Associations Between Physical Activity, Physical Fitness, and Falls Risk in Healthy Older Individuals

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ASSOCIATIONS BETWEEN PHYSICAL ACTIVITY, PHYSICAL FITNESS, AND FALLS

RISK IN HEALTHY OLDER INDIVIDUALS

by

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Objective: The purpose of this study was to assess relationships between objectively

measured physical activity, physical fitness, and the risk of falling. *Methods*: A total of n=29

subjects completed the study, n=15 male and n=14 female age (mean±SD)= 70± 4 and 71±3

years, respectively.   In a single testing session, subjects performed pre-post evaluations of falls

risk (Short-from PPA) with a 6-minute walking intervention between the assessments. The falls

risk assessment included tests of balance, knee extensor strength, proprioception, reaction time,

and visual contrast. The sub-maximal effort 6-minute walking task served as an indirect

assessment of cardiorespiratory fitness. Subjects traversed a walking mat to assess for variation

in gait parameters during the walking task. Additional center of pressure (COP) balance

measures were collected via forceplate during the falls risk assessments. Subjects completed a

Modified Falls Efficacy Scale (MFES) falls confidence survey. Subjects' falls histories were

also collected. Subjects wore hip mounted accelerometers for a 7-day period to assess time spent

in moderate to vigorous physical activity (MVPA). *Results*: Males had greater body mass and

height than females (p=0.001, p=0.001). Males had a lower falls risk than females at baseline

(p=0.043) and post-walk (p=0.031). MFES scores were similar among all subjects (Median =

10). Falls history reporting revealed; fallers (n=8) and non-fallers (n=21). No significant

relationships were found between main outcome measures of MVPA, cardiorespiratory fitness,

or falls risk. Fallers had higher knee extensor strength than non-fallers at baseline (p=0.028) and

post-walk (p=0.011). Though not significant (p=0.306), fallers spent 90 minutes more time in MVPA than non-fallers (427.8±244.6 min versus 335.7±199.5). Variations in gait and COP variables were not significant. *Conclusions*: This study found no apparent relationship between objectively measured physical activity, indirectly measured cardiorespiratory fitness, and falls risk.

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CHAPTER I

INTRODUCTION

BACKGROUND AND RATIONALE

It is well established that older individuals develop a higher risk of falling. In an attempt to determine the cause of hip fractures in a group of more than 200 older individuals, Parkkari et al. (1999) reported that 98% of fractures were a result of falling. Falls are a major concern among elderly individuals (Chan et al., 2007). Berry and Miller (2008) reported that falls can often cause injury or even disability specifically in older individuals. It has also been established that numerous factors contribute to falling (Thibaud et al., 2012). Several mediating factors associated with aging have been reported by Berry and Miller (2008) including impaired vision, proprioception, balance, medication usage, and loss of muscle mass. The relationship between physical activity levels and physical fitness levels as they relate to falls risk is a topic of concern and debate. A review by Gregg, Pereira, and Caspersen (2000) found no clear effects or associations between physical activity levels and the risk of falling. In contrast to this, a recent meta-analysis of observational (i.e., cross-sectional, case-control, and cohort) studies found that higher physical activity levels might lower the risk of falls (Thibaud et al. 2012). A study by Graafmans, Lips, Wijlhuizen, Pluijm, and Bouter (2003) found that older subjects with the highest levels of physical activity had a lower falls risk than other subjects with lower activity levels. In an earlier study, Graafmans et al. (1996) reported that impairment to mobility, but not physical activity had a strong effect on increasing falls risk.

Physical activity may be a mediator of impaired mobility which is related to falls. Graafmans et al. (1996) goes on to recommend physical exercise (fitness improvement) in an

effort to reduce mobility impairment. Chan et al. (2007) reported that high levels of physical activity are related to higher falls risks, but that higher physical performance scores are related to lower falls risk in subjects over 65 years of age. However, Mertz, Lee, Sui, Powell and Blair (2010) suggested that poor fitness (cardiorespiratory fitness) levels and low levels of physical activity may contribute to an elevated risk of falling and that higher physical activity levels and higher levels of fitness (cardiorespiratory fitness) may reduce falls.   Chan et al. (2007) and Mertz et al. (2010) agree that improved fitness/physical performance may reduce falls risk, but they disagree on the effect of physical activity on the risk of falls in older subjects. Furthermore, it has been found in a recent training intervention study that physical conditioning/functional fitness status plays a significant role in the risk of falling, by demonstrating that improvements in areas such as balance and strength were related to a reduced risk of falls (Emilio, Hita-Contreras, Jimenez-Lara, Latorre-Roman, & Martinez-Amat, 2014). Furthermore, the findings of Morrison, Colberg, Parson, and Vinik (2012) would suggest that improved functional fitness levels (i.e. improved balance ability and strength) reduces the risk of falling as well.

Physical activity and fitness levels are not the only area of concern when it comes to falls risk. In the past, studies have examined the influence of various types of fatigue on various factors that influence the risk of falling. In a review, Papa, Garg, and Dibble (2015) reported that lower body fatigue, especially in the muscles around the ankles, is known to contribute to impairing reactive postural control ability. King, Stylianou, Kluding, Jernigan, and Luchies (2012) found that older individuals have less control of torque development at the ankle in general when compared to a group of younger individuals. In their review, Helbostad et al. (2010) also found that muscular fatigue impairs balance and hinders the ability to perform functional tasks. It would seem that in previous literature, a large number of studies focus on

fatigue caused by targeted resistance exercise rather than activities of daily living which may relate better to conditions that older populations might encounter. A common recommendation in past studies is that factors contributing to increased risk of falls risk should be treated by some exercise intervention to minimize the tiring or detrimental effects of fatigue.

STATEMENT OF THE PROBLEM

It would seem that physical activity and fitness levels in relation to falls risk has been well studied, however a variety of problems do exist in the literature. There is currently a disagreement in the literature about the effects of physical activity levels on the risk of falling. Some studies support high activity levels to reduce the risk of falling (Graafmans et al. 2003; Mertz et al. 2010; & Thibaud et al. 2012), while others claim the opposite (Chan et al. 2007), or claim no effect at all (Graafmans et al. 1996; Gregg et al. 2000). The paradoxical relationship between physical activity and falls risk as explained by Graafmans et al. (2003) is that physical activity is required for optimal function of mechanisms that control balance, yet when individuals are active they are at risk simply because they are susceptible to threats that cause falls.

Perhaps the most limiting factor in the literature concerning physical activity and falls risk is the reliance on subjective measures of assessing physical activity (i.e. self-completed surveys and questionnaires). Subjective measures of physical activity have been used in past literature (Chan et al. 2007; Graafmans et al. 2003; Graafmans et al. 1996; Gregg et al. 2000; Mertz et al. 2010; & Thibaud et al. 2012). It has been clearly demonstrated by Dyrstad, Hansen, Holme, and Anderssen (2014) that self-completed surveys of physical activity levels correlate very poorly with objectively recorded physical activity levels, particularly in older populations.

Currently, there is a lack of research on the relationship of physical activity levels and falls risk using objective measures of physical activity. Furthermore, the use of subjective measures for reporting falls information is also a limitation to previous literature.

A commonly occurring situation in the literature on physical activity and fitness levels in relation to falls risk is that many studies used fall incidence (after-the-fact data) to evaluate relationships between fitness and physical activity levels, rather than including tests specifically designed to assess falls risk. In many studies the information regarding incidence of falls was commonly collected with self-completed reports/journals or other subjective measures like questionnaires (Chan et al. 2007; Graafmans et al. 2003; Graafmans et al. 1996; Mertz et al. 2010). In studies where actual assessments of falls risk were performed, there is usually a limitation to the method used. For example, Emilio et al. (2014) used an indirect method of assessing falls risk that was limited to just walking traits and simple balance assessments. In the area of physical activity and fitness levels in relation to falls risk, there is currently a need for research that uses a robust and reliable assessment of falls risk.

A strong assessment of falls risk is essential when gauging an individual's susceptibility to falls. In an interesting article by Singh et al., (2012) subjects were randomly assigned to two equal groups, one of which received targeted treatment for weaknesses detected by a robust battery of tests. The robust assessment included assessments of physical abilities, mental, nutritional, and health statuses to identify weaknesses in "predictors of frailty, mortality, and nursing home admission" (Singh et al., 2012, p. 25). They reported significant quality of life improvements for individuals receiving targeted treatment over control subjects. The use of a robust falls risk assessment can identify physiological weaknesses that if treated may help to reduce the risk of falling in older populations. A robust and valid assessment of falls risk would

also provide a more reliable risk evaluation than the evaluations of risk provided in studies that only examine a few or even one factor contributing to falls risk. The Physiological Profile Assessment (PPA), thoroughly discussed by Lord, Menz, and Tiedeman (2003), offers an assessment of physiological factors that are well known to contribute to falls risk using valid and reliable tests well suited for use in older populations.

Another weakness in some studies is the lack of a close temporal relationship between the measurement of fitness (the factor) and a fall (the outcome). For example, Mertz et al. (2010) used baseline cardiorespiratory fitness data to relate apparent fitness levels to falls that were reported by survey more than 5 years after the baseline assessment of fitness in some subjects. As a result, the actual fitness levels of the subjects at the time of survey completion may not have been known. A similar time related issue was present in Chan et al. (2007), where the actual physical fitness levels of the subjects may not have been known at the time of a reported fall. There is a clear need for a timely assessment of the relationship between falls risk and physical fitness. To be more specific, there is currently a need in the literature for a study that examines the relationship between cardiorespiratory fitness levels and the risk of falling using a robust falls risk assessment.

The effect of the type of tiring or fatiguing exercise on risk of falls is another area of uncertainty in the literature. Many studies have examined the detrimental effects of targeted fatigue on factors that contribute to falls risk in elderly subjects (Helbostad, Leirfall, Moe-Nilssen, & Sletvold, 2007; Helbostad et al., 2010; King et al., 2012; Papa et al., 2015). The effects of fatigue from performing activities of daily living on falls risk has been the focus of relatively little research. Emilio et al. (2014) attempted to examine this by focusing on a limited number of falls risk factors which included balance, strength, and flexibility. However, the

tiring stimulus utilized was beyond what an individual would likely experience. There is currently a need in the literature for a study that assesses the tiring effects of an acute bout of exercise that is similar to an activity of daily living on the risk of falling in older subjects.

From the current state of the literature, the following questions have arisen and are in need of evaluation with a future study:

I. What relationship exists between objectively measured physical activity levels and the risk of falling in older subjects?

II. What relationship exists between cardiorespiratory fitness and falls risk in older subjects?

III. What potential tiring or performance enhancing effect will an aerobic exercise bout that is similar to an activity of daily living have on the risk of falling in older adults?

STATEMENT OF THE PURPOSE

To address the problems and questions raised by the current state of the literature; the primary purpose of this study will be to assess the relationship between objectively measured physical activity levels and the risk of falling in a timely manner. Secondary purposes will include examination of (1) the potentially tiring or performance enhancing effects of a walking task that emulates an activity of daily living on the risk of falling and (2) the relationships between cardiorespiratory fitness (indirectly measured via submaximal 6-minute walking task), physical activity, and the risk of falling. This will be accomplished by having a group of

moderate to low-risk older subjects with an age range of 65-79 report for testing on one occasion.

