VALIDITY OF A FUNCTIONAL OBSTACLE COURSE AS A TOOL TO SCREEN FOR FALL RISKS IN OLDER ADULTS

by

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ABSTRACT

INTRODUCTION: There is currently no specific instrument or test to diagnose fall risks in older adults. A functional obstacle designed and based on current research and the components of falls has the potential to be an effective method of diagnosing fall risks in older adults. **PURPOSE**: The purpose of this study was to determine the construct validity and reliability of the Modified Functional Obstacle Course (MFOC) and to examine the instrument's intra-obstacle measurement parameters. **METHODS**: Participants (N = 63) performed a single series of three common fall risk assessments: Activity Specific Balance Confidence Scale; Dynamic Gait Index and the Tinetti Balance Test (ABC, DGI, & TBT); and, the new Modified Functional Obstacle Course (MFOC). The order of tests, per series, was randomized between participants. Participants (N = 30) from the original sample returned for a single day of testing on the MFOC. **DATA ANALYSIS:** Construct validity and reliability was determined by measuring correlation (r) to the (ABC, DGI & TBT). Intra-obstacle analysis was performed by using principal component analysis. **CONCLUSION**: The Modified Functional Obstacle Course demonstrated a moderate to high construct validity, $r(63) = .75 - .76$, $p < .05$, in correlation to the convergent measures and it demonstrated high test re-test reliability, $r(30) = .99$, $p < .05$ and internal consistency. Principal component analysis demonstrated five distinct components within the MFOC, which accounted for 78% of the variability in scores.

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CHAPTER I: INTRODUCTION

Background of the Problem

The post World War II surge of childbirths has created the largest generation of Americans to date. This group, of approximately 76 million people, will become 65 years or older in the year 2015 (Brault, 2007). Unfortunately, the latest report by the Center for Disease Control and Prevention (2008) indicates that one in three adults who are currently 65 years of age or older have suffered from a fall and the trend is expected to continue. This problem makes falls a central cause of fatality and serious injuries in older adults (Lewell, Vaillancourt, & Sosnoff, 2006). The high rate of falls, coupled with the pending increase in the number of older adults in America, makes diagnosing and treating fall risks a high priority, for both researchers and clinicians. Furthermore, health care costs remain high for the treatment of fall-related injuries (Brault, 2008). This creates a need for individuals who are at risk of falling to receive pre-emptive treatment, in order to avoid the otherwise costly expense of trauma care.

It is common knowledge that aging is associated with a decrease in physical function and performance, including a lack of balance and mobility, which increases the likelihood of an accidental fall (Lexell, Taylor, & Sjostrom, 1998). In addition, aging commonly decreases sensory capabilities, neurological responses, muscular strength and power, and cognitive function; all of which contribute to a higher probability of accidental falls (Huan, 2010). While the severity and actual types of all forms of degeneration vary from individual to individual, physical degeneration is often accompanied by cognitive degeneration, which has a substantial effect on the risk of falls (Pfisterer, et al., 2003).

One of the most prevalent and immediate determinants of falling is muscular degeneration (*i.e.*, Senile Sarcopenia). Less common impairments that affect the rate of falls are neuromuscular (proprioceptive) atrophy, cognitive degeneration, ocular, and/or macular degeneration (Lewell, et al., 2006; Sosnoff & Voudrie, 2009). All of these components play a substantial role in maintaining balance and proper gait. For example, muscular strength helps prevent fatigue, which can cause falls. Muscular strength also helps a person maintain proper gait and navigate through environmental hazards. Sensory awareness is central to making observations about the surroundings, so an individual can adjust his, or her, gait or path to avoid falling (Lewell, et al, 2006; Sosnoff & Voudrie, 2009). In addition to the physical causes of falls, the risk of falling is confounded by psycho-social causes (Arnadottir, Lundin-Olson, Gunnardottir & Fisher, 2010). For example, current research has shown a correlation between low balance self-efficacy and increases in falls (Simpson, Worsfold, Fisher & Valentine, 2009).

While the degeneration of many physical and psycho-social components often correlates to age, they always can be reversed or slowed, through appropriately designed interventions (Shumway-Cook & Woolacott, 2001; Spirduso, Franci, & MacRae, 1995). Despite these advances in preventive treatment for falls, there is still, however, a lack of proper diagnostic instruments and/or methods to determine who is in the most need of these interventions (Oliver, et al., 2004).

