cost of Sedentary Behaviors in Older Adults Using a Portable Elliptical Device: Pilot.* American College of Sports Medicine. National Meeting. May 27, 2015. Poster Presentation, Board #296.

2.3.9. **Wenos, T.K.**, Espinoza, J.L., Akers, J.D., Wenos, D.L., & Edwards, E.S. *Perceived Enjoyment and Perceived Exertion during Run Sprint Interval Training in Sedentary Overweight/Obese Women*. American College of Sports Medicine, National Meeting. May 30, 2014. Poster Presentation, Board #230.

2.4. Regional and Local Research Presentations

2.4.1. **Rowley, T.W.**, Cho, C., Swartz, A.M., Strath, S.J. *A Validated Model to Predict Maximal Oxygen Consumption Using a 9-Minute Walk Test.* University of Wisconsin-Milwaukee College of Health Sciences Research Symposium. May 4, 2018. Poster Presentation.

2.4.2. **Rowley, T.W.**, Cho, C., Swartz, A.M., Miller, N.E., Strath, S.J. *Predicting Maximal Oxygen Uptake in Adults Using a Walk Test.* University of Wisconsin-Milwaukee College of Health Sciences Research Symposium. May 5, 2017. Poster Presentation.

2.4.3. Jahanian, O., **Rowley, T.W.,** Strath, S.J., Silver-Thorn, B., Slavens, B.A. Impact of Geared Wheels on Energy Expenditure During Manual Wheelchair Mobility. University of Wisconsin-Milwaukee College of Health Sciences Research Symposium. May 5, 2017. Poster Presentation.

2.4.4. **Rowley, T.W.,** Swartz, A.M., Staudenmayer, J., Keenan, K., Welch, W.A., Cho, C.C., Strath, S.J. *Energy Cost of Slow and Normal Gait Speed in Adults With and Without Lower-body Impairments.* University of Wisconsin-Milwaukee College of Health Sciences Research Symposium. May 6, 2016. Poster Presentation.

2.4.5. **Rowley, T.**, Welch, W., Strath, S., Winker, K., Russo, M., Swartz, A. *A Comparison of Two Interventions to Decrease Sedentary Behavior in Healthy Older Adults.* University of Wisconsin-Milwaukee College of Health Sciences Research Symposium. May 1, 2015. Poster Presentation.

2.4.6. Wenos, J.Z., Richardson, E., Richardson, J., & **Wenos, T.K**. *Identifying Partners for Collaboration to Support Children with Developmental Coordination Disorder*. Virginia Association for Health, Physical Education, Recreation and Dance Regional Convention VAHPERD conference. November 6, 2009. Oral presentation.

3. TEACHING
3.1. Classroom Instruction
3.1.1. F2019-Present
Kinesiology 270 *Activity and Fitness Assessment.* (Saginaw Valley State University)

Student Learning Objectives:

- Demonstrate an understanding of the importance of physical activity and fitness related concepts in overall health and performance.
- Describe concepts and strategies related to the testing and development of health and skill related components of fitness.
- Identify and evaluate personal skills/abilities necessary to effectively implement a variety of physical activity and fitness tests in both large and small populations.
- Demonstrate the ability to prepare lesson plans and teach a physical education class.
- Implement appropriate instructional strategies, assessment methods, demonstrations, and instructional prompts for fitness assessments and developmental activities.

3.1.2. F2019-Present
Kinesiology 354 *Clinical Exercise Prescription.* (Saginaw Valley State University)

Student Learning Objectives:

- Summarize the epidemiology (e.g. prevalence rates, incidence rates, etc.) of various diseases/chronic conditions such as controlled cardiovascular disease (e.g. heart disease, diabetes mellitus, hypertension), cancer, neuromuscular disorders, and conditions specific to special populations (e.g. children, older adults).
- Understand and describe the basic pathophysiology of a variety of diseases/chronic conditions and how normal physiological processes are altered.
- Understand and describe how exercise acutely interacts with and affects a variety of diseases/chronic conditions.
- Understand and describe the best exercise testing modifications for a variety of diseases/chronic conditions.
- Understand, describe, and implement the best exercise prescription recommendations for a variety of diseases/chronic conditions, utilizing and building on the FITT principle.

3.1.3. F2018-Summer 2019
Kinesiology 230 *Health Aspects of Exercise and Nutrition- online*. (University of Wisconsin-Milwaukee)

Student Learning Objectives:

- Understand evidence-based concepts related to overall physical health, physical fitness, and nutrition, and behaviors related to exercise and healthy eating.
- Assess nutrition and eating behaviors and use goal-setting and decision-making skills to enhance physical fitness and reduce health risks.
- Assess exercise behaviors and use goal-setting and decision-making skills that enhance physical fitness and reduce health-related risks.
- Analyze the interaction between exercise, nutrition and eating behaviors and how physical health fits into multi-dimensional perspectives of overall health and well-being.
- Evaluate and take responsibility for their own physical health through the examination of personal values and beliefs related to physical fitness and healthy eating.
- Demonstrate the ability to access and evaluate valid health information and health-promoting products and services.

3.1.4. F2017- S2018
Kinesiology 488 *Professional Preparation Seminar*. (University of Wisconsin-Milwaukee)

Student Learning Objectives:

- Develop a professional résumé or CV and cover letter.
- Understand where to search for jobs and how to break down a job listing.
- Understand and describe the interview process while employing interview techniques.
- Identify professional organizations and affiliations specific to your future career.
- Understand how social media can be used as a networking tool.
- Define Interprofessional Education and describe its importance in the field.
- Determine career goals for the 2 years beyond undergraduate studies.