In this cross-sectional design, subjects will serve as their own controls. In a single testing session the subjects will perform a short-form Physiological Profile Assessment (PPA) to obtain a baseline falls risk score, followed by a modified 6-minute walk fatiguing protocol following procedures similar to those reported by Goldman, Marrie, and Cohen (2008). The 6-minute walking task will be used as a tiring exercise bout that mimics a potentially tiring activity of daily living and as a measure of cardiorespiratory fitness. After the walking protocol, subjects will repeat the short-form PPA protocol in order to examine the relationship between falls risk and the tiring effects of the 6-minute walking task. At the end of the session, the subjects will be provided with waist worn accelerometers to objectively measure their physical activity levels over the course of one week. After completion of the study subjects will be given two reports (pre- and post- walk) generated by the PPA web based software that details information regarding fall susceptibility and provides recommendations for improvement in weaknesses detected (Lord et al., 2003).

The primary variables of interest will include: (1) the physical activity levels found by the objective use of accelerometers, (2) the falls risk score prior to and following the 6-minute walk as reported by the short-form PPA, and (3) the performance on the submaximal effort modified 6-minute walk (i.e. total distance covered, which will be taken as an indirect measure of cardiorespiratory fitness). Additional variables will include (1) two ratings of perceived exertion (RPE) collected during the 6-minute walk, (2) center of pressure measures collected via a balance force plate during the standing balance portion of the PPA, (3) footfall and gait measures collected during the 6-minute walk via a Gaitrite device (CIR Systems, Havertown), and (4)

classification of subjects as either a faller or non-faller. Based on performance in the 6-minute walk, the data will be examined for relationships between cardiorespiratory fitness and falls risk. Statistical analysis will also be performed to examine relationships between objectively measured physical activity levels and falls risk as well as the relationship between the objectively measured physical activity levels and the performance on the 6-minute walk. To allow for these analyses to be done, physical activity levels and 6-minute walk performances (cardiorespiratory fitness levels) will be rank ordered and an additional statistical test will be performed to assess the relationship of the 6-minute walk with falls risk scores by comparing pre and post 6-minute walk measures of falls risk.

RESEARCH HYPOTHESES

H_a1: Subjects with higher objectively measured physical activity levels will have a lower falls risk (as reported by the short-form PPA) at the baseline assessment of falls risk, than subjects with lower objectively measured physical activity levels.

H_a2: After the 6-minute walk protocol, subjects with higher apparent levels of cardiorespiratory fitness (i.e. greater distance covered) will have an improvement in falls risk.

H_a3: After the walk protocol, subjects with higher objectively measured physical activity levels will show an improvement in their falls risk score (reduction in falls risk score pre-to-post walk as determined by the PPA).

$H_0 4$: There will be a positive correlation between physical activity levels (time in MVPA) and cardiorespiratory fitness levels (performance on 6-minute walk, i.e. distance covered in 6 minutes).

NULL HYPOTHESES

$H_0$1: Subjects with higher objectively measured physical activity levels will not have a lower falls risk (as reported by the short-form PPA) at the baseline assessment of falls risk, than subjects with lower objectively measured physical activity levels

$H_0$2: After the 6-minute walk protocol, subjects with higher apparent levels of cardiorespiratory fitness will not have an improvement in falls risk.

$H_0$3: After the walk protocol, subjects with higher objectively measured physical activity levels will not show an improvement in their falls risk score.

$H_0$4: There will not be a positive correlation between physical activity levels and cardiorespiratory fitness levels (performance on 6-minute walk).

LIMITATIONS OF THE STUDY

- Performance of subjects on the sub-maximal effort 6-minute walking protocol may be poor due to lack of effort.

- Subjects may drop out of study.

- Subjects may alter their physical activities levels despite recommendations not to, affecting accelerometer data (physical activity data).

- Subjects may misuse accelerometers leading to inaccurate data collection.

- This study will employ a cross-sectional rather than an experimental design. Findings will be correlational in regards to the relationships between physical fitness, physical activity, and falls risk

- The Actilife 6 software (software to be used for Physical activity (PA) analysis) does not have cutpoints (MVPA) specifically developed for older populations; however the Freedson, Melanson, and Sirard (1998) and Sasaki, Dinesh, and Freedson (2011) cutpoints are commonly used in the literature and will be relatable to previous studies.

DELIMITATIONS OF THE STUDY

- Subjects will be instructed not to alter their activity levels during usage of accelerometers to obtain data that actually reflects habitual activity levels.

- The subject population selected will be controlled for using healthy subjects that meet specific criteria for moderate to low risk of cardiovascular disease according to the American College of Sports Medicine (ACSM) guidelines detailed by Pescatello, Arena, Reibe, and Thompson (2014).

ASSUMPTIONS OF THE STUDY

- The submaximal effort, modified 6-minute walk protocol slightly modified from the protocol described by Goldman et al. (2008) will accurately reflect subject's cardiorespiratory fitness levels. Modifications to the Goldman et al. (2008) protocol will include a 30-meter cone-to-cone walking distance and the use of a measuring wheel to track distance covered by the subject.

- The short-form PPA (falls risk assessment) will provide an accurate reflection of subject's falls risk.

- The accelerometer collected objective measure of physical activity will accurately represent subject's normal activity levels.

OPERATIONAL DEFINITIONS AND TERMS

- Older subjects – male and female subjects between the ages of 65 and 79 years.

- Low to moderate risk – based of ACSM cardiovascular disease (CVD) risk stratification guidelines as presented by Pescatello et al. (2014). According to population definition, all subjects will have "age" as a risk factor. Low risk will include asymptomatic individuals with less than 2 known risk factors (Pescatello et al., 2014). Moderate risk will include asymptomatic individuals with greater than or equal to 2 known risk factors (Pescatello et al., 2014).

- Cardiorespiratory fitness – distance covered on submaximal effort 6-minute walking cardiorespiratory fitness assessment field test.

- Physical activity levels – time spent in moderate to vigorous physical activity (MVPA), collected objectively with accelerometers. Moderate activity begins at 3 metabolic equivalents (MET's) and Vigorous activity at 6 METs or greater (Pescatello et al., 2014). Previous studies have developed MVPA scoring thresholds designed to reflect MET values (Freeson et al., (1998); Sasaki et al., (2011)).
  - F98 - MVPA threshold for moderate activity developed by Freedson et al., (1998) classifies the lower threshold for moderate activity at 1955 counts per minute.
  - VM3 - MVPA threshold for moderate activity developed by Sasaki et al., (2011) classifies moderate activity beginning at 2691 counts per minute.

- Metabolic Equivalent (MET) – One MET is an oxygen consumption of $3.5 \text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$.

- Falls risk – an individual's susceptibility to falling as determined by the short-form Physiological Profile Assessment (PPA) developed and detailed by Lord et al. (2003).

- PPA – Physiological Profile Assessment, a battery of tests validated to assess falls risk in older individuals (Lord et al. 2003).

SIGNIFICANCE OF THE STUDY

The novel contribution of this study will be its timely assessment of the relationships that exist between physical activity levels, cardiorespiratory fitness levels, and falls risk in older individuals by using a valid and reliable assessment of falls risk and objectively measured physical activity levels. Additionally, this study may help to reinforce the idea that older individuals should remain physically active and that they should maintain or improve their levels of cardiorespiratory fitness not only to improve general health but also in an effort to reduce the risk of potential falls. Furthermore, study participants may benefit from learning what potentially modifiable and correctable deficiencies they may have after performing the short-form PPA assessments.

CHAPTER II

REVIEW OF THE LITERATURE

INTRODUCTION

The purpose of this study is to examine relationships between physical activity/physical conditioning and the risk of falling in an older population; therefore this literature review is divided into three sections. First, the current state of the literature relating physical conditioning to falls risk will be briefly discussed; and weaknesses in the literature will be addressed. Next, the known effects of fatigue/tiring exercise and how it may relate to the susceptibility of falling in the current literature will be addressed. Furthermore, according to Gregg et al. (2000) physical activity levels are known to be a factor that might influence falls risk. However, there is debate in the literature as to whether or not physical activity levels contribute to or help to reduce falls or falls risk. Therefore, the final section will consist of a discussion of issues in the current literature. The literature discussed is largely focused on older subjects. Some overlap in the three topics is present within the reviewed studies.

PHYSICAL CONDITIONING AND FALL SUCEPTIBILITY

Although the main purpose of a study by Morrison et al. (2012) was to examine the relationships between balance, falls risk, and the issue of neuropathy in older populations, their secondary purpose is more relevant to the present study. This secondary purpose involved examining the effects of balance/strength training on falls risk and variations in postural control. Their subjects (37 men and women, with an average age around 63.5 years) were assigned to one of four separate groups: fallers and non-fallers without diabetes (healthy controls) and fallers and non-fallers with diabetes. Subjects completed three testing sessions; however sessions 2 and 3

(in which falls risk/balance assessments were done) are of the most interest. Between sessions 2 and 3, the investigators had the subjects perform 6 weeks of balance and strength training. The authors used a comprehensive assessment of physiological abilities to assess falls risk before and after the intervention. After the training intervention their results showed that all groups (including the healthy control groups) had significantly decreased their risk of falling, with the diabetic faller group having the greatest improvement. Diabetic fallers also had significant improvements in balance variables following the intervention. The authors conclusions support the idea that balance/strength training can help reduce falls risk.

Emilio et al., (2014) examined the influence of a proprioceptive training program with a duration of 12 weeks on balance, strength, flexibility, and the risk of falling. The subjects of this study were 54 subjects, all of whom were at least 65 years of age. The subjects were assigned to either an experimental or control group. The mean age in years of both groups was in the late 70s. For the intervention protocol, the control group maintained usual levels of activity. The experimental intervention involved 12 weeks of supervised exercise sessions twice a week including: walking, stretching, and proprioceptive exercises. To assess the effectiveness of the experimental training intervention the authors measured pre- and post- intervention dynamic/static balance, mobility about the hip, lumbar strength, flexibility, and the risk of falling. The two groups were similar at baseline for all variables, but only the experimental group significantly increased in post-intervention flexibility, lumbar strength, and balance. Post intervention falls risk scores were significantly higher in the experimental group, but the authors point out that a higher score on the falls risk assessment means that there is a lower risk of falling. To elaborate, the authors explain that higher scores on the falls risk assessment represented improved balance ability. Their results also showed a significant positive

relationship between hip mobility, dynamic balance, and lumbar strength improvements and higher scores (improvements) on the falls risk assessment used. The authors concluded that improved physical condition by means of improved dynamic balance, hip mobility, and lumbar strength relates to a reduced risk of falling. The authors do mention that a limitation to this study is that falls risk was assessed with an indirect method.

It seems that in the current literature, higher levels of fitness regardless of the specific area may help to reduce the risk of falling. The literature shows that individuals with higher levels of conditioning in the areas of balance and strength brought about by specific balance and strength training (Morrison et al., 2012) or via a proprioceptive training intervention (Emilio et al., 2014) can help to contribute to reducing the risk of falling. Furthermore Chan et al. (2007) reported that higher rather than poorer performances in various physical tasks were related to a reduced risk of falls. Mertz et al. (2010) reported that higher cardiorespiratory fitness levels were related to fewer falls and protection against potential falls, but time-sensitive methodological issues render their findings questionable. Therefore, the relationship between cardiorespiratory fitness and falls risk is an area that is in need of further research.

FATIGUE, AGE, AND RISK OF FALLING

King et al. (2012) compared the effects of fatigue in young versus older populations on force control of the plantar flexors. This study included 25 healthy subjects who were split into either a young-subjects or older-subjects group with mean ages of 26 and 71 respectively. The authors had the subjects perform sub-maximal isometric force control tests of the plantar flexors before and after a warm up, immediately after fatigue, and every minute for 5 minutes after a fatigue protocol. The force control tests involved maintaining a constant sub-maximal force for

15 second. The fatigue protocol in this study involved 3 maximal force contractions of the plantar flexors, each maintained until force production dropped below 50% of a pre-determined maximal voluntary contraction force obtained at the onset of the study. Time to fatigue and data involving measures of torque were their variables of interest. Their results showed no significant difference in time to fatigue between the two groups, nor did they find a significant effect of fatigue in the older subjects. However they did report significantly slower torque onset times and a slower rate of torque development in the older subjects when compared to the younger subjects. The authors concluded that older subjects had an impaired ability to control torque production at the ankle, which could increase the risk of falling due to impaired ability to restore balance.