The interlinking and often varied causes of falls in the elderly make diagnosing fall risks complicated. The complexity is exacerbated by the numerous and varied types of assessment tools to diagnose fall risks. These assessments often test specific individual causes of a fall, as opposed to taking a more holistic approach (Brault, 2008). Each test, or assessment, looks at one aspect, from physical to psycho-social causes of falls. The Tinetti Balance Test (TBT) takes the most comprehensive approach and is the most widely used (Stevens, 2008). The TBT is a series of small functional tests that assess a participant on both balance and gait; however, it does not assess other contributing components (Tinetti, 1986). Other popular tests measure postural sway, using postugraphical analysis equipment and functional mobility tests that measure muscular strength and performance. There are also various forms of psychological or social tests, such as the Activities Specific Balance Confidence Scale, that measures self-efficacy and self-confidence (Simpson, et al., 2009).

Because many of the common assessments currently used to diagnose fall risks examine a single factor, they exclude other potential risk-factors. This paradigm implies that fall risks are similar to conventional ailments that can be detected by a single anomaly, such as lack of strength or cognitive function. However, the causes of falls are multi-factorial and a single risk factor may not constitute a high risk of falling (Oliver, et al.,, 2004). The complexity of the interrelation of all fall risks makes any assessment that examines a single risk factor incomplete. In an attempt to remedy this problem, Means, Rodell and O'Sullivan (1996; 1998) created a functional obstacle course to test the sum impact of all determinants of fall risks. They theorized that an obstacle course designed to replicate everyday environmental hazards would measure a participant's ability to navigate through these obstacles and, thus, measure the sum impact of all possible weaknesses in the necessary components of balance. The functional obstacle course was modified from its original form and has not been validated (Means & O'Sullivan, 2000; Means, 2005).

Purpose of the Study

Given the problem caused by the single dimensional perspective of current fall risk screening instruments, there is a need for a tool that provides a more comprehensive assessment of a person's risk of falling. A diagnostic tool was created in 1996 by Means, Rodell, and O'Sullivan to tackle this issue. However, after the researchers performed the initial validity studies, they later modified the course design to promote the mobility and safety of the course. The specific tasks, within the course, were not changed, only the arrangement and dimensions were modified (Means & O'Sullivan, 2000; Means, 2005). The modifications, although minimal, have not been validated. For the purpose of this study, the course was further modified to include a new task and to remove a duplicate task. The purpose of this study was to (a) examine the construct validity of the MFOC, by measuring the correlation of the MFOC to current assessments, (b) examine the reliability, and (c) further determine construct validity and intra-obstacle discrimination via principal component analysis.

Need for the Study

As previously stated, falls are a multi-faceted phenomenon that involve numerous physiological components and socio-psychological parameters that have resulted in several, separate tests to diagnose the same problem (Oliver, et al.,, 2004). Until there is a single, unified understanding of fall risks for older adults, research, and diagnostics will be slow and will yield highly varied results. The benefits of creating a single, unified measurement that encompasses all causes, both physiological and psycho-social, include: enabling the academic and professional community to better screen for fall risks and compare normative results through varied populations. The original functional obstacle course has previously been shown to correlate to the Tinetti Balance Test (TBT) (Means, et al., 1996). If a modification of this original course correlates to three assessments that evaluate the function of various fall related components, it will demonstrate that there is a common denominator between these components that can be assessed by a single diagnostic test.

In order to properly diagnose fall risks, an obstacle course must be sufficient in length, to allow enough time for the observer to note any complications that the participant may face. The obstacle course must also incorporate truly functional tasks, such as walking up stairs, or on an uneven surface (Ka-chun, et al.,, 2008). It must incorporate a quantitative element that correlates to environmental difficulties, such as how many times a participant needs extra support (e.g, the use of a railing, etc.) (Means, 2005). A functional obstacle course, such as the one created by Means, et al.,(1998) replicates every-day environmental obstacles; thus, it inherently taxes the physiological and psycho-social components that play substantial roles in maintaining healthy balance and mobility.

As previously mentioned, a diagnostic tool that takes a multi-factorial and holistic environmental approach to examining fall risks will be better suited to make accurate assessments, thus allowing individuals to receive pre-emptive treatment.

Hypotheses

The functional obstacle course will show a high and positive correlation to the (a) Tinetti Balance Test, (b) Dynamic Gait Index, (c) Activities Specific Confidence Scale, and demonstrate high test re-test reliability.

Limitations

This study had a relatively small sample size ($N = 63$) for a validity study. The sample population may not have been a true sample of the intended demographic because a convenience sample was used. The individuals who participated lacked general diversity of ethnicity. Also, because they were recruited solely from the Boise, Idaho community, it is likely that they were more uniform in their income and education levels.

