Spring 2013

The Validity And Reliability Of The Fort Hays State University Shuttle Walk Test

Lynae Wright
Fort Hays State University

THE VALIDITY AND RELIABILITY OF THE FORT HAYS STATE UNIVERSITY SHUTTLE WALK TEST

being

A Thesis Presented to the Graduate Faculty

of Fort Hays State University in

Partial Fulfillment of the Requirements for

the Degree of Master of Science

by

Lynae Wright

B.S., Fort Hays State University

Date ______________________ Approved ____________________________

Major Professor

Approved ____________________________

Chair, Graduate Council

THESIS COMMITTEE APPROVAL

The Thesis Committee of Lynae Katharine Wright hereby approves of her thesis as meeting partial fulfillment of the requirements for the Degree of Master of Science.

Approved ______________________________
Dr. Greg Kandt
Chair, Thesis Committee

Approved ______________________________
Dr. Michael Madden
Committee Member

Approved ______________________________
Dr. Duane Shepherd
Committee Member

Approved ______________________________
Dr. John Zody
Committee Member

ABSTRACT

A variety of time limited, distance limited and incremental shuttle walk tests have been utilized to evaluate functional fitness. Most incremental shuttle walk tests require the same leg to always be on the inside of the walking pattern; therefore receiving more stress because the body's mass shifts to the inside foot. Only one previous study used a figure-8 walking pattern, it was not used to measure functional fitness (Hess, 2010).

The purpose of this study was to determine the validity and reliability of the Fort Hays State University (FHSU) shuttle walk test of functional walking fitness incorporating a figure-8 walking pattern. This study includes participants performing two different shuttle walk tests: the FHSU shuttle walk and the previously validated Modified Shuttle walk test (MSWT). Dependent variables were total number of shuttles completed, final walking velocity and rating of perceived exertion (RPE). Independent variables were shuttle walk version (MSWT and FHSU), age and gender. Peak walking velocity during a single 10 meter walk was also evaluated.

A Repeated Measures Analysis of Variance (ANOVA) was utilized to test for a significant difference total number of shuttles completed and RPE between the FHSU and MSWT. Test-retest reliability for both variables during the FHSU was also evaluated. Significant differences were found for total number of shuttles completed between the MSWT and FHSU. There was an increase in total number of shuttles completed during the FHSU shuttle walk (152.4 ± 52.21 shuttles) when compared to the Modified Shuttle Walk test (MSWT) (132.9 ± 48.12 shuttles). No significant differences were found in the total number of shuttles completed by participants who performed the same FHSU shuttle walk both days or in RPE for either group. The results indicate that performance during

the shuttle walk test is independent of age and gender. The FHSU test can be considered valid and reliable although it results in more total shuttles completed than the MSWT.

ACKNOWLEDGMENTS

First, I would like to give a tremendous thank you to my advisor and mentor, Dr. Greg Kandt for his guidance, advice and patience along the way. Thank you to each of my thesis committee members, Dr. Michael Madden, Dr. Duane Shepherd and Dr. John Zody, who were more than generous with their time and expertise. I would also like to extend a huge thank you to Dr. John Raacke for his help in statistically analyzing my results. This thesis would not have been completed without each of you.

I cannot thank my parents, Wade and Cindy, enough for all your love and support. I am constantly reminded of how blessed I am to have such selfless, loving, hardworking parents. I would not be where I am today without you. I also want to acknowledge my siblings, Emily, Ethan, Madison and Lucy, who can always make me laugh and put a smile on my face.

DEDICATION

To my best friend, Marcus Maust, for all your support and encouragement through not only this research project but also every day. I look forward to many more years of laughs, adventures and unforgettable memories. I love you, MJ.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIXES

Chapter 1

Introduction

Functional fitness can be evaluated using a variety of simple self-paced or controlled pace walk tests. Solway, Brooks, Lacasse and Thomas (2001) described a functional walk test as “an exercise test that measures functional status or capacity, mainly the ability to undertake physically demanding activities of daily living” (p. 257). Walk tests are easy to administer, do not require expensive equipment and are therefore economical. They allow cardiorespiratory fitness of individuals to be tested very simply with an activity that is performed every day (Solway, Brooks, Lacasse & Thomas, 2001).

Over the years, many shuttle walk tests have been developed including the incremental, modified and the endurance shuttle walks. The first incremental shuttle run test was developed to assess maximal power in adults by Leger and Lambert (1982). The goal of Leger and Lambert’s method was to reproduce a test similar to graded exercise tests performed on treadmill, and was first used to assess maximum aerobic power in physically fit individuals (Campo, Chilingaryan, Berg, Paradis, & Mazar, 2006; Liu, Plowman & Looney, 1992). The method relied on increasing the speed of the subjects incrementally, by using an external pacing system, as they ran back and forth between two lines, 20 meters apart.

Singh and colleagues (1992) developed an incremental shuttle walk test (ISWT) modeled on the protocol from Leger and Lambert’s 20-meter shuttle run test to assess functional capacity in individuals with chronic airway obstruction. They modified Leger and Lambert’s protocol by decreasing the length of the course to 10-meters and adding two levels to the original 10 level protocol. They also made the speeds proportional to the speeds of running used in the 20-meter shuttle run test. The ISWT started at a speed of 1.12 mph, gradually increased by 0.38 miles per hour at the end of each stage and ended at a speed of 5.3 miles per hour. In the primary validity study, they compared the performance on the ISWT to the performance on a 6-minute walk test (6MWT). The results indicated that 9 out of 15 of the participants with chronic airway obstruction had a higher heart rate, higher maximal oxygen consumption, and higher Borg's breathlessness scale rating after the ISWT indicating the ISWT was more valid than the 6MWT for eliciting peak functional fitness (Singh, 1992).

The modified shuttle walk test (MSWT) was designed by Bradley and colleagues in 1998. They found that the original ISWT did not elicit maximal responses in adults with cystic fibrosis. They further modified the shuttle walk by adding 3 more levels (now a 15-level test) and increased the maximal speed in level 15 to 6.38 miles per hour instead of the previous 5.3 miles per hour. The purpose of their study was to compare the performance of the MSWT with peak oxygen consumption measured directly during a maximal treadmill test. Their results found a strong correlation between the performance of the MSWT and peak oxygen consumption on a treadmill test (Bradley, Howard, Wallace & Elborn, 1998).

A study by Hess, Brach, Piva and VanSwearingen (2010) used a figure-eight walking pattern in a test of walking mechanics. This unique walking pattern allowed the researchers to compare a curved walking path to the typical straight-path. The study did not use an incremental shuttle walk to assess functional capacity but instead was focused on exploring the correlates of curved path walking in older adults with walking difficulties. They discussed the mechanics of curved walking such that the outer leg travels a greater distance and the inner leg experiences a longer stance time as the body's center of mass shifts to the inner foot while turning (Hess, et al., 2010). This relates to one of the concerns during a normal ISWT, the same leg stays on the inside during the entire test. A figure-8 walking pattern could possibly provide a solution for this problem in future shuttle walk tests.

Walking velocity may play a major role in performance on the ISWT and can also be used as a measure of health. Fritz & Lusardi (2009) stated walking velocity has been found to predict health status and functional decline in clinical settings. In the article titled "Walking Speed; the 6th vital sign", walking speed is discussed as an excellent predictor of health status and mortality risk. It provides a functional perspective to the health status of an individual along with other vital signs such as blood pressure, pulse, respiration, pain and temperature.

Statement of the Problem

The purpose of this study is to determine the validity and reliability of the Fort Hays State University (FHSU) shuttle walk test of functional walking fitness incorporating a new figure-8 walking pattern.

Sub-Problems

Within the problem of this study, the following sub-problems were investigated:

1. The number of total shuttles completed during the FHSU shuttle walk will be compared to the shuttles completed during the MSWT shuttle walk.
2. The number of total shuttles completed during the FHSU shuttle walk will be compared to the shuttles completed during the MSWT in the MSWT Comparison group A and C.
3. The number of total shuttles completed during the FHSU shuttle walk will be compared to the shuttles completed during the MSWT in the MSWT Comparison group males and females.
4. The difference between peak walking velocity and the final velocity during the FHSU shuttle walk will be compared to the difference between peak walking velocity and final velocity during the MSWT.
5. The correlation between peak walking velocity and the FHSU shuttle walk final velocity will be compared to the correlation between peak walking velocity and the MSWT final velocity.
6. The RPE from FHSU shuttle will be compared to the RPE from MSWT.
7. The RPE from FHSU shuttle walk test trial one will be compared to the RPE from FHSU shuttle walk test trial two.

8. The RPE from the first trial of the shuttle walk will be compared to the RPE from the second trial of the shuttle walk in the FHSU Reliability group and MSWT Comparison group A and C.
9. The RPE from trial one will be compared to the RPE from trial two between males and females.
10. The number of total shuttles completed during the first trial of the FHSU shuttle walk will be compared to the shuttles completed during the second trial of the FHSU shuttle walk.
11. The number of total shuttles completed during the first trial of the FHSU shuttle walk will be compared to the shuttles completed during the second trial of the FHSU shuttle walk in the FHSU Reliability group A and C.
12. The number of total shuttles completed during the first trial of the FHSU shuttle walk will be compared to the shuttles completed during the second trial of the FHSU shuttle walk in the FHSU Reliability group males and females.