Papa et al. (2015) recently reviewed six studies for the purpose of analyzing the effects of fatigue on anticipatory and reactive postural control during dynamic tasks. The older subjects in the reviewed studies were all healthy people with a mean age of 67.5 years. For inclusion, the authors sought out original studies involving muscular fatigue of the trunk or lower body. No static postural control studies were included. All of the articles were in English, which the authors mentioned as a limitation. All but one article focused on reactive postural control. Of the six studies analyzed, the three that had significant effects of fatigue included a localized fatigue of the muscles of the ankle. The authors concluded that acute fatigue of the muscles may impair reactive postural control among older populations and that this may contribute to falls risk.

The purpose of another review by Helbostad et al. (2010) was to examine the effects of fatigue of the trunk/lower body musculature on balance and performance in varying functional tasks. The authors specifically looked for articles with appropriate fatigue protocols (lower

extremity/trunk) with subjects that were over 50 years of age. After an exhaustive search, the authors included 7 studies that met their criteria for inclusion. The authors reported the age range of subjects in the studies included was between 55 and 86 years. All of the studies but one used subjects from a healthy population. Unlike Papa et al. (2015), this review included articles that examined quiet stance. The authors reported that all but one study reviewed found significant effects of fatigue on balance during either quiet stance or a dynamic functional movement. The authors concluded that fatiguing the muscles of the lower body/trunk causes impairments in balance and ability to perform functional tasks. They also mention that fatiguing protocols may be helpful in predicting falls.

The purpose of an article by Helbostad et al. (2007) was to analyze the effects of fatigue brought about by repetitive sit-to-stand movements on gait characteristics. The subjects (44 males and females over the age of 70) were assigned to either an experimental fatigue group or control group. All subjects performed pre-fatigue walking trials including a warm up trial followed by three actual walking trials back and forth over a 7 meter mat with a 4.7 meter device that measure foot strikes situated along it. They specified that the three walking trials were (1) slow, (2) self-selected pace, and (3) as fast as possible while still walking. Subjects in the experimental fatigue group then performed a protocol in which repetitive sit-to-stands were done in an armless chair to volitional fatigue, after which they performed a post-fatigue walking trial of two trials at a self-selected pace. Subjects in the control group rested between the pre and post fatigue self-selected pace walking trials. Variables of interest were time as well as vertical displacement during sit-to-stand movements, walking speed, trunk acceleration monitored by an accelerometer mounted over the lower spine, and foot fall parameters such as step length/width and step length/width variability. Fatigue was also listed as a variable of interest that was

measured by looking at changes in velocity between 5 repetitions at the beginning and end of the sit-to-stand trial. Sit-to-stand velocity was shown to have decreased during the fatigue protocol. Subjects in both groups significantly increased walking speed in the post fatigue trials. The experimental fatigue group had significantly increased medio-lateral trunk acceleration after fatigue, increased step width and step-length variability after fatigue and increased vertical inter stride trunk acceleration variability. The authors concluded that after fatigue the subjects used a gait pattern more similar to that of frail individuals and those of people at a higher risk of falling.

The four preceding studies from previous literature demonstrate that with age the risk of falling can be high, especially when in a fatigued state with the exception of King et al. (2012) who found that their older subjects may have a limited ability to restore balance seemingly regardless of fatigue. However, it must be pointed out that in previous literature the tiring stimulus has largely been limited to fatiguing exercise of the trunk/lower body musculature (Helbostad et al., 2007; Helbostad et al., 2010; King et al., 2012; & Papa et al., 2014). One study attempted to tire/fatigue subjects using a stimulus that imitated a daily activity (Helbostad et al., 2007). However, in Helbostad et al. (2007) the fatiguing stimulus of having subjects perform prolonged and rapid sit-to-stand movements seems to be quite intense; perhaps a stimulus such as walking would serve as a better tiring/fatiguing stimulus more similar to what an individual may actually encounter.

PHYSICAL ACTIVITY LEVELS AND FALLS RISK

The purpose of a study by Graafmans et al. (1996) was to examine the relationships of various risk factors of falling with incidence of falls in an elderly population over 28 weeks. The subjects were 354 individuals, both male and female, with an average age of 83 years. Measured

risk factors/variables included personal medical histories, mobility testing on four occasions, physical activity levels (assessed with questionnaires), medicine usage (assessed with questionnaires), cognitive ability, and orthostatic impairment. It was explained that the mobility testing involved balance, sit-to-stand, tests of leg strength, and walking tasks. The investigators collected self-completed journals from the subjects every 2 months that detailed fall incidence. The authors reported that impaired mobility and orthostatic impairment were related to falls and reoccurring falls. Subjects with poor cognitive abilities and medical histories that included a stroke were at an elevated risk for reoccurring falls. Additionally, the authors reported that neither medication use nor physical activity levels were significantly related to falls. The authors concluded that severity of impairment to mobility was the greatest factor related to falls.

Gregg et al. (2000) reviewed the literature on the effects of physical activity on falls and fractures. They examined observational studies and randomized controlled trials with exercise as the intervention published prior to the year 2000. Physical activity was measured subjectively rather than objectively in the majority of observational studies. They also examined the effects of physical activity on fractures by looking at past studies focusing on hip and other common fracture sites in elderly people. The authors reported that although high levels of physical activity during leisure time did not reduce falls risk, exercise interventions involving balance and strength exercise may reduce falls risk. Furthermore, the investigators found that observational literature supported the idea that increased physical activity can reduce hip fracture risk. The authors came to the conclusion that with the exception of balance and strength exercise, physical activity and exercise interventions had no clear effect on falls risk.

The purpose of a study conducted by Graafmans et al. (2003) was to analyze the relationship between physical activity levels and falling, as well as analyzing the potentially

helpful effects of using walking aids. The subjects of the study were 710 elderly men and women with an average age of 82.8 years. It was pointed out that only 694 subjects completed the study. The investigators collected fall incidence data and physical activity data via questionnaires pertaining to the previous year. The results showed a non-linear relationship between physical activity levels and falls, so the authors split the subject's results into quartiles. Their results clearly showed that subjects with the highest activity levels had the lowest risk of falling. Their results also showed that using a walking aid in the second most active quartile reduced the risk of falling. The authors concluded that high levels of activity may reduce the risk of falling and that a walking aid may reduce the risk of falling in people who are moderately active (third highest quartile of activity levels).

Chan et al. (2007) examined the relationship between physical activity/performance and the incidence of falls. The subjects of this study were nearly 6000 men at least 65 years of age, all of whom were enrolled in an ongoing fracture study. Physical activity information was collected by survey, which the authors acknowledged was inferior to direct measures. Subjects performed a baseline battery of physical performance tests including leg power testing, grip strength, a sit-to-stand task, and several walking tests. Fall incidence data were obtained from questionnaires mailed periodically to subjects with recall bias as a potential limitation. The authors reported household activities as the primary factor from the physical activity information analyzed. Subjects with higher leg power, higher grip strength, and faster walking times in a narrow walking task had a lower fall risk than subjects with poorer performance scores. However, they also reported that the most active subjects had a higher risk of falling in general. The authors concluded that higher falls risk was related to both high levels of self-reported physical activity and poor physical performance. A limitation to this study is that there is no

indication that subjects completed more than just one physical activity survey or fitness assessment beyond the baseline assessments, meaning that the actual physical activity and fitness levels may not have been known at the time of a reported fall.

This issue of time sensitive measures is also a weakness in a study by Mertz et al. (2010) using data from the Cooper Aerobics Center Longitudinal Study. The authors attempted to examine relationship between cardiorespiratory fitness and physical activity with falls incidence while walking. Subjects were 20 to 86 year old males (n=8163) and females (n=2395). A baseline fitness assessment included data from a maximal treadmill test and self-reported baseline physical activity data. Fall incidence data were acquired from a follow-up survey on which subjects recalled fall information. This after-the-fact survey method of obtaining falls information was acknowledged as a limitation. Subjects over 65 years of age reported more fractures than younger subjects. Sedentary men and men with low fitness levels reported more falls while walking than more fit counterparts. Although subjects at least 65 years of age with low fitness and activity levels had higher walking related falls than their more fit and active counterparts, this difference did not reach statistical significance. The authors concluded that higher fitness (baseline cardiorespiratory fitness) and physical activity levels may help to reduce or prevent falling while walking. However, this study does contain weaknesses. First, the time elapsed between the baseline fitness assessment and the completion of a follow up survey took longer than six years in some cases. In addition there is no indication of any control for changes in fitness status after baseline testing. This raises the issue that the cardiorespiratory fitness status of the subjects is not known at the time they took the falls information surveys.

Thibaud et al. (2012) conducted a meta-analysis of the literature on physical activity and on the risk of falling. The authors reviewed a total of 23 studies of subjects over 60 years of age

that met their requirements for inclusion. Of 23 reviewed studies on risk of falls, 17 examined physical activity levels, eight examined sedentary lifestyle, and two compared physical activity and sedentary lifestyles. The authors concluded that physical activity was significantly related to a reduced risk of falling and that sedentary lifestyles put subjects at a higher risk of falling. The authors commented that higher physical activity levels may be a good indication of a reduced risk of falls. However, a weakness discussed yet not explicitly listed as a limitation by the authors was that the physical activity data were collected by questionnaires in every study discussed.

There is a clear disagreement in the literature as to whether or not high levels of physical activity help reduce or increase the risk of falls, with some studies in favor of higher levels of activity (Graafamans et al., 2003; Mertz et al., 2010; & Thibaud et al., 2012), and some against higher levels of activity (Chan et al., 2007). Two studies in particular could not find any clear effect of physical activity levels on fall susceptibility (Graafmans et al., 1996; & Gregg et al., 2000). Though the majority of studies favor higher levels of activity in reducing falls, it is difficult to determine if this is in fact the favorable position due to several weaknesses present in the current literature. Previous literature has largely relied on subjective measures of physical activity or have examined studies that used subjectively measured physical activity rather than more accurate objective measures (Graafmans et al., 1996; Gregg et al., 2000, Graafmans et al., 2003; Chan et al., 2007; Mertz et al., 2010; & Thibaud et al., 2012). Secondly, many studies rely on rather subjective after-the-fact methods of obtaining falls information (Graafmans et al., 1996; Graafmans et al., 2003; Chan et al., 2007; & Mertz et al., 2010). Futhermore, after-the-fact data only reports the incidence of falls. It does not address the risk or susceptibility of falling.

Two studies addressed below will to clarify why subjective measures of physical activity levels (i.e. surveys and questionnaires) are poor instruments when compared to objectively obtained data and also provide support for using a robust assessment of falls risk in timely manner, rather than after-the-fact methods of falls incidence data reporting to assess the risk of falling.