Delimitations

In order to increase the variation in physical ability and age, participants were recruited from a wide range of locations. Participants were recruited from exercise facilities, senior community centers, independent living retirement facilities, current research studies, and by local physician referrals. Furthermore, participants were required to be: a) over the age of 65, b) free of cognitive impairments, and c) wholly able to complete the study with low risks, as required by the Institutional Review Board of Boise State University.

Assessments that were used to correlate and compare to the functional obstacle were chosen by their focus on specific aspects of falls (physiological, cognitive, and behavioral) and by their popularity in pertinent research and medical practice.

Operational Definitions

- Fall: When any part of the body involuntarily touches the ground
- Fall-risk: A person who has a high probability of falling within the next six months
- Assessment: Diagnostic tool to determine fall risks
- Test: A trial of an assessment that results in data collection
- Balance: The ability to maintain a static equilibrium, including: standing without postural sway and sitting without swaying or leaning
- Mobility: The ability of a person to move freely in a dynamic and changing environment while maintain safe posture, gait, and balance

Significance of the Study

This study begins the process of trying to determine if an obstacle course, which is broader in scope and incorporates environmental challenges, could be used in place of several separate instruments for fall risk screening; these assessments included the Activity Specific Balance Confidence Scale, Dynamic Gait Index, and Tinetti Balance Test. These assessments were chosen for their wide use in research and clinical settings and their reported range of measurement abilities. The obstacle course has the potential to reduce the number of tests used for the purposes of screening for fall risks and increase the efficiency of the process, while maintaining and possibly enhancing its efficacy. The current study differed from previous research by Means, et al., (1996, 1998, 2000) in as it validated the MFOC against three convergent measures (ABC, DGI, & TBT) as opposed to only a single source. Furthermore, the current study looked at intra-obstacle discrimination to investigate measurement constructs within the MFOC.

Summary

This chapter outlined the background of the problem and the need and significance of the current study. Falls are one of the main causes of fatalities and injuries for adults $\geq$ 65 years old (Brault, 2008). Currently, there are several assessments that attempt to diagnose fall risks in older adults, in order to identify those individuals who need pre-emptive care. However, these assessments do not use a comprehensive perspective to assess fall risks, despite falls being caused by a number of broad and intricate mechanisms. A functional obstacle course assesses the sum impact of all fall risk factors, thus using a holistic perspective to assess fall risks.

CHAPTER II: LITERATURE REVIEW

With high and rising medical costs for injuries and the number of fatalities related to falls in older adults, there is a need to have a comprehensive understanding of how to identify those at a high risk of falling. If an older adult can be diagnosed as a fall risk and given preventive treatment, it can potentially cut fatalities, injuries, and reduce the growing burden on the medical system. Unlike several ailments that are common with older adults, predicting and labeling an older adult as a fall risk is difficult because of its broad and multi-factorial aspects. This review will examine: (a) the main components that contribute to fall risks, both intrinsic and extrinsic, (b) common diagnostic methods and (c) why an environmental measurement, such as a functional obstacle course, may be a better means of predicting falls in older adults.

Societal Impact of Falls

Falls are a common concern for people over the age of 65 years old and continue to place a burden on the American health care system. The Centers for Disease Control estimate that more than 33% of those over the age of 65 will have an accidental fall in the next six months (Stevens, 2008). In 2000, there were over 10,000 fatal falls and 2.6 million non-fatal (but medically treated) fall-related injuries. Medical costs in that year alone exceeded 19 billion dollars (Stevens, Corso, Finkelstein, & Miller, 2006). The annual costs of fall related injuries and deaths are predicted to soar past $40 billion in the next ten years (Englander, Hodson & Terregrossa, 1996).

A partial reason for the large increase in medical expenses is the large shift in age-related demographics in the United States. A report released by The Centers for Disease Control and Prevention and The Merck Foundation (2007) estimated that by 2030, 20% of the American population will be over the age of 65, with a substantial increase in life expectancy. The average life expectancy for adults in the United States has increased 25% from 65 to 81 years, from 1968 to 2010, respectively (Cohen, 2010). This increase in the percentage of the American population who will be older than 65 years and the increase in life expectancy have created a larger opening for possible fall injuries and fatalities. While medical advancements have increased the average life expectancy of Americans, little has been done to decrease the negative effects of aging on older adults. This has caused an inverse correlation between the increase in life expectancy and the number of reported accidental falls.