Definition of Terms

Fort Hays State University shuttle walk test. A walk test that requires participants to walk at a gradually increasing speed in a figure-8 pattern around two cones placed 8.5 meters apart

Functional fitness. The ability to perform predominantly aerobic, oxygen-using work, which includes performing activities of daily living (Fleg et al., 2000).

Functional walk test. An exercise test that measures functional status or capacity, mainly the ability to undertake physically demanding activities of daily living (Solway et al., 2001).

Heart rate reserve. (HRR)The range of heart rate from rest to maximum; a percentage of this range is typically used to establish target heart rates in training, as % HRR provides similar intensities as equivalent values of % VO_2 (Ehrman, 2010).

Heart rate. The number of times the heart contracts, usually expressed in beats per minute (Ehrman, 2010).

Incremental shuttle walk test. A walk test, 10-meters in length, that requires participants to walk at a gradually increasing speed until they reach a symptom-limited maximum (Lewis, Newall, Townend, Hill, & Bonser, 2001).

Modified shuttle walk test. An endurance test that requires participants walk at increasing speeds back and forth on a 10 meter course, marked by two cones at both ends (Campo et al., 2006)

Rating of perceived exertion. Involves subjectively rating how hard one is working (Borg, 1982)

Delimitations

The following study was delimited to 28 volunteers from the Health and Human Performance (HHP) department 445, 845 and 850 classes and from the Fort Hays State University Active Aging Program and HHP Faculty. The study was also delimited to what physiologically occurs in individuals working up to 84% of their age-adjusted heart rate reserve.

Limitations

The results from the study may or may not represent functional walking fitness for like age groups in other schools or communities. The walking speed, stride length and motivation varied for each individual and were not controlled by the researcher. The HHP students will not be pre-screened for any injuries that have occurred prior to participating in the study. Prior injuries such as a knee surgery or ankle injury could limit them during the test when compared to participants who have not previously had any injuries.

Assumptions

The following assumptions will be made during the study. Each participant has the ability to walk, increase walking speed in response to audio signals, and to reproduce preferred and maximal walking velocity. The participants understood and followed directions given to them.

Null Hypotheses

1. The difference between total shuttles completed in the FHSU shuttle walk test compared to the total completed in the MSWT will not be statistically significant.
2. The difference between total shuttles completed in the FHSU shuttle walk test compared to the total completed in the MSWT in the MSWT Comparison group A and C will not be statistically significant.

3. The difference between total shuttles completed in the FHSU shuttle walk test compared to the total completed in the MSWT in the MSWT Comparison group males and females will not be statistically significant.
4. The difference between peak walking velocity and final velocity during the FHSU shuttle walk and peak walking velocity compared to final velocity during the MSWT will not be statistically significant.
5. The difference in correlation between peak walking velocity and the FHSU shuttle walk final velocity and the correlation between peak walking velocity and the MSWT final velocity will not be statistically significant.
6. The difference in final RPE on the FHSU shuttle walk compared to the final RPE from the MSWT will not be statistically significant.
7. The difference in final RPE from the FHSU shuttle walk test trial one compared to the final RPE from the retest FHSU shuttle walk will not be statistically significant.
8. The difference in RPE from the first trial of the shuttle walk compared to the RPE from the second trial in the FHSU Reliability group and the MSWT Comparison group A and C will not be statistically significant.
9. The difference in RPE from the first trial of the shuttle walk test compared to the second trial of the shuttle walk test between males and females will not be statistically significant.

10. The difference of total shuttles completed in the first trial of the FHSU shuttle walk to those completed in the second trial of the FHSU shuttle walk will not be statistically significant.
11. The difference of total shuttles completed in the first trial of the FHSU shuttle walk to those completed in the second trial of the FHSU shuttle walk in the FHSU Reliability group A and C will not be statistically significant.
12. The difference of total shuttles completed in the first trial of the FHSU shuttle walk to those completed in the second trial of the FHSU shuttle walk in the FHSU Reliability group males and females will not be statistically significant.

Significance of the Study

Much of the research involving the ISWT has been performed on pulmonary rehabilitation patients or patients with cardiac history. There is very little data concerning performance of shuttle walk tests on normal, healthy individuals (Brown, & Wise, 2007). This study, using the FHSU shuttle walk test, will incorporate both young, healthy individuals and older adults as participants.

Past research studies have shown similar VO_2 max predictions from the results of the ISWT and a true maximal cardiopulmonary test (Lopez-Campos et al; 2008; Morales, Montemayor & Martinez, 2000; Fowler, Singh & Revill, 2005; Brown & Wise, 2007). Maximal exercise tests are expensive and require considerable participant motivation. The importance of this test is that the participants do not have to perform a maximal test to get an accurate indication of their VO_2 max and functional walking fitness.

The new figure-8 walking pattern is a potentially beneficial addition to ISWT because past shuttle walk tests have only required the participants to walk back and forth around two cones. This unique walking pattern would eliminate one leg from receiving most of the stress during an ISWT and balance the stress onto both legs. This could possibly allow the participants to walk further during the test and reduce the possibility of one leg fatiguing more quickly.

With evolving understanding of the importance of walking velocity as an indicator of health, mortality risk and functional fitness, it is important to better understand the relationship between velocity on an incremental test and peak walking velocity. In the simplest scenario, terminal incremental walking velocity might be equivalent to peak walking velocity, eliminating the need for a separate walking velocity test. Even if this is not the case, the actual relationship between peak velocity and final incremental velocity may improve our understanding of the complicated role of walking velocity in functional capacity.

Walking tests have been continually modified to fit different populations and fitness levels. More research needs to address the search for one test that can measure functional walking fitness and be used to accommodate different types of populations and levels of physical fitness. The results from this study will help determine whether these specific modifications provide consistent accurate test results that can be reciprocated to determine functional capacity from a single test.

Chapter 2

Review of Literature

Introduction

A variety of walking tests including time-based (2-minute walk, 6-minute walk and 12-minute walk), fixed-distance (one mile and 2-km) and velocity-based (self-paced and incremental) have been well researched and validated (Solway, 2001). While these tests have proven valid and useful, time and distance based protocols have also been criticized because they are self-paced and effort dependent even though they are typically utilized in individuals who do not regularly exercise. Shuttle walk test protocols have been introduced to counteract these limitations (Singh et al., 1992). Shuttle walk tests are primarily used to assess endurance or functional fitness. Only one study was identified that utilized a figure-8 walking pattern (Hess et al., 2010), however, it utilized a curved figure-8 pattern 5 feet in length to evaluate turning mechanics in older adults with walking disabilities.

The ISWT was originally developed by Singh, Morgan, Scott, Walters, and Hardman (1992) to overcome the limitations of the six-minute walk test and determine functional capacity in COPD patients. An advantage of the ISWT is that it resembles a maximal graded treadmill test but does not require maximal effort. The goal of a sub maximal test is "to produce a sufficient level of exercise stress without physiologic or biomechanical strain" (Noonan & Dean, 2000, p.784). In the original study by Singh et al. (1992) participants achieved a greater cardiovascular response (higher peak heart rate) during the shuttle walk compared to the six-minute walk test. According to the American

Thoracic Society and the American College of Chest Physicians (2003), "VO_2 max is the best index of aerobic capacity and the gold standard for cardiorespiratory fitness" (p. 229). The ISWT has strong correlations when predicting VO_2 max and therefore relates closely to the gold standard of exercise testing, a maximal cardiopulmonary exercise test performed either on a cycle ergometer or treadmill (Lopez-Campos et al., 2008; Morales et al., 2000; Fowler et al., 2005; Brown & Wise, 2007). These same results have also been seen in patients with lung disease and cardiac pacemakers (Payne & Skehan, 1996; Singh, 1992).

Functional Fitness

The purpose of testing functional fitness is to determine the ability of an individual in everyday, routine activities (Fleg et al., 2000). Walking is a familiar activity performed daily by most individuals and is frequently used to determine functional fitness (Fleg et al., 2000; Morales et al., 1999; Solway et al., 2000; van Bloemendaal, Kokkeler & van de Port, 2012). In older adults, affordable, easy to administer, sub maximal tests are important for patients after surgery or diagnosis of chronic illness. The ISWT correlates highly with VO_2 peak, which is often used to indicate functional capacity (Lopez-Campos et al., 2008; Morales et al., 2000; Fowler et al., 2005; Brown & Wise, 2007).