Dyrstad et al., (2014) compared the accuracy of a short form physical activity questionnaire against accelerometer data in 1751 males and females with an age range of 20 to 80 years. Subjects wore accelerometers for a week and completed a physical activity survey. Accelerometer data from no less than 4 days were used to objectively measure physical activity. Counts data from the accelerometers were used to classify physical activity as sedentary, low, moderate, or vigorous intensity. The authors also calculated the time each subject spent per day at each activity level. The surveys allowed subjects to report their activity levels in the past week to determine the amount of time per day each subject spent at a low, moderate, or intense activity level. The results showed that all subjects reported less time being sedentary, more time in vigorous activities, and surprisingly reported less time in moderate activity when compared to the data from the accelerometers. Based on survey data, men reported spending more time in moderate/vigorous activities than women, but accelerometer data revealed no difference in moderate/vigorous activity between men and women. The authors commented that the survey was designed for people 18 to 65 years of age and that it may not be suited to people over the age of 65. To highlight this, self-reported time spent in sedentary activity by subjects over 65 years of age was 3.5 hours less than sedentary activity based on accelerometer data. The authors conclude that survey data does in fact vary from objectively collected accelerometer data, especially at high levels of activity.

In the past literature it has been shown that a robust and comprehensive battery of tests can help detect weaknesses pertinent to a particular area of interest. A recent review published by Singh et al. (2012) examined the effects of a year-long comprehensive experimental treatment intervention on a multitude of health/quality of life variables compared to a group receiving standard care. Variables included mortality, the usage of any nursing homes, activities of daily living, and the use of assistive devices. The 124 subjects were men and women at least 55 years of age who had undergone surgery for a minor hip fracture. The authors randomly assigned their subjects to either an experimental or control group. All subjects underwent a comprehensive battery of testing to assess their weaknesses/strengths in "predictors of frailty, mortality, and nursing home admission" (Singh et al., 2012, p. 25). In addition to standard treatment, the experimental group also received an average of 80 supervised progressive resistance training sessions exercising twice a week for one year as well as targeted treatment for weaknesses found after the baseline battery of assessments. These treatments included but were not limited to balance training and nutritional advice. Their control group only received standard care. Their results showed that the odds of mortality and the use of a nursing home were reduced more than 80% in the experimental group compared to the control group. Their experimental group also had significantly less use of assistive devices than the control group. The authors concluded that the experimental treatment reduced mortality, nursing home usage, usage of assistive devices, and increased independence in activities of daily living. This study provides strong evidence for using a robust battery of assessments to detect deficiencies that contribute to frailty, much as the PPA detailed by Lord et al. (2003) detects physiological deficiencies that are known to contribute to the risk of falling in older individuals.

CONCLUSIONS

The current state of the literature has highlighted the importance of physical conditioning which seems to be beneficial in reducing falls, the impact of tiring exercise, and an uncertainty in the relationship between physical activity and falls. The literature has also demonstrated that physical activity levels and its relationship with falls is in need of further research, specifically with objective measures (i.e., accelerometers). The literature has also demonstrated a need for the use of an assessment of the "risk" of falling (rather than incidence of falls) when looking at relationships between physical activity, fitness, and fall susceptibility. Lastly, although the literature favors improved physical conditioning, there is a lack of research looking into cardiorespiratory fitness and falls risk using objectively measured physical activity and a timely falls risk assessment.

CHAPTER III

METHODS

PARTICIPANTS

There were 29 subjects in this study based on one-tailed power calculations carried out in

SAS software (SAS Institute, 2009) using pilot data from an ongoing and unpublished study with

an alpha of .05 and a power of 0.7. Subjects were 65-79 year old males and females who are

asymptomatic for cardiovascular, pulmonary and metabolic diseases and who are at no greater

than moderate risk for cardiovascular disease according to the criteria listed in the current ACSM

Guidelines for Exercise Testing and Prescription (Pescatello et al., 2014). Risk stratification was

assessed using the "AHA/ACSM Health/Fitness Facility Pre participation Screening

Questionnaire" as presented in Pescatello et al. (2014, p. 25). Subjects also completed the

"PAR-Q & YOU" as presented in the current ACSM guidelines for exercise prescription

(Pescatello et al., 2014, p. 24) to further screen and exclude any potentially high risk or

symptomatic individuals. This moderate or lower risk classification served to maximize

participant recruitment from the general population and would allow for participation in 6-

minute walk field test. Prior to the beginning of data collection, the research protocol was

approved by the Old Dominion University Institutional Review Board. Prior to the beginning of

the study, subjects received a verbal explanation of the study protocol and provided written

informed consent.

EXPERIMENTAL PROTOCOL

Subjects reported for one visit during which they acted as their own controls. Initially the

subjects signed a consent form, and then completed a short-form physiological profile

assessment (PPA) as developed by Lord et al. (2003) to serve as a falls risk assessment that will establish a baseline falls risk score. Following the baseline falls-risk assessment; the subjects performed a 6-minute walk field test to determine their individual levels of cardiovascular fitness. After completion of the 6-minute walk, the subjects completed the short-form PPA again to assess the tiring effects of the 6-minute walk task. Following the completion of the second falls-risk assessment protocol subjects were provided with accelerometers. The accelerometers were worn for a period of 7 days to gain an objective measure of physical activity. The order for the subject's visit was be as follows:

1. Sign consent form in presence of an investigator.

2. Complete the Modified Falls Efficacy Scale (MFES).

3. Collect descriptive data (i.e., height, weight, gender, and age).

4. Short-form PPA falls risk assessment (baseline values).

5. 6-minute walk field test.

6. Short-form PPA falls risk assessment (post walk).

7. Provide accelerometers/accelerometer usage instructions.

INSTRUMENTATION

Modified Falls Efficacy Scale

Subjects completed this questionnaire to determine their self-confidence as it related to falling and the performance of daily activities. Specifically, the subjects completed the Modified Falls Efficacy Scale (Tinneti, Richman, and Powell, 1990; Hill, Schwarz, Kalogeropoulos, &

Gibson, 1996). Briefly, this survey consists of 14 Likert-scaled items that concern the confidence a subject has in his or her ability to perform various activities of daily living. The average of the 14 items is taken as the variable of interest; this score can range from 0 (poor) to 10 (excellent).

Falls Risk Assessment

Subjects completed the short-form screening version of the Physiological Profile Assessment (PPA) as described by Lord et al., (2003) to establish a risk of falling score.   As detailed by Lord et al. (2003), the short form version of the PPA has a short administration time and includes five previously validated tests: an edge contrast vision test, a proprioception task for the lower body, reaction time assessment, a balance assessment of postural sway, and an assessment of muscular strength for the extensors of the knee.   Data from each of the five tests were entered into a manufacturer developed web-software program (Lord et al., 2003) which produced a falls risk score for each subject in the baseline and post 6-minute walk conditions. The procedures for the five tests are described in Lord et al. (2003). Precise step-by-step guidelines and procedures are detailed in a long-form PPA instruction manual provided with the PPA kit (a standardized kit sold by the developers of the PPA, Fallscreen, Neuroscience Research Australia, New South Wales, AU). The PPA kit manufacturers also provided all validated testing materials and instruments to be used. All falls risk testing in this study were performed following the precise guidelines set forth in the long-form PPA instruction manual.

In order to maximize the measurement sensitivity to account for the potential tiring effects of the 6-minute walk field test, the tests involved in the short-form PPA were performed in the following order (at baseline and post 6-minute walk):

1. Postural sway testing

2. Knee extensor strength testing

3. Proprioception

4. Reaction time

5. Edge contrast sensitivity

The first test to be performed was postural sway testing as described previously by Lord et al. (2003) and by Lord, Clark and Webster (1991) when it was originally developed, using precise guidelines and verbal commands as detailed in the long-form PPA instruction manual (Fallscreen, Neuroscience Research Australia, New South Wales, AU). Briefly, according to Lord et al. (2003) and Lord et al. (1991) this test typically involves having the subject stand still for a period of 30 seconds in four different testing conditions: eyes open or eyes closed, while standing on the floor or on a foam pad. Additionally, according to Lord et al. (2003) and Lord et al. (1991) the subjects are to be fitted with a waist mounted rod that will hang off the subject posteriorly with a pen fixed to the end of the rod that traces postural sway as the subject moves onto paper. According to Lord et al. (1991) the variables of interest are anterior-posterior sway and medio-lateral sway in millimeters. This test will be performed in the eyes open condition standing on a foam pad. The average of 3 trials were taken as the score.

Center of Pressure (COP)

To collect additional balance data beyond the capability of the simplistic pen-and-paper tracing postural sway measures of the physiological profile assessment, subjects performed the standing balance assessments atop a Bertec balance plate (Model BP 6040, Bertec Corporation,

Columbus, OH, USA, sample rate: 100Hz) to collect COP data. Subjects were instructed to stand atop the force plate during the three postural sway trials, resulting in six 30-second data files for each subject (i.e., 3 pre-walk and 3 post-walk). Dependant variables of interest will include: mean COP velocity, maximum COP velocity, COP path length, mean COP anterior-posterior excursion (AP), mean COP medio-lateral (ML) excursion, SD of COP AP excursion, SD of COP ML excursion, range of COP AP, and range of COP ML. Analysis of COP data were performed in MATLAB (Mathworks R14, Natick, MA, USA).

The second test required by the short-form PPA was a knee extension force production test according to Lord et al. (2003). This test has been described by Lord et al. (1991) and again by Lord et al. (2003). Briefly, the subject sits in a chair and performs a maximal voluntary contraction of the quadriceps with the knee hanging from the chair at 90 degrees (Lord et al., 2003). Rather than contracting against a force gauge mounted to the chair and fixed to the subjects leg above the ankle described by both Lord et al. (1991) and Lord et al. (2003), the subjects contract against a tensiometer (provided by the PPA kit) mounted to the wall behind the chair for greater stability and safety. The opposing end was attached above the subject's ankle. This test was performed only with the subject's dominant leg, similar to the description given by Lord et al. (1991). The force production score was recorded in kilograms as the best of three trials, similar to Lord et al. (1991). Verbal commands and instructions were given to the subjects following precise steps provided by the long-form PPA instruction manual (Fallscreen, Neuroscience Research Australia, New South Wales, AU). Subjects were also instructed to avoid performing the Valsalva maneuver during this test for their safety.

The third required test according to Lord et al. (2003) was a test of proprioception following precise guidelines set forth in the long-form PPA instruction manual (Fallscreen,

Neuroscience Research Australia, New South Wales, AU). Briefly, the subjects were seated in a tall chair with an acrylic sheet standing on the floor "inscribed with a protractor" between their right and left legs (Lord et al. 2003, p. 241). Lord et al. (2003) goes on to explain that through five recorded trials, the subjects will attempt to bring their lower limbs into alignment with their eyes closed. Specifically the subjects attempted to match the placement of their big toes on either side of the sheet according to Lord et al. (2003). The difference in foot placement in degrees was recorded for each trial according to Lord et al. (2003).

The fourth test required by the short-form PPA according to Lord et al. (2003) was a test of reaction time about the hand. Both Lord et al. (2003) and Lord et al. (1991) explain that this test involves a depressible switch and a light stimulus. According to Lord et al. (2003) a computer mouse with a light on it is used to perform this test; the investigator uses an electronic timer to control the light stimulus. The subjects completed five familiarization trials followed by 10 recorded trials, with the reaction time in milliseconds as the score for each trial (Lord et al., 1991; Lord et al., 2003). This test was carried out following the guidelines set forth in the Long-form PPA instruction manual (Fallscreen, Neuroscience Research Australia, New South Wales, AU).

For the final required test, Lord et al. (2003, p. 240) explains that the PPA uses a visual test known as "the Melbourne Edge test" in order to assess contrast sensitivity in subjects. According to Verbaken and Johnston (1986, p. 731), this test uses a chart with a number of circles that have edges within them that are continually reducing in contrast and have a "variable orientation". The last correct guess of edge orientation at the lowest contrast is taken as the subject's score (Lord et al. 2003). This test was carried out following the guidelines as presented

in the Long-form PPA instruction manual (Fallscreen, Neuroscience Research Australia, New South Wales, AU).