The Effects of Ageing on Physical Function

The effects of aging on the general state of health are well researched, but vary with the individual (Hayes, Wolfe, Truijillo, & Burkell, 2010). There are common ailments that often contribute to an increased risk of falling, including muscular degeneration (i.e, senile sarcopenia). Ageing is correlated to a high degree of loss in muscular density and cross-sectional area (Hayes, et al., 2010). Despite the dramatic onset of sarcopenia, the cause is still not entirely understood. Along with muscular degeneration, aging is also associated with neuromuscular degeneration. This causes a lack of general power within the muscles, which has been shown to be a large determinant of fall risks (Granacher, Zahner, & Gollhofer, 2008).

The decline in physical elements such as muscular strength and size, as well as neuromuscular degeneration are often accompanied by a decline in cognitive function, another common result of aging. Often patients with these disorders become easily confused and disoriented, especially in low light, resulting in falls. This issue is exacerbated when it is combined with ocular or macular degeneration (Lewell, et al., 2006, Sosnoff & Voudrie, 2009).

Balance, Mobility, and Mechanisms Related to Falls

The causes of falls have been systematically viewed in relation to balance and mobility. Balance and mobility (or deficiencies therein) are substantial portions of the causes of falls; however, new research has shown a more complex interrelation of varying mechanisms. The exact mechanisms that lead to a high-fall probability, associated with balance and mobility, in an individual, can be broken into two categories: intrinsic and extrinsic. Intrinsic mechanisms are those components that control the anatomical factors related to maintaining dynamic balance (vestibular, sensory, and motor) (Spirduso, Francis, & MacRae, 1995). Intrinsic factors are those that operate outside of the influence of external stimuli. Extrinsic factors are those that have often been termed as risk factors in the environment, or created by the environment. A majority of falls are the result of a combination of intrinsic and extrinsic factors

Intrinsic Components

The physiology of balance consists of several complex but interlinking components. The four primary components of balance consist of the vestibular apparatus, the ocular system, the nervous system (proprioception), and strength. The vestibular system is central to maintaining both static and dynamic balance. Located in the inner ear canal, the vestibular apparatus (the main component of the vestibular system) is a conch shell-shaped organ that detects changes in linear and angular displacement, as well as rate of change (acceleration). This information is sent directly to the central nervous system, in order to trigger pertinent motor programs to avoid losing balance (Highstein, Fay, & Popper, 2004). If a person begins swaying, or otherwise begins to lose balance, the vestibular apparatus (if functioning properly) notifies the CNS, which instantly corrects the problem in order to maintain proper stability (Young & Tolbert, 2007). In many cases, the vestibular apparatus works in conjunction with other sensory organs, such as the ocular system.

The ocular system gathers information about the environment in order to allow immediate changes in an individual's path or gait pattern. Information gathered for automatic response by the CNS is slightly more complex and works parallel with the vestibulo-ocular reflex (VOR). In VOR, the vestibular apparatus detects changes in angular movement and the individual's line of sight moves in conjunction with the change (Vaina, Beardsley, & Rushton, 2009).

Vision also functions with the autonomic nervous system to make adjustments based off of gathered information on changes in depth, velocity, and acceleration. This is termed optic flow. Optic flow is a process in which we visually gather data on changes of depth of objects in the environment. This information can be used for cognizant and attentive processing (e.g., how far an oncoming car is in traffic) or automatic processing. The latter of the two processes is central in maintaining balance (Vaina, et al., Rushton, 2009).

Both the vestibular and ocular system can be said to gather ex post facto information, whereas the third component, proprioception, gathers information about the working musculature. Proprioception is the information gathered by mechanoreceptors on the body's spatial position in order to maintain balance and make movement more efficient. As it relates to balance and falls, proprioception is broken into three major mechanoreceptors: muscle spindles, golgi tendon organs (GTO's), and free nerve endings (FNE). Muscle spindles are part of the muscle and are composed of four to six muscle fibers engrossed in a collagenous layer, which send kinetic or kinematic information to the CNS to create immediate information processing in an emergency. In many cases, the CNS sends an action potential to antagonist muscle to contract in order to prevent over lengthening. In the case of balance, the role is to correct any unintentional shifts in muscle activation in order to regain equilibrium (Sosnoff & Voudrie, 2009).