Applications of Walk Tests

An application of walk tests is to evaluate health-related fitness. One of the main purposes of functional fitness testing for older adults is to identify those who may be at risk for falls or the inability to perform everyday activities without help (Rikli & Jones, 2002). The Senior Fitness Test (SFT) was developed as a new test battery by Rikli and Jones (2002) to measure strength, flexibility, agility and aerobic capacity through a series of safe and easy to administer tests for older adults. The SFT included a 6-minute walk test as the measure to determine aerobic endurance. Another example of a health-related fitness walk test is the 2-km walk developed by Suni and colleagues (1998). This walk test is designed for healthy, active individuals between the ages of twenty and sixty-five by the Urho Kaleva Kekkonen Institute (UKK). The participants are asked to walk as fast as possible at a steady pace for two-thousand meters or 5 laps around a four-hundred meter track (Oja, Malmberg, & Pokki, 1998). These walk tests provide an assessment of health and fitness and can help develop a personalized exercise program.

Walk tests have also been used in clinical settings for patients with a variety of diseases. The 6-minute walk test was originally developed by Singh (1992) and tested on chronic obstructive pulmonary disease (COPD) patients. It has since been used in cardiac rehabilitation programs to determine appropriate work intensity for an individual before they start the program and to measure progress at the end of the program. In a study completed by Gayda, Choquet, Temfemo, & Ahmaidi (2003), a 20-meter shuttle walk was found suitable for estimating VO_2 max and functional capacity in coronary artery disease patients. Although a variety of tests have been researched, the walk tests that are applied most often include the 6-minute walk and the ISWT.

6-Minute Walk Test & Shuttle Walk Tests

The 6-minute walk test was first developed as a modification from the 12-minute walk test for people with COPD who were unable to complete the full twelve-minute test (Wise & Brown, 2005). The 6-minute walk test has many advantages including; ease of administration and does not require expensive equipment. This test also allows the participants to rest during the test if needed which can be important in patients with severe COPD (Turner, Eastwood, Cecins, Hillman & Jenkins, 2004). Disadvantages of the 6-minute walk test include it can only be performed on an individual basis; self-paced speed, motivation and encouragement cannot be standardized (van Bloemendaal et al., 2012).

Both the 6-minute walk test and ISWT have been validated as tests to measure functional capacity (Wise & Brown, 2007). Vagaggini et al. (2003) performed a study to compare the cardiorespiratory performance of each test; the ISWT and the 6-minute walk. The results of this study showed similar cardiorespiratory performances in the tests even though the shuttle walk test is closer to a sub maximal test (Vagaggini et al., 2003). The authors noted the test was limited to eighteen subjects, which could partially explain these results. Singh and colleagues (1992) discovered patients with chronic airway obstruction walked further and achieved greater maximal heart rates during the incremental shuttle walk compared to the six-minute walk test. Similar results were found by Swinburn, Wakefield, and Jones (1985). They found lower results for VO_2 max during self-paced compared to paced-tests. Therefore, it was concluded that participants tend to choose a speed that will allow them to be comfortable instead of pushing themselves to reach maximal performance (Swinburn et al., 1985).

Turning Mechanics

Walk tests are most often used to measure functional fitness, but there are others with the purpose of measuring mechanics such as turning efficiency. However, except for the one study performed by Hess et al. (2010), turning efficiency has not been considered an element of typical shuttle walk performance. During the ISWT, participants tend to use the same leg on the inside (close to the cone) or to turn on throughout the entire test. This in turn leads to the outside leg travelling farther around each cone. For the most part, the ISWT consists of straight path walking. Hess et al. (2010) investigated the validity of a walk test that used both curved and straight walking paths to utilize the abilities it takes to accomplish everyday walking activities. They developed the Figure-of-8 Walk Test (F8W), which included a figure-8 pattern around two cones placed five meters apart. The researchers were interested in time, steps, smoothness of gait, physical function, and movement control.

One study by Bardin & Dourado (2012) considered the possibility that there is an association between the number of falls and performance on an ISWT in elderly women due to lower cardiorespiratory fitness levels and a lack of balance and agility. The turning aspect of the ISWT requires agility, balance, and the test itself requires cardiorespiratory fitness. This could explain why there is a correlation with balance, the occurrence of falls and performance on an ISWT (Bardin & Dourado, 2012). The FHSU shuttle walk could provide participants with a better functional fitness evaluation, as they would use both curved and straight walking paths and prevent one leg from receiving more stress than the other.

Walking Velocity

Walking velocity is generally assessed to “describe differences in walking speed between patient populations or describe the relationships between walking speed and other health-related and/or functional outcomes” (Graham Ostir, Fisher & Ottenbacher, 2008). Previous research has stated that walking velocity could be used in a clinical setting to predict health status and functional decline (Fritz & Lusardi, 2009; Bohannon, 1997). Walking requires utilizing many organ systems, which explains why a slower gait could represent organ systems not working properly (Studenski, 2009). According to Studenski (2009), walking velocity could have many vital applications in a clinical setting including identifying individuals with current disability, testing to diagnose a clinical problem and to assessing change over time.

There are two types of gait testing; laboratory gait analysis and clinical testing. Laboratory gait analysis requires expensive equipment and a higher amount of training while clinical testing is inexpensive and easy to administer (Wolf, Pamela, Gage, Gurucharri, Robertson & Stephen, 1999). The Timed 10-Meter walk test is a clinical test that has been used in previous studies to measure walking velocity and has provided valid and reliable results (Wolf et al., 1999).

Conclusion

After reviewing previous research, there are numerous studies on the different types of walk tests, time-based, fixed-distance and velocity-based, in a variety of populations and settings. Little research has been performed on developing a single walk test to measure functional fitness of an individual. There are further limitations in the research when it comes to using a shuttle walk test to assess healthy individuals. There have been no studies conducted utilizing a figure-8 pattern as the walking path during an ISWT.

Chapter 3

Methodology

Introduction

The purpose of this study is to evaluate the validity and reliability of the Fort Hays State University (FHSU) shuttle walk as a measure of functional walking fitness. Preliminary and operational procedures will be used to further investigate the problem of this study. The purpose of preliminary procedures will be used to organize the study, while the purpose of the operational procedures will be to give details on how the study will be explained and conducted. The preliminary procedures will include: 1) selection of subjects, 2) selection of instrumentation, and 3) selection of research design. The operational procedures will include: 1) instruction for subjects, 2) test administration and 3) data collection.

Preliminary Procedures

Selection of subjects. The subjects used in this study included 28 college-age volunteers from the HHP 447 Instrumentation class. Another 12 volunteers came from the Active Aging Program (AAP) including Aquacise and the Personal Fitness Programs (PFP) and the Health and Human Performance (HHP) faculty.

The individuals in the AAP all received clearance from their physician before participating and completed a health history/risk factor questionnaire. All AAP volunteers were sent a Recruitment Letter from the researcher (See Appendix A). All participants read and signed an informed consent form before participating in the study. They were asked to direct any questions regarding the study to the researcher before beginning the test.

The college-age volunteers from the HHP classes were recruited by the researcher visiting the classes and reading a description of the study from the informed consent document (See Appendix B). This was followed by an open invitation to participate. Those who chose to participate read through and signed the informed consent before participating in the study. All students in these HHP classes are required to participate in a certain number of pre-professional experiences. Pre-professional development for these classes can include participating as a research subject in a research study. The students were not pre-screened because they routinely participate in activity-based classes, which require working at a much higher intensity than the walk test used in this study.

The volunteers were first divided into age groups, college-age and AAP participants. Within these main groups, the participants were divided into the FHSU Reliability group and the MSWT Comparison group, through random assignment. Each participant in the college-aged group was given a number of one through twenty following the order in which they signed up. The odd numbers were placed in the FHSU Reliability group C (C referring to college) and the even numbers were placed in the MSWT Comparison group C. The participants in the MSWT Comparison group C were required to perform two different shuttle walk tests in order to assess validity, compared to the FHSU Reliability group C who performed the same shuttle walk test on both days to assess reliability. Random assignment was also used to determine which test the participants in the MSWT Comparison group C performed on the first and second visits. Once the participants were decided for the MSWT Comparison group C, they were assigned a number one through ten. The odd numbered participants performed the FHSU shuttle walk test on the first visit and the MSWT on the second visit. The even numbered participants performed the MSWT on the first visit and the FHSU shuttle walk test on the second visit. This same procedure was used for the twenty Active Aging volunteers. The only difference was that the divided groups were named the FHSU Reliability group A (A for Active Aging) and the MSWT Comparison group A.

Selection of instrumentation. The setting for the study was either an auxiliary gym or the Aerobic Dance room located in Cunningham Hall on the campus of Fort Hays State University. Participants performed two different shuttle walk tests, the FHSU shuttle walk and the MSWT. The purpose of this study was to determine the validity of the newly developed figure-8 shuttle walk test against the previously validated MSWT.

The original 10-meter shuttle walk test consisted of participants walking 10-meters back and forth using a pivot turn to change direction at the end of each shuttle. Participants found the pivot turns to be uncomfortable. The MSWT was developed from the ISWT with the main change being participants walked back and forth around two cones placed 9-meters apart. The assumption was the peaks of the turns at the end of each shuttle made the walk a full 10-meters like the original ISWT.