Tiring Exercise Stimulus – 6-Minute Walk Protocol.

The potentially tiring exercise stimulus to assess cardiorespiratory fitness was a modified 6-minute walking task. The modified 6-minute walk procedure and verbal script described by Goldman et al. (2008) was used with only slight variations. In Goldman et al. (2008), subjects were told to walk back and forth over a 175-foot distance. In this study, a 30 meter distance was used due to limitations in laboratory hallway length. A 30-meter distance has been recommended by the American Thoracic Society (ATS, 2002) for performing 6-minute walking tests. Small orange safety cones marked the 30-meter distance rather than the colored tape mentioned by Goldman et al. (2008). Goldman et al. (2008) used markers every 8.5 feet to track distance covered and utilized a dropped bean bag or tape to mark the ending position of the subject. The investigator followed the subject while walking with a measuring wheel to measure covered distance more precisely. The heel of the subject's hind foot at the end of the 6 minutes was considered the endpoint of the test. The only variable of interest was the total distance covered by the subject in meters. This variable served as a numerical estimate of cardiorespiratory fitness.

Gaitrite

Additional footfall and gait variables were measured during the 6-minute by using a Gaitrite device (CIR Systems, Havertown, PA, USA) placed along the floor in the middle of the 25-meter 6-minute walk pathway. This device is a 20-foot mat that recorded footfall and gait variables including ambulation time, velocity, cadence, normal velocity, step time, step length,

cycle time, HH base, swing time, stance time, single support, and double support as a subject walks over it. A second investigator captured footfall and gait variables via laptop computer as the subject walked over the Gaitrite device during the 1st and 5th minute of the 6-minute walk to assess for variations in footfall and gait patterns that may present over the duration of the walking task (e.g., markers of fatigue).

Rating of Perceived Exertion (RPE)

Subjects provided an estimate of their perceived level of exertion during the 6-minute walk in order to assess their individual levels of effort throughout the 6-minute walk. Subjects were familiarized with the 6-20 Borg RPE scale (Borg, 1970) immediately following the instructions for the 6-minute walk. Specifically, subjects were asked to report an RPE at 15 seconds into the first minute of the walk and again at 5:15 in the final minute of the walk. Following the 6-mintute walk protocol, the subjects completed the short-form PPA protocol a second time to allow for analysis of changes in falls risk score against the baseline condition.

Accelerometry (Physical Activity Levels)

Accelerometers were used to collect objective information about physical activity levels. Specifically the time spent in moderate to vigorous physical activity (MVPA) over the course of 7 days was the objective measure of physical activity. The subjects were provided with an Actigraph GT3X-BT triaxial accelerometer (ActiGraph, LLC, Pensacola, FL). Using Actilife 6 software (ActiGraph, LLC, Pensacola, FL). The accelerometers were set up using a regular initialization option with a sample rate of 30Hz in10-second epochs. During the initialization of the accelerometer in Actilife 6 software, subject information including subject number, weight in pounds, and gender was input for subject identification purposes. The devices were set to begin

and end data collection at 12:00 AM on the first day and at 12:00 AM on the eighth day,

respectively. The subjects were instructed to wear the accelerometer during waking hours only

centered over their non-dominant hip in a manner similar to Sandroff et al. (2012). Subjects

were also instructed to record in a daily log the times that they began and ended wearing the

accelerometer each day, similar to what has been described by Copeland and Esliger (2009). As

discussed by Sandroff et al. (2012) subjects were instructed to refrain from getting the

accelerometers wet to avoid damaging the instrument. The subjects were sent home with the

accelerometers and a follow-up meeting was scheduled by the investigator to retrieve the devices

after the 7-day data collection period. Subjects were provided with a daily log and wearing

instructions described by Sandroff et al. (2012).

For analysis of the accelerometer data, Actilife 6 software (ActiGraph, LLC, Pensacola,

FL) was used to determine the time spent in MVPA.

Data from the accelerometer were downloaded into a lab computer with Actilife 6

software. The time logs were examined to ensure that the subjects wore the device at for least

five days, at least one of which was a weekend day. Using MVPA data from at least five of

seven total days has been performed previously by Copland and Esliger (2009), however the

inclusion of a weekend day was not specified. Prior to performing MVPA analysis, the default

option for weartime validation in Actilife 6 was performed on the raw accelerometer data.

Unlike Copland and Elsiger (2009) who used a 10hr time frame for analysis each day, this study

had no restrictive daily time periods.   In Actilife 6 software, the option to exclude non-wear time

was selected prior to processing the data. For MVPA scoring using the non weartime-validated

data, the standard option of adult cut points developed by Freedson et al. (1998) was selected and

used to classify time spent in MVPA.   A triple axis vector magnitude (VM3) scoring option

developed for use with tri-axial accelerometers by Sasaki et al., (2011) was also used to score the physical activity data. According to the manufacturer's website, the data were converted automatically from 10-second to 60-second epochs to allow for MVPA analysis (https://help.theactigraph.com/entries/22225385).   After processing the data in Actilife 6 software Microsoft Excel output documents were created and displayed the total time spent in MVPA over the course of the 7-day period.

REQUIRED MATERIALS

A full description of the short-form PPA equipment can be found in Lord et al. (2003). Briefly these items include a tall chair, an acrylic sheet for proprioception, a waist-mounted rod for sway measures, medium density foam for sway testing, a special computer mouse for reaction time, a timer for reaction time, and edge contrast sensitivity testing materials. One item that varies from the description given by Lord et al. (2003) is the spring gauge discussed for knee extensor testing. An electronic tensiometer was used instead (updated item supplied by manufacturers of the PPA). Blank computer paper served as media for sway tracings. The 6-minute walk protocol will require two small orange cones, a stopwatch, and a measuring wheel to track distance covered. A Gaitrite walking mat (CIR Systems, Havertown, PA, USA) for gait variable collection during the 6-minute walk. Actigraph GT3X-BT accelerometers and Actilife 6 software will be used for analysis of physical activity levels (ActiGraph, LLC, Pensacola, FL). A Bertec balance plate model BP6040 (Bertec Corporation, Columbus, OH, USA) for use during the assessment of postural sway.

STATISTICAL ANALYSIS

All data were examined for normality. Data not normally distributed was assessed using non-parametric analysis (i.e., Mann-Whitney U and Spearman correlation). Change in PPA falls-risk score were analyzed by mixed model approach of the generalized linear model in SAS (SAS Institute, 2009, Cary, NC). Associations between 6-minute walk distance, time in MVPA based on Actigraph data, and falls risk and change in falls risk (post-walk PPA minus pre-walk PPA) was examined by Pearson Product Moment Correlation Coefficient. All data analyses were performed using IBM SPSS Version 21(Armonk, NY), SAS (SAS Institute, 2009, Cary, NC), and MATLAB (Mathworks R14, Natick, MA, USA). The criterion for statistical significance was set at $\alpha=0.05$. Unless otherwise indicated, summary group data were reported as mean±SD.

CHAPTER IV

RESULTS

MAIN OUTCOMES

Subjects

A total of 29 subjects (n = 15 male and n = 14 female) participated in the study (Table 1).

All subjects who entered the study completed the protocol in its entirety.

Table 1. Subjects

Variable	Males (n = 15)		Females (n = 14)		
	Mean	SD	Mean	SD	(Sig.)
Age (years)	70	4	71	3	0.728
Body Mass (kg)	80.74	15	62.7	10.5	0.001*
Height (m)	1.71	0.07	1.63	0.05	0.001*

*(Sig.) Significant difference between genders.

MFES (Modified Falls Efficacy Scale)

MFES was not normally distributed with a median of 10 and an interquartile range of 0.

All statistical analyses involving MFES were non-parametric procedures.

Physical Activity Data

All subjects completed the 7-day waist-worn accelerometer data collection protocol

without issue. The mean times spent in MVPA for the 29 subjects were: 264.8 minutes ± 152.4

minutes (F98) and 361.1 minutes ± 212.5 minutes (VM3). Additionally, F98 MVPA data were

not normally distributed. All statistical procedures involving F98 MVPA were nonparametric

procedures.

Correlation with Baseline Falls Risk z-scores

The correlation between MVPA VM3 and z-scores at baseline was not significant (r= -0.14, p = 0.457). Similarly, the correlation between MVPA F98 and the baseline z-scores was not significant ($r_{spearman}$= -0.17, p = 0.378).

Correlation with Delta-Falls Risk Score

Delta-Falls risk scores were not normally distributed. No correlation was found between delta-falls risk and F98 MVPA ($r_{Spearman}$=0.26, p=0.18). No correlation was found between delta-falls risk and VM3 MVPA ($r_{Spearman}$=0.11, p=0.56). All statistical analyses involving delta-falls risk scores were nonparametric procedures.

Short Form PPA (falls risk assessment)

The overall mean±SD baseline falls risk for all subjects was -0.35 ± 0.75. The mean post-walk falls risk was -0.41 ± 0.60. There was no significant change between baseline and post-walk falls risk for the 29 subjects (p = 0.589).

Individual PPA components

The individual tests of the PPA are detailed in table 2. Knee extension and edge contrast were greater after the walk compared to before the walk. Otherwise, PPA components werenot significantly changed following the 6-minute walk.

Table 2. Baseline vs. Post-Walk PPA Components for n=29.

	Baseline			Post-Walk			
Variable	Mean	SD	SE	Mean	SD	SE	(Sig.)
ML-Sway	19.40	9.17	1.70	20.92	9.53	1.77	0.692
AP-Sway	23.86	7.88	1.46	24.44	7.29	1.35	0.468
Knee Ext	31.39	12.09	2.25	32.58	12.37	2.30	0.021*
Edge Contrast	20.97	1.38	0.26	21.31	1.61	0.30	0.035*
Proprioception	1.67	1.16	0.21	1.64	1.25	0.23	0.923
Reaction time	214.13	36.15	6.71	209.64	25.83	4.80	0.252
Falls Risk	-0.35	0.75	0.14	-0.41	0.60	0.11	0.589

*(Sig.) = significant difference between fallers and non-fallers. The above table details the comparative performance of all subjects on the PPA at the baseline and post-walk assessments. Subjects performed significantly better following the walking protocol in the knee extension and edge contrast vision test. No other variable was significantly different following the 6-minute walking intervention.

6 -Minute Walking Task

The mean distance covered by the 29 subjects was 614.1 meters ± 87.4 meters.

Correlation between Walk Distance and Falls Risk

The association between walk distance and delta falls risk (change in z-score) was not significant ($r_{Spearman}$= 0.20, p = 0.294). There was no association between walking distance and, respectively, baseline falls risk Z-score ($r_{Pearson}$=-0.33, p=0.079) or post-walk falls risk Z-score ($r_{Pearson}$ =-0.20, p=0.288).

Correlations between Walk Distance and Physical Activity Data

There were no associations between walking distance and F98 MVPA ($r_{Spearman}$ =0.20, p=0.293) or VM3 MVPA ($r_{Pearson}$=0.59, p=0.759).

Gaitrite Variables

All 29 subjects completed walking over the Gaitrite at the beginning and end of the 6-minute walking task, Time Points 1 and 2 respectively. Data were unusable for three subjects, leaving n = 26 subjects with data acceptable for analysis. Gaitrite variables are presented below (Table 3). Gaitrite variables were not significantly changed during the 6-minute walk.

Table 3. Gaitrite Time Point 1 vs. Time Point 2.