Proprioception is a category within the area of the nervous system. Strength, as a component of balance and mobility, is well understood. Strength is not a mechanism, but the effect of interrelated mechanisms such as muscular characteristics and nerve innervations. Muscles produce contractions; however, the strength of these contractions depends on several physical parameters of the muscle. Muscles need a strong electrical signal through a series of afferent nerves, which requires a healthy nervous system. Power, defined as force*velocity, is central in maintaining balance and mobility. It is limited by the muscle fiber type and the fatigue resistance of the muscle (Guincestre & Sesboue, 2006).. The ability of a muscle to resist fatigue is limited by the fiber type and by the metabolic pathways that buffer accumulated hydrogen ions, as result of anaerobic cellular respiration (Guincestre & Sesboue, 2006).

Strength, like proprioception, sensory perception, and the vestibular apparatus plays a crucial role in maintaining safe balance. However, as previously mentioned, aging diminishes the efficacy of these systems. It is difficult to predict at what age, or rate, degeneration will occur, only that aging correlates to this degeneration. As biological aging increases, the intrinsic components of balance often decrease (Spirduso, Francis, & MacRae, 1995).

Thus far, the discussion has covered the four major intrinsic components of balance, the vestibular, ocular, proprioceptive, and muscular systems and how they function and relate to one another. The vestibular apparatus detects changes in temporal position and acceleration and can control line of sight during head rotation, whereas vision also communicates with the CNS through optic flow. However, falls are not exclusively caused by impaired balance, nor by impaired physiological components alone. Interrelated with, or independent of, the above components are the neurophysiological mechanisms that help individuals process information effectively; this is termed cognitive function.

Cognitive function includes proper neurophysiological components of mental function that allows for proper information processing, such as visual recognition (Nagamatsu, Liu-Ambrose, & Carolan, , 2009). The contributions of cognitive function, or neurophysiological function, to balance and falls are still being investigated. However, there is clear information on how impairments in this area can affect the likelihood of falls. A lack of cognitive function, in these terms, can be best understood through general dementia. Dementia is often a chronic and progressive deterioration of multiple higher cortical functions, including memory, orientation, calculation, and recognition. Dementia is most common in older adults, with a high rate of dementia patients institutionalized for fall related injuries (Verghese, Lipton, Hall, Kuslansky, Katz, & Buschke, 2002).

Ageing has been shown to increase the risk of degeneration for all of the above intrinsic components. Ageing decreases sensory capabilities, reflexes, muscular strength and power, and cognitive function, all of which have a substantial effect on the likelihood of a fall (Huan, 2010).

Extrinsic Components

Falls are often attributed to intrinsic factors and in many cases these factors play a significant role. However, falls happen in an open environment that is influenced in part by psycho-social factors and the environment itself. Psycho-social components, as they relate to fall risks, can be defined as the fear of falling, or balance self-efficacy (Bandura, 1986).

Situational specific self-confidence, or self-efficacy, is a complex model that has been shown to play a large role in a variety of behaviors (Bandura, 1986). Among these behaviors, self-efficacy has shown to be a large determinant of fall risks (Arnadottir, et al., 2010; Pang & Eng 2008). A lower level of self-efficacy is linked to increases in falls. In several studies, low self-efficacy was a better determinant than physiological components at identifying those at a higher risk of falling (Arnadottiret al., 2010; Pang & Eng 2008; Simpson, et al., 2009). Fear of falling (low self-efficacy), diminishes a person's ability to safely navigate through environmental obstacles, thus leading to an increase in falls.

The following table summarizes the intrinsic and extrinsic mechanisms, discussed above, that relate to falls (Table 1).

Table 1. Summary of Intrinsic and Extrinsic Mechanisms Related to Falls

Component	Relation to Balance and Mobility	Classification
Vestibular	Detects changes in spatial movement, including angular displacement. Prevents postural sway and directs line of sight during spatial rotation	Intrinsic
Ocular	Main component of sensory information, central to detecting changes in the environment	Intrinsic
Proprioceptive	Detects changes in muscular and skeletal movement and activation	Intrinsic
Strength	Exclusive mechanism of bodily movement and central to maintaining static and dynamic balance	Intrinsic
Cognitive	Governs all voluntary executive function	Intrinsic
Self-Efficacy	Fear of falling decreases the efficacy of internal mechanisms	Extrinsic

Interrelationship of Mechanisms (Environmental)

Unlike the above intrinsic/extrinsic causes of falls, environmental obstacles are an indirect but important consideration when evaluating the likelihood of a fall. A study done by Hitcho et al. (2004) looked at descriptive causes of falls in 183 patients (male = 86, female = 97) in hospital settings. The data were collected from self-report surveys, incident reports filed by nurses, and physician diagnosis. The researchers examined common demographic and physical characteristics as well as the circumstances of the falls. The results showed, as expected, that a majority of the falls (67%) occurred in patients over the age of 60, with no significant difference in gender or reason for the initial hospital stay. The most alarming results were the general lack of correlation in the patient's demographics and physical characteristics; with the exception of muscle weakness, which was statistically significant. There was little indication that one common illness was the main culprit for the falls and even the high correlation between falls and muscle weakness is questionable due to the extended stay of many of the elderly patients (i.e., extended bed rest causes muscular atrophy and may not be a true indicator of the fall). Half of the patients were fully alert at the time of the fall, while others were confused. Only 30% of the patients were previously labeled as "fall risks." However, there is an indication that environmental factors played a contributing role.