During performance of these two tests in Exercise Physiology labs at FHSU, it was observed that college students performed better during the original ISWT with pivot turns. The same lab was completed the next semester and the results confirmed identical findings. These results were unexpected due to the original test being a longer distance and the pivot turns being uncomfortable. The first question to investigate was the actual distance walked during the 9-meter MSWT. Distance was measured by laying a tape measure along the approximate walking pattern. The measurement provided evidence the actual distance covered during one segment of the MSWT was longer than 10-meters (mean = 10.65) meters. It is important to keep in mind the path of the turn around each cone was not controlled. As the idea of incorporating a figure-8 pattern was being considered for another modification to the MSWT, the distance was decreased. The distance of 8.5 meters was chosen because while measuring a rough estimate of the figure-8 walking pattern, 8.5 meters was closer to a total of 10-meters for one shuttle.

The MSWT was chosen as a criterion test for this study because it has been extensively validated and because it is the incremental shuttle walk test of choice in clinical settings (Bradley et al., 1998; Bradley, Howard, Wallace & Elborn, 2000; Campo et al,, 2006). The study was limited to one criterion test so participants would not be discouraged because of multiple walk test trials.

A Freelap digital automated timing system, including a stopwatch and TX Junior Transmitters, was used to establish walking velocities for each participant. Other instruments used in this study were two orange cones, a measuring tape. Borg's Rating of Perceived Exertion (RPE) scale was used to determine perception of exercise intensity and exertion (See Appendix D). A commercially available shuttle test audio signal, TeamBeep, was used to provide the audio signal throughout the test. Although no validity studies were found, this signal is assumed to be highly valid and reliable because it emits the audio signal on the standardized shuttle segment durations and relies on the computer clock for timing.

Selection of research design. This study was designed to validate a new shuttle walk test. The independent variables were the type of incremental shuttle walk test, the MSWT and the FHSU shuttle walk; age and gender. The dependent variables are total shuttles completed, RPE, and walking velocity. The study was conducted at the quasi-experimental level using a two group, test-retest model with two levels and random assignment.

Operational Procedures

Instruction for subjects. The participants were encouraged to give their full effort during the test as a major part of this study is determining validity. It was also stressed that the participants may stop at any time during the study for any reason. The decision to opt out of participating has no effect on the quality of care, academic standing, and eligibility to participate in the AAP.

Test administration. The researcher who was trained in the proper test protocol collected data. The subjects were randomly divided into two groups as described in the Selection of Subjects section. The participants in the FHSU Reliability groups A and C performed two trials of the FHSU shuttle walk on two separate days. The MSWT Comparison groups A & C performed one trial each of the following tests on separate days; the MSWT and FHSU shuttle walk. A maximum of three subjects was tested at one time.

The participants were asked to report to either an auxiliary gym or the Aerobic Dance room. On the first visit, participants from both groups performed two walking velocity tests and one shuttle walk test. The walking velocity tests were timed first using the Freelap timing device. All performers were asked to securely fasten the Freelap Stopwatch with the Sprint Belt around their waist.

Walking velocities were determined by using a walking velocity 10-meter test. Each participant performed two trials at a comfortable, preferred pace and two more trials at a maximal walking speed pace. First, the participants were asked to walk past two transmitters, placed 10-meters apart, at their preferred, comfortable walking pace with an additional five meters on each end for acceleration and deceleration. This was explained to them as the normal walking speed they would use to get from one point to another, not in any hurry. Each participant performed two trials at this pace. The times for each trial were recorded on the data sheet (See Appendix C). Next, the participants performed another 10-meter walk except this time they were asked to walk as fast as they possibly could from one transmitter to the next without running. This was the participant's perceived maximal walking speed. They performed two trials of this test and the results were recorded.

The third test performed on the first visit for the FHSU Reliability groups A and C was the FHSU shuttle walk. This shuttle walk used a newly incorporated figure-8 pattern. The cones were placed 8.5 meters apart for this test. At the end of the walk test, the participants were asked to rate their effort and exertion using Borg's Rating of Perceived Exertion scale.

The FHSU shuttle walk test keeps pace with a pre-recorded audio file. The test begins with a series of beeps and recorded instructions. The participants were instructed to walk in a figure-8 pattern around the two cones. All participants were shown an example of the walk pattern by the researcher before starting the test. The test requires participants to complete a turn around the cone as the audio signal beeps. The time between beeps gets increasingly shorter after each minute long stage. The test was terminated after the third time in a row the participant was more than 0.5 meters away from the cone when the pre-recorded signal beeped.

The MSWT Comparison groups A and C performed the same two walking velocity tests described for the FHSU Reliability groups A and C on their first visit. Next, they performed the MSWT or the FHSU shuttle walk test depending on which test they were randomly assigned. The MSWT involved walking back and forth around the outside of two cones placed 9.0 meters apart keeping pace with a pre-recorded audio signal. They were instructed on the walk pattern and then shown an example from the researcher. Each stage of the test sped up 0.17 meters per second every minute. Each change in velocity was indicated buy unique audio signal of three beeps. The test was terminated when the participant was more than 0.50 meters away from the cone three times in a row at the sound of the beep.

The second visit for the FHSU Reliability groups A and C followed the same protocol as the first visit. It included exactly the same tests performed on visit one including; two trials of comfortable walking velocity, two trials of peak walking velocity and one trial of the FHSU shuttle walk test. The second visit for the MSWT Comparison groups A and C included the same walking velocity tests as visit one. The shuttle walk test performed was either the FHSU shuttle walk test or the MSWT. This was decided by random assignment before data collection had begun.

Data collection. The data was organized and analyzed using the Statistical Package for the Social Sciences 20.0 (SPSS). A Repeated Measure Analysis of Variance (ANOVA) was used to analyze the number of total shuttles completed and RPE from trial one and trial two of the shuttle walk tests performed by all participants. All data was analyzed at the 0.05 level of significance. When significance was found, Tukey's Least Significant Difference test was used.

Chapter 4

Results

Introduction

The purpose of this study was to evaluate the validity and reliability of the FHSU shuttle walk test of functional walking fitness incorporating a new figure-8 walking pattern. Each subject performed a 10-meter comfortable and maximal walking velocity test and a shuttle walk test on two separate days at least forty-eight hours apart.

All data was collected over 24 days during March and April in an auxiliary gym or the Aerobic Dance room in Cunningham Hall. Twenty-eight HHP college students, 15 males (mean age = 270.07 ± 19.21 months) and 13 females (mean age = 262.77 ± 12.50 months) participated from Fort Hays State University class, HHP 447 Instrumentation in Health and Human Performance. Another seven males (mean age = 703.6 ± 46.41 months) and five females (mean age = 674.8 ± 50.98 months) from the AAP and HHP faculty also participated. The college-aged students were identified by a C after their code number and the Active Aging individuals have an A after their number. Only one male college student did not complete both days of the study. This was due to scheduling conflicts associated with his involvement with FHSU athletics.

An ANOVA was used to analyze the data. The analyzed data is represented in Figures and Tables. The descriptive statistics tables for the FHSU Reliability group and the MSWT Comparison group of the AAP participants are illustrated in Tables 1 and 2 respectively.

.Table 1

Descriptive Statistics for Active Aging Participants: FHSU Reliability Group

			AA: FHSU Reliability					
	Gender	N	Mean	SD		N	Mean	SD
Day 1 Total Shuttles					Day 2 Total Shuttles			
	M	5	125.2	34.39		5	101.8	23.49
	F	1	183.0	-		1	155.0	-
	Total	6	134.8	38.77		6	110.7	30.18
Day 1 RPE					Day 2 RPE			
	M	5	5.20	3.51		5	5.50	1.87
	F	1	7.00	-		1	7.00	-
	Total	6	5.50	3.22		6	5.75	1.78

Table 2

Descriptive Statistics for Active Aging Participants: MSWT Comparison Group

			AA: MSWT Comparison					
	Gender	N	Mean	SD		N	Mean	SD
Day 1 Total Shuttles					Day 2 Total Shuttles			
	M	2	150.0	38.18		2	135.5	27.57
	F	4	122.0	36.89		4	98.25	25.46
	Total	6	131.3	36.29		6	110.7	30.18
Day 1 RPE					Day 2 RPE			
	M	2	6.50	2.12		2	5.50	2.12
	F	4	6.25	2.63		4	5.88	1.93
	Total	6	6.33	2.25		6	5.75	1.78

Table 3

Descriptive Statistics for College-age Participants: FHSU Reliability Group

	College: FHSU Reliability							
	Gender	N	Mean	SD		N	Mean	SD
Day 1 Total Shuttles					Day 2 Total Shuttles			
	M	8	179.5	31.80		8	139.1	63.15
	F	7	134.4	57.43		7	161.1	51.13
	Total	15	158.5	49.61		15	149.4	56.95
Day 1 RPE					Day 2 RPE			
	M	8	5.75	2.25		8	6.25	2.25
	F	7	4.71	3.15		7	5.71	3.40
	Total	15	5.27	2.66		15	6.00	2.75

Table 4

Descriptive Statistics for College-age Participants: MSWT Comparison Group

	College: MSWT Comparison							
	Gender	N	Mean	SD		N	Mean	SD
Day 1 Total Shuttles					Day 2 Total Shuttles			
	M	8	186.5	51.83		8	166.1	49.33
	F	6	128.0	46.61		6	110.8	39.22
	Total	14	161.4	56.43		14	142.4	52.04
Day 1 RPE					Day 2 RPE			
	M	8	5.888	2.47		8	6.50	2.78
	F	6	4.17	1.72		6	4.67	2.16
	Total	14	5.14	2.28		14	5.71	2.61

The descriptive statistics for the FHSU Reliability group and the MSWT Comparison group of the college-age individuals are presented in Tables 3 and 4.