3.1.5. S2016 -F2016
Kinesiology 330 *Exercise Physiology* (University of Wisconsin-Milwaukee)

Student Learning Objectives:

- Understand and "compare and contrast" the normal acute and chronic physiological responses to exercise as they pertain to the metabolic, cardiopulmonary, neuromuscular, and endocrine systems in healthy adults.
- Illustrate and describe the basic pathways that make up the different systems, such as but not limited to: glycolysis, gas diffusion, and nerve impulses.
- Compare and contrast how the different systems respond and adapt

to anaerobic and aerobic exercise, how they change from rest, sub-maximal, and maximal exercise, and how different exercise conditions affect each system.
- Identify cardiovascular disease risk factors and describe the effects of exercise on those risk factors.

Laboratory Instruction

3.1.6. F2014-S2019 Kinesiology 330 *Exercise Physiology* (University of Wisconsin-Milwaukee)
- Duties included overseeing laboratory experiments specific to Exercise Physiology, reviewing and connecting content from lecture, maintaining and calibrating teaching equipment, and grading weekly laboratory assignments and examinations.

4.2.2. S2015/16 Kinesiology 400 *Ethics and Values in the Health and Fitness Professions*. (University of Wisconsin-Milwaukee)
- Monitored discussion boards, provided graded feedback to papers and assignments

4.2.3. F2012-S2014 Kinesiology 421 *Exercise Testing and Prescription*. (James Madison University)
- Duties included overseeing laboratory experiments specific to Exercise Testing and Prescription, reviewing and connecting content from lecture, teaching skills specific to the American College of Sports Medicine GETP, administering laboratory practical's, overseeing student case studies, and grading weekly laboratory assignments and exams.

3.2. Invited Classroom Presentations

3.2.1. "Balancing TA and Graduate Student Responsibilities".
Presented on 08/20/2018. Graduate Teaching Assistant Orientation.
University of Wisconsin-Milwaukee, Milwaukee, WI.

3.2.2. "Body Composition Assessments and Techniques".
Presented on 3/29/2018. NUTR 430- Advanced Nutrition and Metabolism.
University of Wisconsin-Milwaukee, Milwaukee, WI.

3.2.3. "Cardiovascular Disease, Energy Expenditure, and Energy Availability".
Presented on 3/19/2018. HTH 478/OT 580- Occupational Dysfunction.
James Madison University, Harrisonburg, VA.

3.2.4. "Benefits of Physical Activity and Exercise".
Presented on 3/20/2017. HTH 478/OT 580- Occupational Dysfunction.
James Madison University, Harrisonburg, VA.

3.2.5. "HIT and Public Health: The Great Debate".
Presented on 2/13/2017. KIN 910- Advanced Seminar.

University of Wisconsin-Milwaukee, Milwaukee, WI.

Course Development and Implementation

3.2.6. Course Redesign- Gamification
KIN 230- *Health Aspects of Exercise and Nutrition*
University of Wisconsin-Milwaukee, Summer 2018

3.2.7. Course Development
KIN 290- *Health and Wellness as We Age*
University of Wisconsin-Milwaukee, Summer 2017

3.2.8. BS Kinesiology Curriculum Committee
University of Wisconsin-Milwaukee, Spring 2016

3.3. Student Supervision/Mentorship

3.3.1. Undergraduate Research Mentor
University of Wisconsin-Milwaukee, Spring 2018-present

- Mentored and trained undergraduate students who were assisting with dissertation data collection.
- Number of students: 3

3.3.2. Research Training Supervisor
University of Wisconsin-Milwaukee, Spring 2017-Fall 2018

- Trained undergraduate and graduate students on standard operating procedures for data collection methods for a federally funded research project.
- Number of students: 6

3.3.3. Kinesiology Personal Training Practicum Supervisor
James Madison University, Spring 2014

- Supervised and assisted undergraduate students in their personal training practicum.
- Number of students: 4

3.3.4. Undergraduate Research Mentor
James Madison University, Fall 2013-Spring 2014

- Mentored undergraduate students who were assisting me with my thesis data collection.
- Number of students: 3

4. SERVICE

4.1. Departmental/University Service

4.1.1. 2019 SVSU Poverty Simulation
4.1.2. 2019 SVSU Freshmen Move-In
4.1.3. 2019 SVSU Fresh Start
4.1.4. 2019 KINE 100 Meet the Faculty
4.1.5. 2019-2020 SVSU Kinesiology Dept, Social Media Team

4.1.6. 2019-2020 SVSU Kinesiology Dept, Exercise Science Self-study/Course Mapping Committee
4.1.7. 2014-2019 Go Milwaukee! High School Senior Recruitment Event

4.2. Professional Service
4.2.1. 2019 Reviewer: *Performance Enhancement and Health*

4.3. Community Service
4.3.1. 2019 MKE Marathon Packet Pickup
4.3.2. Veteran's Day 5k/10k Course Support

5. PROFESSIONAL MEMBERSHIP
5.1. Professional Memberships
5.1.1. American College of Sports Medicine
5.1.2. Midwest Region- American College of Sports Medicine
5.1.3. Omicron Delta Kappa- Honors Fraternity