The most common environmental causes, according to the previous study by Hitcho et al. (2004), were issues with the floor surface and lighting. A majority of the falls that were caused by self-reported "slips" were due to wet surfaces on the floor. Another 8% of the falls were caused by patients trying to avoid obstacles and a total of 30% of the falls occurred in the late hours of the night and in low-light situations. In summary, a total of 74% of falls were caused by environmental factors (not all causes are mentioned here).

In addition to the high rate of falls caused by environmental factors, a high number of the patients had many of the disorders that have been previously deemed as contributors to falls. This could possibly indicate that the physical or mental factors that are associated with falls impede the body's ability to adapt to changing environmental surfaces and lighting conditions. Despite limited research, current studies have shown a correlation to specific environmental hazards (e.g, low lighting, smooth surfaces, uneven surfaces, stairs) and accidental falls (Gill, Williams, Robinson, & Tinetti, 1999).

The review, thus far, has discussed specific components of the physiology of balance and mobility, psychosocial components, and environmental approaches. A thorough review of the literature shows that there is no one specific cause of falls, but varied and interrelated components. Falls are seldom caused by an exclusive risk factor. Many risk factors do not exist separate from each other, but are influenced by one another. Environmental hazards are directly related to an individual's ability to manipulate the environment, while maintaining equilibrium, which is altered by intrinsic factors, as well as self-efficacy and the reciprocal is true for self-efficacy. Figure 1 (below) gives a visual representation of the interrelation of these factors.