Analysis of Variance Results

Validity. Null Hypothesis 1: The difference in total shuttles completed in the FHSU shuttle walk to those completed in the MSWT will not be statistically significant. The Repeated Measures ANOVA found significance in the difference between the mean values of total shuttles completed during the FHSU shuttle walk when compared to the MSWT. Total shuttles completed during the MSWT (mean total shuttles = 132.9 ± 48.12 shuttles) when compared to total shuttles performed during the FHSU shuttle walk test (mean total shuttles = 152.4 ± 52.21 shuttles). Test order was counterbalanced so test order did not impact this difference. The Repeated Measures ANOVA results for total shuttles completed in the MSWT Comparison group are presented in Table 5.

Null Hypothesis 1 was rejected. In the MSWT Comparison group, the number of total shuttles completed during the MSWT was lower than total shuttles completed during the FHSU shuttle walk. The mean total shuttle values indicated significantly fewer shuttles completed ($p = 0.002$) during the FHSU shuttle walk when compared to the MSWT.

Null Hypothesis 2: The difference of total shuttles completed in the MSWT to those completed in the FHSU shuttle walk in the MSWT Comparison group A and C will not be statistically significant. The Repeated Measure ANOVA did not identify a significant difference between age groups in the MSWT Comparison group.

Null Hypothesis 2 was retained. The difference between total shuttle mean values by age group did not meet the criteria for statistical significance.

Null Hypothesis 3: The difference of total shuttles completed in the MSWT to those completed in the FHSU shuttle walk in the MSWT Comparison group males and females will not be statistically significant. The Repeated Measure ANOVA did not identify a significant difference in total shuttles between genders in the MSWT Comparison group (Table 5).

Null Hypothesis 3 was retained. No statistical significance was found between total shuttle mean values with regard to gender (Table 5).

Table 5

Repeated Measures ANOVA Results for Total Shuttles: MSWT Comparison Group

	SS	df	MS	F	Significance
Test	2757.30	1	2757.30	13.134	0.002*
Age Group	.241	1	.241	0.001	0.973
Gender	17.52	1	15.52	0.083	0.773
Test, Age Group & Gender	74.50	1	74.50	0.355	0.560

*$p < 0.05$

Null Hypothesis 4: The difference between peak walking velocity compared to the final velocity during the FHSU shuttle walk and peak walking velocity compared to the final velocity during the MSWT will not be statistically significant. A Tukey LSD Post Hoc Analysis was conducted because the difference between peak walking velocity and the final velocity on the shuttle walk tests was found to be significant. The Repeated Measures ANOVA results for walking velocity are presented in Table 6. The results from the Tukey LSD Post Hoc Analysis are shown in Table 7.

Null Hypothesis 4 was rejected. The differences between peak velocity and the final velocities on both the FHSU shuttle walk and the MSWT were found to be statistically significant at the 0.05 level.

Table 6

Repeated Measures ANOVA Results for Walking Velocity

	SS	df	MS	F	Significance
Test Version	0.663748	1	0.663748	4.326	0.034*

*p < 0.05

Table 7

Tukey LSD Post Hoc Analysis of Test Version

	MD	SE	Significance
Peak Velocity – FHSU Final Velocity	0.401	0.061	0.002*
Peak Velocity- Modified Final Velocity	0.254	0.053	0.008*
FHSU Final Velocity – Modified Final Velocity	0.214	0.051	0.013*

*p < 0.05

Null Hypothesis 5: The difference in correlation between peak walking velocity and the FHSU shuttle walk velocity and correlation between peak walking velocity and the MSWT final velocity will not be statistically significant. The significance test between the correlations is presented in Table 8.

Table 8

Test for Significant Difference between Correlations of FHSU Final Velocity to Peak Velocity and MSWT Final Velocity to Peak Velocity

FHSU		MSWT	
$r_a =$	0.77861	$r_b =$	0.76575
$n_a =$	20	$n_b =$	20
	Z = 0.09		
	P (two-tailed) = 0.9283		

Note. r_a is the correlation coefficient between FHSU final velocity and peak velocity. r_b is the correlation coefficient between MSWT final velocity and peak velocity. Z is the z-value for the Fisher r to z transformation to assess the significance of the difference between two correlations.

The relation between peak walking velocity and final velocity during the FHSU shuttle walk and the MSWT are illustrated in Figures 1 and 2.

Figure 1. Scatter plot of Relation between Peak Walking Velocity and Final Velocity on FHSU

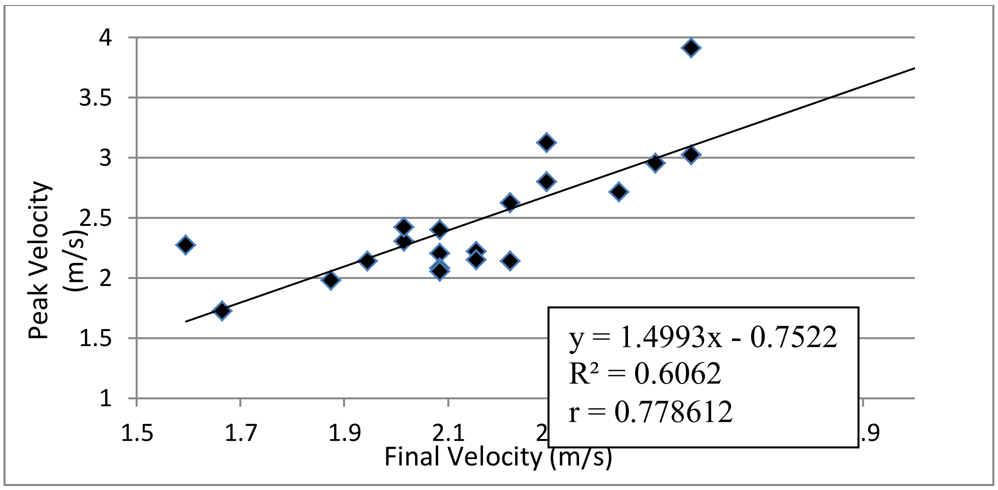
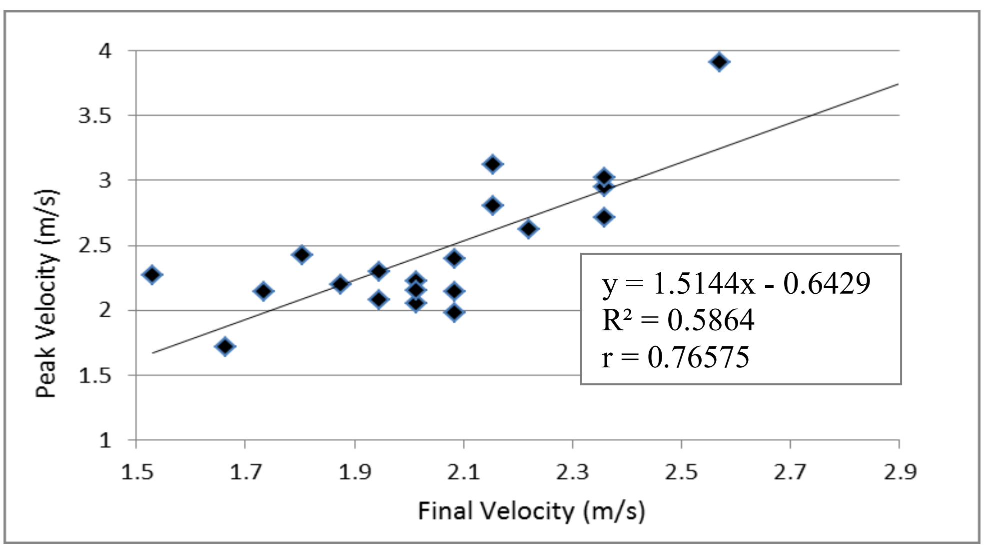


Figure 2. Scatter plot of Relation between Peak Walking Velocity and Final Velocity on MSWT



Null Hypothesis 5 was retained. No statistically significance difference was found between the correlation of peak walking velocity and the FHSU shuttle walk velocity compared to the correlation of peak walking velocity and the MSWT final velocity.