Variable	Time Point 1			Time Point 2			
	Mean	SD	SE	Mean	SD	SE	(Sig.)
Ambulation time	6.27	0.87	0.17	6.23	0.99	0.19	0.824
Velocity	2.87	0.57	0.11	2.84	0.58	0.11	0.745
Cadence	179.21	31.72	6.22	178.73	28.78	5.64	0.922
Normal Velocity	132.99	14.73	2.89	133.66	16.73	3.28	0.784
Step Time	2.06	0.34	0.07	2.06	0.33	0.06	0.945
Step Length	0.91	0.09	0.02	0.95	0.21	0.04	0.389
Cycle Time	80.90	10.09	1.98	80.98	7.9	1.55	0.950
HH Base	161.36	19.49	3.82	160.32	16.08	3.15	0.650
Swing Time	10.75	3.55	0.70	10.11	3.85	0.75	0.196
Stance Time	0.37	0.08	0.02	0.39	0.04	0.01	0.344
Single Support	0.54	0.11	0.02	0.56	0.19	0.04	0.580
Double Support	0.39	0.03	0.01	0.48	0.44	0.09	0.310

Gaitrite data collected at the onset (Time Point 1) and near the end (Time Point 2) of the 6-minute walk are represented in the above figure. No significant markers of fatigue or improvement in physical performance were present in any variable.

Rate of Perceived Exertion (RPE) During 6-minute walk

RPE data were collected for 28 of 29 subjects (one subject's data was not recorded due to investigator error). The mean value of the collected scores for RPE reporting times 1 and 2 of all subjects were calculated and input as values for the remaining subject. The first reported RPE was not normally distributed with a mean = 9 and a median value of 7.00. All statistical analyses

involving the first reported RPE were nonparametric procedures. The second reported RPE was

normally distributed with a mean±SD = 12 ± 4.

Correlations of RPE with 6-minute walk distance

Positive correlations were present between 6-Minute Walk Distance and RPE. For RPE-

1, $r_{Spearman}$ = 0.470, (p = 0.010) between higher RPEs and higher walk distance in meters. For the

normally distributed RPE-2, a Pearson Correlation presented a strong correlation coefficient of r

= 0.702, (p<0.001) between higher RPE's and higher walk distance in meters.

Center of Pressure

Baseline and post-walk center of pressure variables are detailed in table 4. No changes

were observed in COP variables during the 6-minute walk.

Table 4. Center of Pressure, Pre-Post Comparison.

Variable	Baseline			Post-walk			
	Mean	SD	SE	Mean	SD	SE	(Sig)
Mean COP Velocity	2.35	0.71	0.12	2.42	0.91	0.14	0.414
Maximum COP Velocity	11.90	3.58	0.61	12.69	5.80	0.97	0.258
COP Path Length	140.93	42.64	7.05	145.38	54.33	8.51	0.414
Mean AP COP Excursion	1.75	0.54	0.10	1.67	0.53	0.10	0.759
Mean ML COP Excursion	0.97	0.45	0.08	0.96	0.47	0.08	0.849
SD of COP AP Excursion	0.64	0.19	0.03	0.64	0.19	0.04	0.932
SD of COP ML Excursion	0.39	0.20	0.04	0.37	0.18	0.03	0.408
Range of COP AP	3.48	0.93	0.16	3.32	0.90	0.16	0.574
Range of COP ML	1.96	0.86	0.15	1.93	0.86	0.14	0.780

Table 4 shows variation in COP variables collected at the baseline and post-walk assessment of falls risk. No significant changes in COP movement were found following the 6-minute walking protocol.

FALLS HISTORY

Out of 29 subjects, n = 8 subjects reported a previous fall and n = 21 reported no previous fall. Those who reported a previous fall were significantly younger (p = 0.022) than those who reported no falls history, mean = 68 years ± 2 years (fallers) versus 71 years ± 4 years (non-fallers). Those who reported a previous fall had significantly greater body mass than those who reported no falls (p = 0.025); 82.5 ± 20.0kg (fallers) versus 68.0 ± 12.1kg (non-fallers). No significant differences were found between faller or non-faller groups for the following variables: Height (p = 0.358), baseline z-score (p = 0.400), post-walk z-score (p = 0.406), 6-minute walk distance (p = 0.431), MVPA F98 (p = 0.981), and MVPA VM3 (p = 0.306). No significant differences existed between fallers and non-fallers at RPE 1 (Mann-Whitney U test, p=0.649) or RPE 2 (independent t-test, p=0.626).

Effect of Falls History on PPA Components

PPA differences between fallers and non-fallers are presented in tables 5 and 6. Fallers had significantly greater knee extension compared to non-fallers before and following the 6-minute walk. Otherwise, there were no differences in PPA components between fallers and non-fallers before or following the 6-minute walk.

Table 5. Baseline PPA Components Fallers vs. Non-Fallers.

Variable	Fallers			Non-Fallers			
	Mean	SD	SE	Mean	SD	SE	(Sig.)
ML-Sway	21.05	8.35	2.95	18.77	9.58	2.09	0.559
AP-Sway	23.89	6.34	2.24	23.84	8.53	1.86	0.989
Knee Ext	39.24	12.59	4.45	28.4	10.74	2.34	0.028*
Edge Contrast	20.88	1.13	0.40	21	1.48	0.32	0.831
Proprioception	1.40	1.39	0.49	1.77	1.08	0.24	0.450
Reaction time	201.40	21.68	7.66	218.98	39.70	8.66	0.249
Falls Risk	-0.55	0.70	0.25	-0.28	0.77	0.17	0.400

*(Sig.) = significant difference between fallers and non-fallers. The above table shows the comparison of fallers and non-fallers at the baseline falls risk assessment. Fallers were found to have significantly higher knee extensor strength than non-fallers.

Table 6. Post-Walk PPA Components Fallers vs. Non-fallers.

Variable	Fallers			Non-Fallers			
	Mean	SD	SE	Mean	SD	SE	(Sig.)
ML-Sway	20.16	6.22	2.20	21.20	10.65	2.32	0.798
AP-Sway	25.73	6.51	2.30	23.95	7.66	1.67	0.569
Knee Ext	41.73	11.57	4.09	29.09	11.01	2.40	0.011*
Edge Contrast	21.5	1.41	0.5	21.24	1.70	0.37	0.702
Proprioception	1.40	0.91	0.32	1.73	1.37	0.30	0.532
Reaction time	197.80	16.87	5.97	214.15	27.51	6.00	0.130
Falls Risk	-0.57	0.52	0.18	-0.36	0.63	0.14	0.406

*(Sig.) = significant difference between fallers and non-fallers. The above table shows the comparison of fallers and non-fallers at the post-walk falls risk assessment, specifically performance in each testing component of the short-form PPA is detailed. Fallers were found to have significantly higher knee extensor strength than non-fallers following the 6-minute walk. All other variables were not significantly different.

Center of Pressure

At the baseline assessment of postural sway, no significant differences were found between fallers and non-fallers for the following variables: mean COP velocity ($p = 0.539$), maximum COP velocity ($p = 0.833$), COP path length ($p = 0.539$), Mean AP COP excursion ($p = 0.778$), mean ML COP excursion ($p = 0.161$), SD of COP AP excursion ($p = 0.601$), SD of COP ML excursion ($p = 0.301$), range of COP AP excursion ($p = 0.795$), and range of COP ML excursion ($p = 0.257$). The center of pressure variables obtained at baseline and post-walk are detailed in Table 7 (Non-fallers) and Table 8 (Fallers). No significant differences were found between fallers and non-fallers irrespective of the walking intervention (Table 9). Additionally, there was no significant interaction effect of fall status in any variable (Table 10).

Table 7. Center of Pressure Variables for Non-Fallers at Baseline and Post-Walk.

	Baseline			Post-Walk		
Variable	Mean	SD	SE	Mean	SD	SE
Mean COP Velocity	2.60	0.97	0.13	2.70	1.39	0.18
Maximum COP Velocity	12.80	4.48	0.59	13.76	7.64	1.01
COP Path Length	156.10	58.14	7.70	161.80	83.32	11.04
Mean AP COP Excursion	1.71	0.60	0.08	1.66	0.56	0.074
Mean ML COP Excursion	1.17	0.53	0.07	1.13	0.67	0.09
SD of COP AP Excursion	0.62	0.21	0.03	0.60	0.17	0.02
SD of COP ML Excursion	0.45	0.21	0.03	0.42	0.23	0.03
Range of COP AP	3.43	1.06	0.14	3.29	1.01	0.13
Range of COP ML	2.28	1.06	0.14	2.23	1.20	0.16

This table details COP variables of non-fallers at baseline and post-walk assessments of standing balance.

Table 8. Center of Pressure Variables for Fallers at Baseline and Post-Walk.

	Baseline			Post-Walk		
Variable	Mean	SD	SE	Mean	SD	SE
Mean COP Velocity	2.10	0.45	0.11	2.15	0.42	0.10
Maximum COP Velocity	11.02	2.69	0.63	11.63	3.97	0.94
COP Path Length	125.76	27.13	6.40	128.97	25.35	5.98
Mean AP COP Excursion	1.80	0.48	0.11	1.67	0.50	0.12
Mean ML COP Excursion	0.77	0.37	0.09	0.79	0.27	0.06
SD of COP AP Excursion	0.66	0.17	0.04	0.68	0.22	0.05
SD of COP ML Excursion	0.34	0.18	0.04	0.32	0.13	0.031
Range of COP AP	3.53	0.80	0.19	3.34	0.78	0.18
Range of COP ML	1.64	0.65	0.15	1.63	0.53	0.13

This table details COP variables of fallers at baseline and post-walk assessments of standing balance.

Table 9. Difference between Fallers and Non-fallers, Irrespective of the Intervention.

COP Variable	Significance
Mean COP Velocity	0.542
Maximum COP Velocity	0.825
COP Path Length	0.532
Mean AP COP Excursion	0.673
Mean ML COP Excursion	0.169
SD of COP Excursion AP	0.327
SD of COP Excursion ML	0.263
Range of COP AP	0.655
Range of COP ML	0.239

This table shows variation in COP variables between fallers and non-fallers regardless of the intervention. No significant differences in COP movement were found between groups.

Table 10. Fallers vs. Non-fallers as a function of Pre-Post Assessments (Interaction Effect).

COP Variable	Significance
Mean COP Velocity	0.785
Maximum COP Velocity	0.935
COP Path Length	0.785
Mean AP COP Excursion	0.934
Mean ML COP Excursion	0.891
SD of COP Excursion AP	0.413
SD of COP Excursion ML	0.977
Range of COP AP	0.728
Range of COP ML	0.983

This table details the interaction effect of falls statuses (faller vs. non-faller) on COP variability. No significant effect existed.

GENDER

MFES (Modified Falls Efficacy Scale)

No significant differences in the overall fear of falling were observed between the male and female subjects. A Mann-Whitney U test showed: males (median score 10, mean rank 16.2) vs. females (median score 10, mean rank 13.71) ($p = 0.266$).

Physical Activity Data

No significant difference was found between men and women regarding VM3 MVPA data, males 277 ± 177 minutes and females 252 ± 152 minutes ($p = 0.667$). A Mann-Whitney U test revealed no significant difference between male (median score 264 minutes, mean rank 15.13) and female subjects (median score 207 minutes, mean rank 14.86) ($p = 0.930$).

Short Form PPA (Physiological Assessment Profile)

Significant differences in falls risk are detailed below (Table 11).