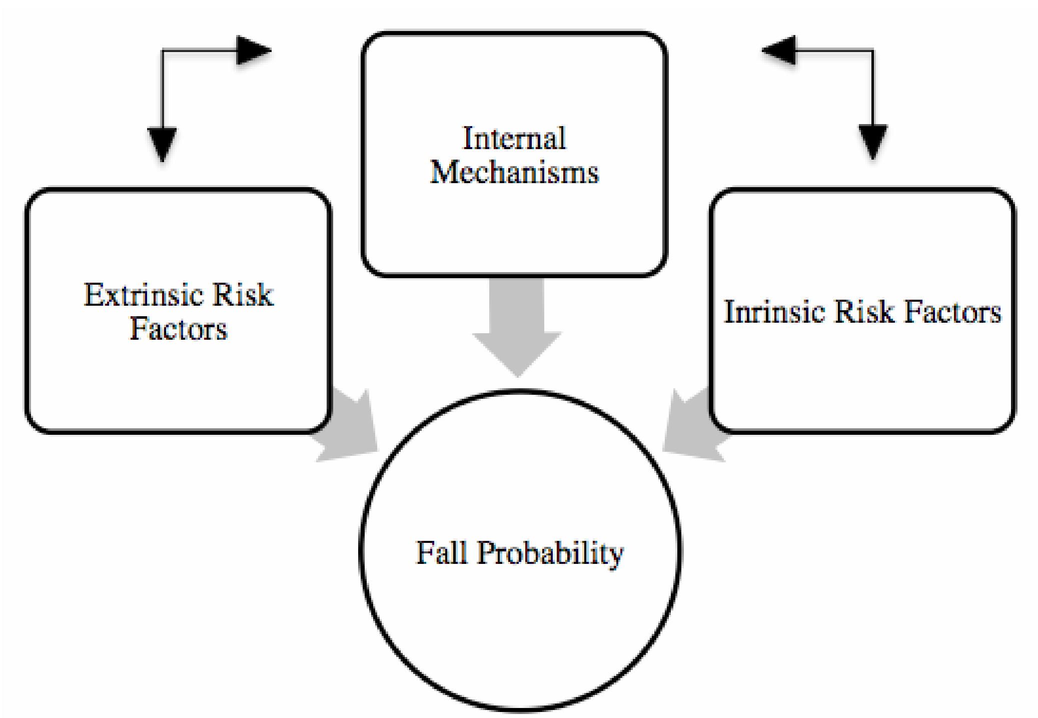


Figure 1. **Interrelation of Intrinsic and Extrinsic Components of Fall-Risks**

Fall-Risk Assessments

There are currently several different assessments, screening tools, and procedures to assess fall risks (Heinze, Dassen, Halfens, & Lohrmann, 2009). However, they often look at single components, as opposed to taking a more holistic and comprehensive approach that considers all contributing components. Research to identify more comprehensive screening tools to assess fall risks is still in the early stages and is slow to progress because of the complex nature of falls. There are several contributing factors that can cause accidental falls. The exact mechanisms that each assessment targets can be difficult to exegete because of the interrelation between mechanisms, including: the fear of falling (or self-efficacy), which may impede a participant's ability to perform a variety of diagnostic tests.

There are, however, popular instruments that have attempted to screen for fall risks in the older adult population, including: the Activity Specific Balance Confidence Scale, Dynamic Gait Index, and Tinetti Balance Test. These assessments can often be labeled as multi-factorial, because they measure multiple components; whereas, instruments that target a specific component are labeled single-factorial.

Single-Factorial Assessments

Activity Specific Balance Confidence Scale (ABC)

The ABC Scale, based on the theory of self-efficacy, is a 16-item self-report questionnaire in which respondents rate their level of self-confidence in specific activities such as "reaching on tiptoes," "walking in a crowded area," etc. (Hatch, Gill-Body, & Portney, 2003). Each of the 16 items is scored on a 0-100% scale, with 100% being fully confident at performing the task without a fear of falling. All of the individual percentiles are averaged to create a total score (Myers, Fletcher, Myers, & Sherk, 1998). There is still little research on the correlation between low scores on the ABC and the risk of falling, so individual practitioners have to use their own judgment when determining whether a participant is at risk of falling, depending on their score. Despite the lack of correlative and normative data, the ABC has been subjected to reliability and construct validity studies and has been shown to have a high test re-test reliability (r = .92) and moderate construct validity when compared to self-efficacy scales, such as the Physical Self-Efficacy Scale (r = .63) (Powell & Myers, 1995). The ABC has not been tested for convergent validity, which would be measured by determining its ability to discriminate against fallers and non-fallers.

The ABC and similar assessment tools are based on the theory that self-efficacy can affect physical performance (Powell & Myers, 1995). There will be more detail on this later in the review, but it is important to note that when examining the determinants of fall risks, they are not limited to physical components. Of course, there are confounding variables when examining the psychological determinants, because they are often preceded by physical limitations. Most often, older adults who have experienced a fall in the past have a lower self-efficacy than those who have not fallen (Hatch, et al., 2003). For this reason, a low score on the ABC Scale may correlate to a higher risk of accidental falls, but this may be attributed to the physical limitations, or circumstances, that caused the initial fall.

Multi-Factorial Assessments

Dynamic Gait Index (DGI)

The DGI was originally created as a method for assessing an individual's ability to safely modify his or her gait during dynamic tasks and was specifically intended as a research tool to evaluate physical rehabilitation interventions (Whitney, Hudak, & Marchetti, 2000). The gait tasks of the DGI were chosen from a review of previous research that had examined changes in gait through various tasks, in pre and postrehabilitation participants (Shumway-Cook & Woollacott, 1995). After its inception, however, it was shown as a moderate predictor of future falls in the elderly. This was determined via a convergent validity study. The DGI showed a moderate ability to discriminate between fallers and non-fallers (Shumway-Cook, Baldwin, Polissar, & Gruber, 1997; Whitney, et al., 2000).

In the DGI, a participant is asked to walk for set distances while performing or encountering eight different tasks. The tasks are varied and include activities such as walking while tilting the head. Participants are scored on set categories of gait modification, with the total score summed at the completion of the test (Shumway-Cook & Woollacott, 1995).

Tinetti Balance Test (TBT)

The TBT requires a participant to perform a series of specific tasks that relate to balance and mobility. The tasks were chosen based on the current research at the time (the test was designed in 1986). The original authors reviewed common activities that correlated to falls. During the test, an administrator scores the participant on an ordinal scale of 0-2 per task. The individual scores are aggregated to create three separate measures: gait assessment, overall balance, and gait and balance combined; with a maximum score of 12 (Tinetti, 1986). Validation studies on the TBT have a high variance. The test has a moderate to high inter-reliability (r = .85) (Raiche, Hebert, & Price, 2000). The TBT has shown moderate to high convergent validity, when correlated to the DGI. However, it has only shown low to moderate construct validity (Lewis, 1993).