Null Hypothesis 6: The difference in RPE from the FHSU shuttle walk compared to the RPE from the MSWT will not be statistically significant. The Repeated Measure ANOVA did not identify a significant difference in RPE between performance of trial one and trial two of the shuttle walk test in the MSWT Comparison group. The RPE results from the Repeated Measures ANOVA for the MSWT Comparison group are presented in Table 9.

Table 9

Repeated Measures ANOVA Results for RPE: MSWT Comparison Group

	SS	df	MS	F	Significance
Test	0.030	1	0.030	0.031	0.863
Age Group	3.000	1	3.000	3.091	0.098
Gender	0.120	1	0.120	0.124	0.730
Test, Age Group & Gender	0.270	1	0.270	0.278	0.605

*$p < 0.05$

Null Hypothesis 6 was retained. The difference between RPE mean values by shuttle walk test did not meet the criteria for statistical significance.

Reliability. Null Hypothesis 7: The difference in RPE from the FHSU shuttle walk trial one compared to the RPE from the retest FHSU shuttle walk will not be statistically significant. The RPE results from the Repeated Measures ANOVA for the FHSU Reliability group are presented in Table 10.

Null Hypothesis 7 was retained. No statistical significance was found in the mean values of RPE from trial one to trial two in the FHSU Reliability group.

Null Hypothesis 8: The difference in RPE from the first trial of the shuttle walk compared to the RPE from the second trial in the FHSU Reliability group and the MSWT Comparison group A and C will not be statistically significant. The Repeated Measure ANOVA did not identify a significant difference in RPE between age groups. The Repeated Measures ANOVA results for RPE between age groups are presented in Table 10.

Null Hypothesis 8 was retained. No statistical significance was found between RPE mean values with regard to age group.

Null Hypothesis 9: The difference in RPE from the first trial of the shuttle walk test compared to the second trial of the shuttle walk test between males and females will not be statistically significant. The Repeated Measure ANOVA did not identify a significant difference in RPE between genders. The Repeated Measures ANOVA results for RPE between genders are presented in Table 10.

Table 10

Repeated Measures ANOVA Results for RPE: FHSU Reliability

	SS	df	MS	F	Significance
Test	1.104	1	1.104	0.317	0.581
Age Group	0.491	1	0.491	0.141	0.712
Gender	0.014	1	0.014	0.004	0.951
Test, Age Group & Gender	0.218	1	0.218	0.063	0.805

$*p < 0.05$

Null Hypothesis 9 was retained. The difference in RPE mean values was not found to be statistically significant in regard to males and females.

Null Hypothesis 10: The difference of total shuttles completed in the first trial of the FHSU shuttle walk to those completed in the second trial of the FHSU shuttle walk will not be statistically significant. The Repeated Measures ANOVA did not identify a significant difference in total shuttles in the FHSU Reliability group between performance on day one and day two of the shuttle walk test. The Repeated Measures ANOVA results for total shuttles are presented in Table 11.

Null Hypothesis 10 was retained. The difference between mean values of two trials of the FHSU shuttle walk test did not meet the criteria for statistical significance.

Null Hypothesis 11: The difference of total shuttles completed in the first trial of the FHSU shuttle walk to those completed in the second trial of the FHSU shuttle walk in the FHSU Reliability group A and C will not be statistically significant. The Repeated Measure ANOVA did not identify a significant difference in total shuttles in the FHSU

Reliability group between age groups. The Repeated Measures ANOVA results for total shuttles between age groups are presented in Table 11.

Null Hypothesis 11 was retained. No significant difference was found between mean values by age group in the FHSU Reliability group.

Null Hypothesis 12: The difference of total shuttles completed in the first trial of the FHSU shuttle walk to those completed in the second trial of the FHSU shuttle walk in the FHSU Reliability group males and females will not be statistically significant. The Repeated Measure ANOVA did not identify a significant difference between genders in the FHSU Reliability group. The Repeated Measures ANOVA results for total shuttles between genders are presented in Table 11.

Null Hypothesis 12 was retained. The difference between mean values by gender did not meet the criteria to be statistically significant.

Table 11

Repeated Measures ANOVA Results for Total Shuttles: FHSU Reliability

	SS	df	MS	F	Significance
Test	1441.86	1	1441.86	0.673	0.423
Age Group	485.15	1	485.15	0.226	0.640
Gender	1330.14	1	1330.14	0.621	0.442
Test, Age Group & Gender	1750.63	1	1750.63	0.817	0.379

*$p < 0.05$

Chapter 5

Discussion, Conclusion and Recommendations

Introduction

The purpose of this study was to analyze the validity and reliability of the FHSU shuttle walk test of functional walking fitness incorporating a new figure-8 walking pattern. The sample was divided by age group and further divided by version of shuttle walk performed. An A referred to the AAP participants while a C was the college-age participants. The results of an ANOVA statistical analysis found a statistically significant difference between the total shuttles completed during the FHSU shuttle walk when compared to the MSWT in the MSWT Comparison group. Final velocity on both versions of the shuttle test had similar correlations to peak walking velocity. No significant difference was found between age groups or gender.

Discussion

The MSWT is considered a criterion test of functional walking performance. It has been accepted and used in previous research to measure functional walking fitness and has been validated against a maximal treadmill test. Validity in this study was evaluated primarily by comparing performance on the FHSU shuttle walk to performance on the MSWT. Significantly more shuttles were completed on the FHSU shuttle walk (mean total shuttles = 152.4 ± 52.21) than on the MSWT (mean total shuttles = 132.9 ± 48.12 shuttles). No significance was found for any other independent variables or interactions. Participants completed more shuttles during the FHSU protocol with no difference in RPE, indicating that the FHSU walking pattern is easier than the MSWT. This indicates the need to analyze whether it is easier because it is a shorter course or because of turning differences? This study did not specifically control for the differences in turning around the cones. The better performance on the FHSU shuttle walk is probably at least partly because of the shorter walking distance. Future studies should directly measure distance covered and should control for turning style differences.

The results from this study show the participants' final velocity during the shuttle walk was less than their peak walking velocity. Final velocity from the shuttle walk is highly correlated to peak walking speed but cannot be used as a substitute for peak walking speed. The final stage completed on the shuttle walk was at a velocity lower than the participants' maximum walking velocity. This indicates that factors other than walking velocity limit incremental walking test performance. As expected during progressive sub-maximal testing, aerobic capacity could be an important limiting factor for incremental shuttle walking performance.

Reliability in this study was evaluated through the performance on the test-retest of the FHSU shuttle walk in the FHSU Reliability group. The results showed no significant difference between the total shuttles completed during the FHSU shuttle walk (mean total shuttles = 151.71 ± 47.10 shuttles) compared to shuttles completed during the retest of the FHSU (mean total shuttles = 160.8 ± 53.10 shuttles). This indicates the performance of the FHSU shuttle walk during trial one and trial two was consistent between participants in the FHSU Reliability group of this study. A recommendation for future studies is to have every participant perform two trials of the FHSU, one trial of the MSWT, and one trial of the standard original 10 meter shuttle walk with pivot turns.

Another type of validity measure for incremental testing would be rate of increase in physiological variables such as heart rate, respiration, and oxygen saturation. Future studies should monitor some or all of these variables. It would be especially useful to accurately measure heart rate because heart rate and heart rate recovery are routinely used during diagnostic incremental treadmill exercise testing.

Most of the participants were students in the HHP department or HHP faculty members. This sample of people regularly participates in physical activity and has likely had previous positive experiences with exercise-based tests. It could be argued that they tend to have a more competitive side and could therefore perform better on these shuttle walk tests than persons from other departments on campus. Future studies should consider testing students and faculty from other departments.

Shuttle walk tests have been implemented primarily in the clinical setting. Currently, most cardiac and pulmonary rehabilitation programs use a 6-minute walk test to measure functional capacity at the beginning and end of a program. Previous research has shown self-paced walk tests, such as the 6-minute walk test, are less likely to push participants to the higher intensities most related to peak functional capacity. Shuttle walks only require walking, an everyday familiar activity, and also have the ability to provide an additional walking velocity aspect unlike self-paced tests. Since walking velocity is receiving greater attention as a unique indicator of functional capacity and as a measure of health status, velocity attained during incremental shuttle walk tests should be specifically evaluated for these purposes even though it is not identical to peak walking velocity attained during a single 10 meter walking velocity test.

Conclusions

Based on the results and within the limitations of this study, the following conclusions were drawn.

1. The FHSU shuttle walk utilized in this study elicited a higher number of total shuttles completed when compared to the previously validated MSWT.
2. Even though the mean total shuttles were less in the active aging group, the difference was not significantly different from the college-age group. Age did not significantly affect the number of total shuttles completed during the MSWT.
3. There was no significant difference between total number of shuttles completed between males and females.
4. Statistical significance was found in the difference between the direct measure peak walking velocity and the final velocity of both the FHSU shuttle walk and the MSWT.
5. There was no statistical significance found between the correlation of peak walking velocity and the FHSU shuttle walk velocity and the correlation of peak walking velocity and the MSWT final velocity.
6. There was no significant difference in RPE from the FHSU shuttle walk to the MSWT.