Table 11. Males vs. Females Falls Risk

	Males		Females			
	Mean	SD	Mean	SD	F	(Sig)
Baseline falls risk	-0.62	0.72	-0.06	0.69	.165	0.043*
Post-walk falls risk	-0.64	0.67	-0.17	0.41	1.524	0.031*

*(Sig) = Significant difference between groups. The above table shows a comparison of falls risk scores between male and female subjects at the baseline and post-walk assessment of falls risk. At both baseline and post-walk male subjects were shown to have a significantly lower risk of falling than female subjects.

6-Minute Walking Task

Males (655.5±80.1 m) had significantly greater (p = 0.006) walking distances than females (569.6±73.6 m).

CHAPTER V

DISCUSSION

INTRODUCTION

This study attempted to assess potential relationships between objectively measured physical activity levels, physical fitness levels, and the risk of falling in a timely manner. The findings and issues of the study will be addressed in the following sections: (1) the hypotheses of the study will be addressed, (2) the contradictory effect of falls history, and (3) gender differences. Additionally, limitations to the study will be discussed in each section according to relevance.

MAIN OUTCOMES

It was hypothesized that subjects with the highest physical activity levels would present the lowest risk of falling at their baseline assessment of falls risk. Interestingly, it was found that no relationship existed between physical activity levels and the risk of falling (at baseline and post-walk). Therefore this study fails to reject the null hypothesis: $H_0 1$. "Subjects with higher objectively measured physical activity levels will not have a lower falls risk (as reported by the short-form PPA) at the baseline assessment of falls risk, than subjects with lower objectively measured physical activity levels". The data suggest that subjects' physical activity levels had no association with their risk of falling. This finding is similar to the findings of Graafmans et al. (1996) and Gregg et al. (2000) who also found no relationship between physical activity and fall susceptibility.

Due to the stringent health requirements for participation in the study, it was also hypothesized that subjects who exhibited the highest levels of cardiorespiratory fitness (assessed by 6-minute walk distance covered) would perform better during their post-walk falls risk assessment than at baseline. To elaborate, rather than a tiring effect of the 6-minute walking task, a warm-up effect was anticipated to occur. However, the data did not support this prospect. Therefore, this study fails to reject the null hypothesis: H_02. "After the 6-minute walk protocol, subjects with higher apparent levels of cardiorespiratory fitness will not show an improvement in falls risk," as no significant correlations between cardiorespiratory fitness and post-walk falls risk scores were found. Further, subjects as a whole were found to have performed similarly on the falls risk assessment at both baseline and at the post-walk assessment. This finding suggests that indirectly measured cardiorespiratory fitness status has no relationship to falls risk in healthy older subjects. Apparent limitations to the 6-minute walk assessment of cardiorespiratory fitness are discussed in detail later in this section.

Similarly, it was expected that subjects who exhibited the highest physical activity levels (time in MVPA) would show an improvement in their falls risk score following the 6-minute walking intervention. However, this study found no significant relationship between physical activity levels and the change in falls risk score. Additionally, the baseline and post-walk falls scores were found to be not significantly different. These findings suggest that subjects preformed similarly on the falls risk assessment at baseline and post walk regardless of how physically active they were. Therefore this study fails to reject the null hypothesis: H_03. "After the walk protocol, subjects with higher objectively measured physical activity levels will not show an improvement in their falls risk score".

A positive correlation was hypothesized to exist between subject's physical activity and cardiorespiratory fitness levels. In other words, the subjects who presented the highest physical activity levels were anticipated to perform similarly higher than their less physically active counterparts on the 6-minute walk. However, this study found no significant correlation between time spent in MVPA and indirectly measured cardiorespiratory fitness (i.e., 6-minute walk distance). Due to the lack of any significant relationship between these variables, this study fails to reject the null hypotheses: H_04. "There will not be a positive correlation between physical activity levels and cardiorespiratory fitness levels (performance on the 6-minute walk)". Therefore, physical activity levels were not associated with 6-minute walking task performance.

In an effort to maximize subject recruitment and ensure a sample of healthy older adults, a sub-maximal effort 6-minute walk was chosen as a way to (1) indirectly measure cardiorespiratory fitness and (2) serve as a potentially tiring exercise intervention. The low RPE values reported during the walk may suggests a lack of effort on part of the subjects. However, not all subjects exhibited a lack of effort; as the data did show that subjects who reported higher RPE values during the 6-minute walk were found to have significantly higher walking distances than counterparts with lower RPE values. A limitation to the Goldman et al. (2008) modified 6-minute walk utilized as the basis of the 6-minute walk in this study is that verbal encouragement from the investigator was forbidden during the walk test. Any possible lack of effort on the part of some subjects potentially could have been controlled for if the investigator could have provided consistent verbal encouragement to each subject during the walking test. It may be the case that the 6-minute walking task was not a sufficiently demanding protocol for the subjects in this study. This possibility is supported by the lack of any significant variations in gait parameters collected during the 6-minute walk. To elaborate, significant impairments would

have been present in the walking parameter data if the protocol had elicited more fatigue. For example, physical fatigue has been shown to negatively impact gait parameters in the past by Helbostat et al. (2007). Additionally, it has been found recently by Morrison, Colberg, Parson, Neumann, Handel, Vinik, Paulson, and Vinik (2016), that physical fatigue induced by means of three 5-minute walking bouts of varied intensity results in an increased risk of falls in individuals 70-79 years of age. Future studies should include a direct maximal effort assessment of cardiorespiratory fitness to control for effort on part of the subject.

Examination of the individual tests making up the falls risk assessment revealed a significant improvement among all subjects in the post-walk performance of both the leg extensor and visual edge contrast tests. It would seem that a warm-up effect occurred following the 6-minute walk leading to improved knee extensor strength; however this had no significant influence on improving post-walk falls risk scores. The improvement in scores on the visual edge contrast test may be due to a simple learning effect of the time sensitive repeated measures design or the fault of the test itself. To elaborate, it has been shown by Wolffsohn, Eperjesi, and Napper (2005) that a backlit version of the Melbourne edge test is more sensitive and reliable than the paper version used in the current study. Though every attempt was made in the current study to maintain similar testing conditions for pre- and post walk trials subtle variation in a subjects sitting position might have influenced scores. Specifically, it may be the case that subjects during the post-walk testing session were more prepared to make an active effort in reduce glare from overhead lighting experienced in the baseline test, potentially resulting in improved scores. Additionally, Wolffson et al. (2005) explained that lighting had a less detrimental influence in the backlit test over the standard method utilizing only paper, this could serve as an improvement to the methodology of the PPA.

FALLS HISTORY

Though only 8 of 29 subjects reported having a previous fall, surprising observational differences were present between subjects with and without a previous falls history. Although the differences were not significant, subjects who did report a previous fall were shown to have a lower risk of falling than those who did not report a previous fall both at the baseline and at the post-walk falls risk assessments. One might expect those with a history of falling would present with a higher risk of falling than those without a history of falling; however the data would suggest the opposite in this study. One possible explanation of this could stem from simple differences in levels of physical activity. For example, using the VM3 physical activity scoring option in Actilife 6 (ActiGraph, LLC, Pensacola, FL) the mean time spent in MVPA was found to be 92 minutes longer for those who reported a fall than those who did not; however this difference was not statistically significant. Though not significantly different, 90 extra minutes of exercise at a moderate to vigorous level would potentially expose subjects to the paradoxical relationship discussed by Graafmans et al., (2003) which simply states that an increased risk of falling is inherent to being physically active. However, in a recent study by Gawler, S., Skelton, D. A., Dinan-Young, S., Masud, T., Morris, R. W., Griffin, M., Kendrick, D., and Lliffe, S. (2016) with 84 percent of the sample population consisting of 65-79 year olds, it was found that subjects who maintained higher MVPA levels after an exercise intervention had reduced falls risk/incidence over a 24 month period than their less active counterparts. The findings in the current study are in agreement with the findings of Gawler et. al (2016), in that the subjects with the lowest falls risk scores tended spend more time in MVPA, however this 90-minute MVPA difference did not reach significance. Additionally, where differences in time spent in MVPA failed to reach significance, such was not the case with knee extensor strength. At both baseline

and post-walk, fallers were found to have significantly higher leg strength than their non-faller counterparts. The superior leg strength of fallers suggest that they were in better shape than their counterparts, it would reason to follow that they spent more time exercising as well.

Another explanation for the phenomenon of fallers presenting with lower falls risk scores may lie within the falls risk assessment itself, specifically pertaining to how subjects were classified as fallers or non-fallers. The PPA requires only that subjects report how many falls they have experienced within an immediate 12 month period preceding their assessment. This raises three limitations, (1) the nature of previous falls is not known and (2) the 12 month time frame excludes falls incidence prior to that period, ruling out potential chronic falls histories, and (3) it is subject to recall bias on the part of the subjects. Furthermore, It has been well established that individuals over the age of 60 have difficulty recalling falls that have occurred within a 3 to 12 month time frame by Cummings, Nevitt, and Kidd (1988). Many subjects in this study were active marathon runners who may have fallen during strenuous exercise as a result of hazards in their exercise environment; unfortunately a major limitation to this study is that the nature of previous falls was not ascertained. Attaining information on the nature of falls would prove invaluable to future research as it would allow differentiating between falls during exercise (e.g. running, jogging, walking) or falls around the household or during daily simple activities.

GENDER

Though this study found no relationships between physical activity levels, the risk of falling, or cardiorespiratory fitness; gender differences did exist.   Men in this study were found to be significantly taller and heavier than female counterparts. Falls confidence as assessed by the MFES showed exceptionally high confidence regardless of gender. However, male subjects

were found to have significantly greater 6-minute walk distances and were at a lower risk of falling than female counterparts at baseline and post-walk assessments.

CONCLUSIONS

This study has found no apparent relationships between objectively measured physical activity, indirectly measured cardiorespiratory fitness, and the risk of falling. Men at a moderate or lower risk of developing cardiovascular disease have been shown in this study to be at a lower risk of falling than female counterparts. Further research is needed to examine why this gender difference exists. A full form physiological profile assessment may provide a more complete assessment of known factors that contribute to falling than the short-form assessment utilized in the current study. Though not of statistical significance, data in this study suggests an apparent practical significance/benefit of >90 minutes of physical activity at a moderate to vigorous level, as more active subjects (fallers) in this study were shown to have higher leg strength and a non-significant lower risk of falling than less active counterparts. Future research should in needed comparing falls risk between groups of varying physical activity levels utilizing groups of similar sample sizes. Future research is needed utilizing a maximal effort exercise test, this may prove to highlight physiological deficiencies in a repeated measures falls risk assessment.

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APPENDIX

Data Collection Sheet

Subject identification number _____.

Age:

Gender:

Height:

Weight:

PPA data at baseline assessment:

Circle one: Faller or Non-Faller

Postural Sway

    Medio-lateral: 1) _____mm. 2) _____mm. 3) _____mm. AVG= _____mm.

    Anterior-posterior: 1) _____mm. 2) _____mm. 3) _____mm. AVG= _____mm.

Knee Extension Strength (circle dominant leg: *right leg* or *left leg*):

Trial	Kilograms
1	
2	
3	

Proprioception:

Trial	Degrees
1	
2	
3	
4	
5	

Reaction times:

Trial	Milliseconds
1	
2	

3	
4	
5	
6	
7	
8	
9	
10	

Visual Edge contrast Score: _____.

Falls risk score baseline: _____*

6-minute walk:

RPE at 15 seconds: _____.

RPE at 5:15:   _____.

Total distance covered: _____meters.

PPA falls risk Post 6-minute walk:

Postural Sway

     Medio-lateral: 1) _____mm. 2) _____mm. 3) _____mm.   AVG= _____mm.

     Anterior-posterior: 1) _____mm. 2) _____mm. 3) _____mm.   AVG= _____mm.