7. There was no significant difference in RPE from the FHSU shuttle walk to the retest of the FHSU shuttle walk.
8. There was no significant difference in RPE with regard to the age group of participants.
9. There was no significant difference in RPE with regard to gender.
10. There was no significant difference between trial one and trial two of the FHSU shuttle walk. This indicates consistent results between the versions of shuttle walk test performed.
11. There was no significant difference identified, therefore age did not affect the number of total shuttles completed during the test-retest of the FHSU shuttle walk.
12. Even though there were fewer females than males who performed the test-retest of the FHSU shuttle walk, there was no significance found between performances.

Recommendations for Further Study

1. Future studies should have the participants perform each type of shuttle walk test more than clarify validity and reliability for specific test protocols in the same subjects.
2. Future studies should utilize more participants of each gender especially in the older adult range.

3. Future studies should consider measuring heart rate or respiratory measures to further validate the FHSU shuttle walk test in comparison to physiological measures.
4. Future studies should consider recruiting participants from a non-physical education department and compare to results obtained from a department such as the HHP department tested in this study.
5. Future studies should control for the turning differences of each participant.
6. Future studies should directly measure the distance covered during the shuttle walk test.

This project was supported by grants from the National Center for Research Resources (5P20RR016475) and the National Institute of General Medical Sciences (8P20GM103418) from the National Institutes of Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Center for Research Resources, the National Institute of General Medical Sciences or the National Institutes of Health.

References

American Thoracic Society and the American College of Chest Physicians statement on cardiopulmonary exercise testing. (2003). *American Journal of Respiratory and Critical Care Medicine*, *167*(2), 211-277. doi: 10.1164/rccm.167.2.211

Bardin, M., & Dourado, V. (2012). Association between the occurrence of falls and the performance on the incremental shuttle walk test in elderly women. *Revista Brasileira de Fisioterapia, 16*(4), 275-280. doi: 10.1590/S1413-35552012005000033

Bohannon, R. (1997). Comfortable and maximum walking speed of adults aged 20-79 years: Reference values and determinants. *Age and Aging*, *26*(1), 15-19. doi: 10.1093/ageing/26.1.15

Borg, G. (1982) Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise, 14 (5), p. 377-81

Borg G. et al. (1983) A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. Medicine and Science in Sports and Exercise, 15 (6), p. 523-528

Bradley, J., Howard, J., Wallace, E., & Elborn, S. (1998). Validity of a modified shuttle test in adult cystic fibrosis. *Thorax*, *54*, 437-439. doi: 10.1136/thx.54.5.437

Bradley, J., Howard, J., Wallace, E., & Elborn, S. (2000). Reliability, repeatability, and sensitivity of the modified shuttle test in adult cystic fibrosis. *Chest*, *117*(6), 1666-1671. Retrieved from http://journal.publications.chestnet.org/data/Journals/CHEST/21948/1666.pdf

Brown, C., & Wise, R. (2007). Field tests of exercise in COPD: The six-minute walk test and the shuttle walk test. *Journal of Chronic Obstructive Pulmonary Disease*, *4*, 217-223. doi: 10.1080/15412550701480125

Campo, L., Chilingaryan, G., Berg, K., Paradis, B., & Mazar, B. (2006). Validity and reliability of the modified shuttle walk test in patients with chronic obstructive pulmonary disease. *Archives of Physical Medicine and Rehabilitation*, *87*(7), 918-922. Retrieved from http://www.sciencedirect.com/science/article/pii/S0003999306002838

Ehrman, J. K. (2010). *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription*. (6th ed.). Baltimore: Lippincott Williams & Wilkins.

Fleg, J., Pina, I., Balady, G., Chaitman, B., Fletcher, B., Lavie, C., Limacher, M., Stein, R., Williams, M & Bazzarre, T. (2000). Assessment of functional capacity in clinical and research applications: An advisory from the committee on exercise, rehabilitation, and prevention, council on clinical cardiology, American Heart Association. *Circulation*, *102*, 1591-1597. Retrieved from http://circ.ahajournals.org/content/102/13/1591.full.pdf html

Fowler, S. J., Singh, S. J., & Revill, S. (2005). Reproducibility and validity of the incremental shuttle walking test in patients following coronary artery bypass surgery. *Physiotherapy*, *91*(1), 22-27. doi: 10.1016/j.physio.2004.08.009

Fritz, S., & Lusardi, M. (2009). White paper: Walking speed. *Journal of Geriatric Physical Therapy*, *32*(2), 2-5. Retrieved from http://web.missouri.edu/~proste/tool/cv/White_Paper___Walking_Speed__the_Sixth_Vital_Sign_.2.pdf

Gayda, M., Choquet, D., Temfemo, A., & Ahmaidi, S. (2003). Cardiorespiratory fitness and functional capacity assessed by the 20-meter shuttle walking test in patients with coronary artery disease. *Archives of Physical Medicine and Rehabilitation*, *84*(7), 1012-1016. Retrieved from http://download.journals.elsevierhealth.com/pdfs/journals/0003-9993/PIIS0003999303000364.pdf

Graham, J., Ostir, G., Fisher, S., & Ottenbacher, K. (2008). Assessing walking speed in clinical research: A systematic review. *Journal of Evaluation in Clinical Practice*, *14*(4), 552-562. doi: 10.1111/j.1365-2753.2007.00917.x

Hess, R., Brach, J., Piva, S., & Van Swearingen, J. (2010). Walking skill can be assessed in older adults: Validity of the figure-of-8 walk test. *Physical Therapy*, *90*(1), 89-99. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2802825/

Leger, L., & Lambert, J. (1982). A maximal multistage 20-m shuttle run test to predict vo2 max. *European Journal of Applied Physiology*, *49*(1), 1-12. doi: 10.1007/BF00428958

Lewis, M., Newall, C., Townend, J., Hill, S., & Bonser, R. (2001). Incremental shuttle walk test in the assessment of patients for heart transplantation. *Heart*, *86*(2), 183-187. Retrieved from http://heart.bmj.com/content/86/2/183.full.pdf html

Liu, N., Plowman, S., & Looney, M. (1992). The reliability and validity of the 20-meter shuttle test in American students 12 to 15 years old. *Research quarterly for exercise and sport*, *63*(4), 360-365.

Lopez-Campos, J., Cejudo, P., Ortega, F., Lopez-Marquez, I., Marquez-Martin, E., Capote, F., Echevarria, M., Montemayor, T., & Barrot, E. (2008). Shuttle walking versus maximal cycle testing: Clinical correlates in patients with kyphoscoliosis. *Respiratory Physiology and Neurobiology*, *160*(3), 334-340. doi: 10.1016/j.resp.2007.10.018

Morales, F., Martinez, A., Mendez, M., Agarrado, A., Ortega, F., Fernandez-Guerra, J., Montemayor, T., & Burgos, J. (1999). A shuttle walk test for assessment of functional capacity in chronic heart failure. *American Heart Journal*, *138*(2), 291-298. Retrieved from http://www.sciencedirect.com/science/article/pii/S0002870399701146

Morales, F., Montemayor, T., & Martinez, A. (2000). Shuttle versus six-minute walk test in prediction of outcome in chronic heart failure. *International Journal of Cardiology*, *76*(2-3), 101-105. doi: 10.1016/S0167-5273(00)00393-4

Noonan, V., & Dean, E. (2000). Submaximal exercise testing: Clinical application and interpretation. *Physical Therapy*, *80*(8), 782-807. Retrieved from http://www.physicaltherapyjournal.com/content/80/8/782.full.pdf html

Oja, P., Malmberg, J., & Pokki, T. (1998). *Guide for the UKK walk test*. (4 ed., pp. 1-19). Retrieved from https://docs.google.com/a/mail.fhsu.edu/viewer?a=v&q=cache:2V9P_Rrh30kJ:www.um.es/desarrollopsicomotor/wq/2010/wqcarrasco2010/BL22_files/TestUkk.pdf &hl=en&gl=us&pid=bl&srcid=ADGEESg-FaRPlMx50BBdPGlP8nmaKHhoKAX0p0r-IRSR9_188U-z0hDRuKLm93VmzwRg7zEsW8NGaDrEeUtM5mDAKC8n6Dm-WK095UUPsdLoCaDd8N_rq6GgBGCo7QKZVRxzsqT738Je&sig=AHIEtbRr1Wj43cgKavclPCO-55g12XxCsQ

Payne, G., & Skehan, J. (1996). Shuttle walking test: A new approach for evaluating patients with pacemakers. *Heart*, *75*(4), 414-418. doi: 10.1136/hrt.75.4.414

Rikli, R.E., & Jones, C.J. (2002). Measuring functional fitness of older adults. *The Journal on Active Aging*, *2*(1), 24-30. Retrieved from http://www.icaa.cc/1-Organizationalmember/member_journal_on_active_aging/2002/march_april/magazine2.pdf

Singh, S. (1992). The use of field walking tests for assessment of functional capacity in patients with chronic airways obstruction. *Physiotherapy*, *78*(2), 102-104. doi: 10.1016/S0031-9406(10)61957-8

Singh, S., Morgan, M., Scott, S., Walters, D., & Hardman, A. (1992). Development of a shuttle walking test of disability in patients with chronic airway obstruction. *Thorax*, *47*(12), 1019-1024. doi: 10.1016/j.apmr.2011.08.012

Solway, S., Brooks, D., Lacasse, Y., & Thomas, S. (2001). *A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain*. (Vol. 119, pp. 256-270). Retrieved from http://journal.publications.chestnet.org/article.aspx?articleid=1079374

Studenski, S. (2009). Bradypedia: Is gait speed ready for clinical use. *The Journal of Nutrition, Health and Aging*, *13*(10), 878-880. Retrieved from http://saintboniface-gaitspeed.wdfiles.com/local--files/bradypedia:is-gait-speed-ready-for-clinical-use/bradypedia.pdf

Suni, J., Oja, P., Miilunpalo, S., Pasanen, M., Vuori, I., & Bos, K. (1998). Health-related fitness battery for adults: Associations with perceived health, mobility, and back function and symptoms. *Archives of Physical Medicine and Rehabilitation*, *79*(5), 559-569. Retrieved from http://download.journals.elsevierhealth.com/pdfs/journals/0003-9993/PIIS0003999398900739.pdf

Swinburn, C., Wakefield, J., & Jones, P. (1985). Performance, ventilation, and oxygen consumption in three different types of exercise test in patients with chronic obstructive lung disease. *Thorax*, *40*(8), 581-586. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1020595/pdf/thorax00236-0023.pdf

Turner, S., Eastwood, P., Cecins, N., Hillman, D., & Jenkins, S. (2004). Physiologic responses to incremental and self-paced exercise in COPD: A comparison of three tests. *Chest*, *126*(3), 766-773. doi: 10.1378/chest.126.3.766

Vagaggini, B., Taccola, M., Severino, S., Marcello, M., Antonelli, S., Brogi, S., De Simone, C., Giardina, A., & Paggiaro, P.L. (2003). Shuttle walking test and 6-minute walking test induce a similar cardiorespiratory performance in patients recovering from an acute exacerbation of chronic obstructive pulmonary disease. *Respiration*, *70*(6), 579-584. doi: 10.1159/000075202

van Bloemendaal, M., Kokkeler, A., & van de Port, I. (2012). The shuttle walk test: A new approach to functional walking capacity measurements for patients after stroke?. *Archives of Physical Medicine and Rehabilitation*, *93*(1), 163-166. doi: 10.1016/j.apmr.2011.08.012

Wise, R., & Brown, C. (2005). Minimal clinically important differences in the six-minute walk test and the incremental shuttle walking test. *COPD: Journal of Chronic Obstructive Pulmonary Disease*, *2*(1), 125-129. doi: 10.1081/COPD-200050527

Wolf, S. L., Pamela, P. A., Gage, K., Gurucharri, K., Robertson, R., & Stephen, K. (1999). Establishing the reliability and validity of measurements of walking time using the emory functional ambulation profile. *Physical Therapy*, *79*(12), 1122-1133. Retrieved from http://ptjournal.apta.org/content/79/12/1122.long

APPENDIXES

Appendix A

Recruitment Letter

3/15/13

Hello!

My name is Lynae Wright. I am a graduate student at Fort Hays State University. I am currently working on my thesis, which is a study involving a shuttle walk test, with Dr. Greg Kandt. I am looking for **30 volunteers between the ages of 55 and 64 years old** from the FHSU Active Aging Program.

The requirements of my study are to come to Cunningham Hall on **two** separate days that are at least 48 hours apart (Ex: Monday and Wednesday). Each visit only takes about **30 minutes each** and will include performing a 10-meter walking velocity test where participants will be asked to walk two trials at a comfortable pace and then walk two trials at a maximal walking speed. Finally, an incremental shuttle walk test will be performed by all participants. This test requires participants to walk back and forth around 2 cones in time to an audio signal. The audio signal gradually speeds up with each stage. The test will be terminated when the participant can no longer keep up with the audio signal.

For those who are in the Personal Training Active Aging Program, one trial of the shuttle walk test will be required at some point during this next year as a part of an annual personal fitness assessment. By participating in my study, you will be able to complete the personal fitness assessment this month. (Although I would love your participation in my study, it is not required to do this assessment now.)

I can test up to 3 people at a time and I am testing every day for the next two weeks. I have included the available times on the back of this sheet. **The final day of testing is Friday April 6th, 2013.** If the times on the back of this sheet do not work for you but you would still like to participate, contact me and we will find a different time that works. My schedule is very flexible and I will work to accommodate your schedules.

If you are interested in helping me with my study please contact me as soon as possible by phone at **(620) 897-7724** or email me at **l_wright24@hotmail.com.**

Thank you for your help in advance!

Sincerely,

Lynae Wright

Appendix B

Informed Consent

INFORMED CONSENT

THE VALIDITY AND RELIABILITY OF THE FORT HAYS STATE UNIVERSITY SHUTTLE WALK TEST

You are asked to participate in a research study conducted by Lynae Wright and Dr. Greg Kandt from the Health and Human Performance Department at Fort Hays State University. This research project is currently being conducted as part of my Thesis for my Master’s degree. Your participation in this study is entirely voluntary. Please read the information below and ask questions about anything you do not understand, before deciding whether or not to participate.

• **PURPOSE OF THE STUDY**
This study will help to evaluate the validity and reliability of the modified shuttle walk and physiological monitoring tools in conjunction. The results from this study will determine whether we can get a complete fitness and functional status from a single test.

• **PROCEDURES**
If you volunteer to participate in this study, you will be asked to do the following things: You will be asked to report to the either Gym 100, 101, 120 or 121 (possibly the Aerobic Dance room) in Cunningham Hall. You will be asked to perform 4 different walking tests on two separate days. The walking tests include a 10 meter preferred walk velocity, a 10 meter peak walk velocity, and two shuttle walk tests. Laps completed and heart rate in each stage of the test will be recorded during each test.

• **POTENTIAL RISKS AND DISCOMFORTS**
Risks of participating in this research study include falling, muscle strains, ligament sprains, fractures, cardiopulmonary problems or even death. In the event of physical and/or mental injury resulting from participation in this research project, Fort Hays State University does not provide any medical, hospitalization or other insurance for participants in this research study, nor will Fort Hays State University provide any medical treatment or compensation for any injury sustained as a result of participation in this research study, except as required by law.

• **POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY**
The participants will not benefit immediately from the results of this research study. As previously mentioned, the results of this study, will potentially allow there to be one test that can provide us with both a fitness and functional status.

• **CONFIDENTIALITY**
Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as

required by law. Confidentiality will be maintained by means of assigning each participant a unique identification number that will be chosen at random by the researcher. The results of this study will not be released to anyone except those involved directly with the research study.

• PARTICIPATION AND WITHDRAWAL

You can choose whether or not to be in this study. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind or loss of benefits to which you are otherwise entitled. You may also refuse to answer any questions you do not want to answer. There is no penalty if you withdraw from the study and you will not lose any benefits to which you are otherwise entitled. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

• IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about this research, please contact:
Lynae Wright - Principal investigator – 620-897-7724, lkwright4@mail.fhsu.edu
Greg Kandt, PhD – Faculty Advisor –785-628-4371, gkandt@fhsu.edu

• RIGHTS OF RESEARCH SUBJECTS

The Fort Hays State University Institutional Review Board has reviewed my request to conduct this project. If you have any concerns about your rights in this study, please contact Dr. Greg Kandt of the Fort Hays State University HHP-IRB at email gkandt@fhsu.edu or Leslie Paige of the Fort Hays State University IRB at lpaige@fhsu.edu.

I understand the procedures described above. My questions have been answered to my satisfaction and I agree to participate in this study. I have been given a copy of this form.

____
Printed Name of Subject

______________________________________ ________________________
Signature of Subject Date

______________________________________ ________________________
Signature of Witness Date

Appendix C

Data Sheet

Data Sheet

Random Code number: Height: Gender:

Shuttle Walk:

	Initial HR:	Initial HR:
	Day 1:	Day 2:
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
	Final HR:	Final HR:
	Final stage & level:	Final stage & level:
	Borg RPE:	Borg RPE:

Walking Velocities:

	Preferred 1	Preferred 2	Maximum 1	Maximum 2
Day 1:				

Day 2:				

Appendix D

Borg's Scale of Perceived Exertion

Borg's Scale of Perceived Exertion

rating	description
6	NO EXERTION AT ALL
7	EXTREMELY LIGHT
8	
9	VERY LIGHT
10	
11	LIGHT
12	
13	SOMEWHAT HARD
14	
15	HARD (HEAVY)
16	
17	VERY HARD
18	
19	EXTREMELY HARD
20	MAXIMAL EXERTION