Knee Extension Strength:

Trial	Kilograms
1	
2	
3	

Proprioception:

Trial	Degrees
1	
2	
3	
4	
5	

Reaction times:

Trial	Milliseconds
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Visual Edge contrast Score: _____.

Falls risk score post: _____*

Physical activity levels:

Total time in MVPA over 7-days: _____

Log Sheet and Instructions

Wearing instruction reminders:

You will wear this accelerometer on centered over your non-dominant hip.

Please wear the accelerometer only during waking hours. (i.e., do not wear to bed at night).

Please do not get the device wet; this may cause damage to the device.

You will wear the device for a period of one week. (i.e., 7 days).

You should NOT alter your normal activity levels during this 7-day period.

The device is programmed to turn on and off by itself, there is no need to open the Velcro pouch.

Record the times that you put on the device in the morning and remove the device at night in the table below:

	TIME PUT ON (morning)	TIME TAKEN OFF (night)
Day 1:		
Day 2:		
Day 3:		
Day 4:		
Day 5:		
Day 6:		
Day 7:		

If you have any questions/concerns please contact the investigator listed below for help/clarification:

Chris Vaughan   Cell Phone: 757-784-6184

                     Email: cvaug018@odu.edu

Research Participation Opportunity

Project title – Associations between Physical Activity, Physical Fitness, and the Risk of Falling in Healthy Older Individuals.

Please take a moment and review the following questions:

- Are you between the ages of 65 and 79 years?
- Are you interested in learning how susceptible you are to falling?
- Are you free of any cardiovascular or metabolic disease?
- Can you walk continuously for 6 minutes?
- Would you like to contribute to the knowledge base?

If you answered YES to the above questions you may qualify to participate in this study.

Overview of the Study:

This study will require only a single visit and approximately 1.5 hours of your time.

In this study you will be asked to perform a brief yet comprehensive falls risk assessment which will assess your vision, reaction time, balance, leg strength, and lower body coordination.

Next you will perform a short bout of exercise in which you will be asked to walk continuously for 6 minutes. Following this you will repeat the brief falls risk assessment a second time.

Finally, you will be sent home with a waist worn device to collect information about your physical activity levels.

If you are interested in participation or would like more information (i.e., risks/benefits and exclusionary criteria), please contact the investigator listed below:

Chris Vaughan B.S., Master's Degree Candidate - Exercise Science and Wellness, Darden College of Education, Old Dominion University

Email: cvaug018@odu.edu

Phone: 757-784-6184

INFORMED CONSENT DOCUMENT

OLD DOMINION UNIVERSITY

PROJECT TITLE: Associations between physical activity, physical fitness, and falls risk in healthy older individuals

INTRODUCTION

The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES. The name of this project is **Associations between physical activity, physical fitness, and falls risk in healthy older individuals.** Testing for this project will take place at the ODU Center for Brain Research & Rehabilitation located in Research Building II, 4211 Monarch Way, Norfolk VA 23508. Testing may take place at locations other than the Monarch Way address.

RESEARCHERS

Responsible Project Investigator:

J. David Branch, PhD

Department of Human Movement Sciences

Darden College of Education

Other Investigators:

Christopher D. Vaughan, B.S.

Steven Morrison, PhD

Joshua Weinhandl, PhD

DESCRIPTION OF RESEARCH STUDY

The purpose of this study is to assess in a timely manner, the relations between directly measured physical activity levels, cardiorespiratory fitness, and the risk of falling prior to and

following a brief bout of physical activity. The protocol for this study has been approved in accordance with Old Dominion University policy.

Time requirements and overview of your visit:

Should you say YES and choose to participate, this study will require only one visit. The required time to complete the visit is approximately 1.5 hours. During your visit if you choose to participate, you will first sign this consent document in the presence of an investigator. Next you will complete a very brief falls confidence survey. Next you will complete a short battery of tests to assess your risk of falling prior to and following a walking exercise bout. Lastly, you will be provided with a take-home waist worn device that will assess your physical activity levels over the course of a single week. Approximately 43 subjects between the ages of 65-79 will be participating in this study.

Measurements and procedures:

Survey:

- You will complete a brief 14 item questionnaire to assess your confidence in avoiding falls.

Falls risk assessment:

Short-form physiological profile assessment (PPA)

- You will be asked to complete some test items including an assessment of standing balance while standing on a force plate, lower body leg strength/coordination, reaction time, and vision.

Walking exercise bout:

- You will be asked to perform a 6-minute walking test in which you will walk back and forth down a hallway as far and as fast as you can between 2 orange cones separated by 30 meters.
- You will be asked to rate your perceived level of exertion during this test to assess your level of effort.
- During this test you will walk over a mat that will collect information about your gait.
- Following the completion of this task, you will be asked to immediately repeat the falls risk assessment of balance, leg strength, lower body coordination, reaction time, and vision.

Physical activity assessment:

- To assess your physical activity levels you will be provided with a waist worn accelerometer to be worn during waking hours for a period of 7 days.
- You will be asked not to alter your normal activity levels during this week long period.

EXCLUSIONARY CRITERIA

You should have completed the AHA/ACSM Health/Fitness Facility Pre- participation Screening Questionnaire and PAR-Q & You documents, in order to determine your eligibility to participate. You must be between 65 and 79 years of age in order to participate. To the best of your knowledge, you should not have any cardiovascular, pulmonary or metabolic diseases that would keep you from participating in this study.

RISKS AND BENEFITS

RISKS: If you decide to participate in this study, then you may face a risk of experiencing the acute effects of aerobic exercise including shortness of breath, becoming fatigued, and soreness of the muscles. You may also face a risk of experiencing a more serious adverse event associated with cardiovascular exercise including myocardial infarction, stroke, cardiac arrest, fainting, dizziness, or even death. You may also experience muscle soreness due to lower body leg strength testing in your tested leg. The risk of falling does exist in this study which could result in injury or embarrassment however; the investigators have attempted to minimize this risk. During the assessments of standing balance, for your protection a spotter will be present at all times during testing to help prevent a potential fall. An investigator will follow behind during the 6-minute walk to record distance covered and to help prevent any potential falls. These risks will be minimized by the pre-participation screening to identify individuals without signs, symptoms of, or diagnosed cardiovascular, pulmonary, or metabolic diseases. There is also a risk of private information becoming known, however the investigators will take every precaution to ensure that your data will remain confidential by removing all personal identifiers from information we collect from you and by securing data in a password-protected computer. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified. Additionally, for your protection the investigator will be certified in CPR, Basic first aid, and the use of an AED in case of an emergency.

BENEFITS:

There are no direct benefits for participating in this study.

Potential benefits may include becoming more familiar with your susceptibility to a potential fall, both prior to and following a brief bout of exercise (i.e., 6 minutes of walking). Additionally, through participation in this study you will undergo a free assessment of your risk of falling from which you may learn of personal weaknesses/deficiencies that are potentially modifiable, which may help to reduce your susceptibility to a fall in the future.

COSTS AND PAYMENTS

The researchers are unable to give you any payment for participating in this study.

NEW INFORMATION

If the researchers find new information during this study that would reasonably change your decision about participating, then they will give it to you.

CONFIDENTIALITY

The researchers will take reasonable steps to keep private information, such as questionnaire information and data, confidential. The researcher will remove identifiers, such as this informed consent document, separate from the research data in order to protect your identity. Research data will also be kept in a secure location. The researchers will not identify you in any report, publication, or presentation. Of course, your records may be subpoenaed by court order or inspected by government bodies with oversight authority.

WITHDRAWAL PRIVILEGE

It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study -- at any time. Your decision will not affect your relationship with Old Dominion University, or otherwise cause a loss of benefits to which you might otherwise be entitled. The researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation.

COMPENSATION FOR ILLNESS AND INJURY

If you say YES, then your consent in this document does not waive any of your legal rights. However, in the remote event of harm, injury, or illness arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury or a problem arises as a result of participation in the research project, you may contact George Maihafer, Ph.D., Chair, ODU Institutional Review Board (757-683-4520, gmaihafe@odu.edu) who will be glad to review the matter with you or the Office of Research (757-683-3460).

VOLUNTARY CONSENT

By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, then the researchers should be able to answer them:

J. David Branch, Ph.D., 757-683-4514, dbranch@odu.edu

D. Christopher Vaughan, B.S. 757-784-6184, cvaug018@odu.edu

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call George Maihafer, Ph.D., Chair, ODU Institutional Review Board (757-683-4520, gmaihafe@odu.edu) or the Office of Research (757-683-3460).

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

Subject's Printed Name & Signature	**Date**

INVESTIGATOR'S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws, and promise compliance. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

Investigator's Printed Name & Signature	**Date**

Immediate Disqualifiers from Participation

Please take your time and carefully check any items on this document that apply to you. Placing a check next to **ANY** of these items may serve to disqualify you from this study.

Do you have **ANY** of the conditions listed below (check items that apply to you):

_____A known cardiovascular disease (Cardiac, peripheral vascular, or cerebrovascular disease)

_____A known pulmonary disease (COPD, asthma, interstitial lung disease, or cystic fibrosis)

_____A Known metabolic disease (Diabetes mellitus (Types 1 and 2), or renal disease)

(The above ACSM high risk disease information was obtained from Pescatello et al., 2014, p. 26.)

Do you have **ANY** of the signs/symptoms of metabolic, pulmonary, or cardiovascular disease (check items that apply to you):

_____Pain, discomfort in the chest, neck, jaw, arms, or other areas that may result from ischemia

_____Shortness of breath at rest or with mild exertion

_____Dizziness or syncope

_____Orthopnea or paroxysmal nocturnal dyspnea

_____Ankle edema

_____Palpitations or tachycardia

_____Intermittent claudication

_____A known heart murmur

_____Unusual fatigue or shortness of breath with usual activities

(The above ACSM Major sign/symptoms of disease were obtained from Pescatello et al., 2014, p. 26.)

Do you have **ANY** of the following <u>contraindications</u> to exercise (check items that apply to you):

_____A recent significant change in the resting electrocardiogram (ECG) suggesting significant ischemia, recent myocardial infarction (within 2 days), or other acute cardiac event

_____Unstable angina

_____Uncontrolled cardiac dysrhythmias causing symptoms or hemodynamic compromise

_____Symptomatic severe aortic stenosis

_____Uncontrolled symptomatic heart failure

_____Acute pulmonary embolus or pulmonary infarction

_____Acute myocarditis or pericarditis

_____Suspected of known dissecting aneurysm

_____Acute systemic infection, accompanied by fever, body aches, or swollen lymph glands.

(The above ACSM contraindications to exercise were obtained from Pescatello et al., 2014, p. 53.)

Reference:

Pescatello, L.S., Arena, R., Reibe, D., & Thompson, P.S. (2014). *ACSM's Guidelines for Exercise Testing and Prescription* (9th ed). Baltimore, MD: Lippincott Williams & Wilkins.

VITA

The primary author and investigator Christopher Deane Vaughan graduated from the Darden College of Education's Department of Human Movement Sciences at Old Dominion University on May 5th, 2012 with a Bachelor of Science degree in Physical Education (emphasis in Exercise Science). The author has multiple semesters of research experience as a Graduate Research Assistant, working primarily with Dr's Corey Rynders and Steven Morrison on a similar study involving falls susceptibility in people with Multiple Sclerosis. The author has previous experience performing 6-minute walking tests, instructing subjects to properly complete surveys, performing falls risk assessment via PPA, collecting and interpreting physical activity data via waist and wrist worn accelerometers, and in subject recruitment. The author is also certified in Adult CPR/AED by the American Red Cross.