Modified Functional Obstacle Course (MFOC)

The MFOC consists of 12 activity specific obstacles that are designed to replicate common environmental hazards (Means, et al., 1996). Each obstacle is designed to challenge the physiological and or behavioral components of balance and ambulatory mobility (Means, et al., 1996). There has not been an extensive study, to date, that has reviewed the measurement constructs of each of the obstacles. This makes it difficult to know, conclusively, what mechanisms related to falls are being measured by the individual obstacles. Five of the stations have varied floor textures. The authors refer to these textures as "floating surfaces" and two more floor surfaces have graded surfaces (an incline and decline). The graded obstacles include stairs (four steps) and a ramp (Means & O'Sullivan 2000). The test also includes opening and closing a door and standing from a chair. The entire course is constructed so that a participant can only complete one task at a time and the order of the obstacles is rigid; the order of the obstacles is the same for all participants. Participants are scored on a quantitative and qualitative scale. The quantitative scale is measured via the time to complete the course and the qualitative score is constructed of the sum of the performance on each of the individual obstacles (with a range of 0-3, per obstacle). See Appendix A for a complete scoring sheet.

The MFOC was originally designed to measure the efficacy of fall risk interventions and was intended to measure all factors related to falls (Means, et al., 1996).

The obstacle course has a moderate to high construct validity ($r = .78$) in correlation to the TBT. However, the layout of the course was modified after the original validity study, and a number of the original obstacles (there were originally 18 obstacles) were removed from the course. This was done to increase the clinical applicability of the course (Means, et al., 1998). The new modified version was correlated to the original and showed high correlation (r = .88); however, an extensive validity study has not been performed. The MFOC and its un-modified version were originally designed by Means, Rodell, and O'Sullivan (1996, 1998; Means & O'Sullivan, 2000; Means, 2005). A summary of the obstacle course as it relates to other assessments is listed below in Table 2.

Table 2. Summary of fall risk Assessments: Validity, Components Assessed, and Classification

Test	Inter-rater Reliability	Test/Re-Test Reliability	Validity	Components Assessed	Classification
Tinetti Balance Test	*	.85 (*r*)[1]	52-73% sensitivity;[2] 52% specificity[3]	*Intrinsic*: Motor, Cognitive, Sensory, Vestibular, Strength	Multi-Factorial
Dynamic Gait Index	64 (κ)[4]	.85 (I*CC*)[5]	X^2=11.27 (p = .0001) (statistically significant) with a score < 19 compared to scores > 19 [6]	*Intrinsic*: Motor, Cognitive, Vestibular, Strength	Multi-Factorial
Activity Specific Balance Confidence	N/A- Self-report questionnaire	.92 (*ICC*)[5]	$F(1,123) = 132$, $p < 0.01$	*Extrinsic*: Self-Efficacy	Single-Factorial
Modified Functional Obstacle Course	*	*	*	*Intrinsic* and *Extrinsic*: Motor, Cognitive, Vestibular, Self – Efficacy, Environmental	Multi-Factorial

[1] Lewis, 1993
[2] Gates, Smith, Fisher & Lamb, 2008
[3] Raiche, Hebert, Prince, Corriveau, 2000
[4] Whitney, Marchetti, Schade & Wrisley, 2004
[5] Lajoie & Gallagher, 2004
[6] Whitney, et al., 2000

History of Obstacle Courses in Research Literature

Obstacle courses (OC) have been used in a relatively small amount of research studies and only one validation study. All pertinent research was performed by Means, et al. between 1996 and 2005 (Means, Rodell, & O'Sullivan, 1996; Means & O'Sullivan, 1998; Means, 2005). In their initial study, the researchers performed a task-specific validation study. The initial design of their OC and research was to investigate its use at measuring balance and mobility in older adults to determine the quality of fall risk interventions, and not as a fall risk assessment. Following the original validation study on the OC, it was modified due to initial design flaws that included "difficult to transport," and "costly." Both of these factors inhibited the OC from being widely used in clinical practice. Furthermore, the obstacle course over-emphasized "outdoor" fall risk factors (Means, 2005) and did not include a chair sit-to-stand task, which has been highly validated as an activity specific indicator of fall risks (Granacher, et al., 2008). The original course (1996) was built for the specific purpose of aiding in on-site analysis of fall risk interventions. It was not until after the original validation study (Means, Rodell, & O'Sullivan, 1998) that the researchers re-designed the course to be more mobile, and thus increase its clinical applicability. Although the original obstacle course design has gone through a validity study for assessing fall risks for older adults, the modified version of the obstacle course has not been validated.

Obstacle courses have also been used as a research tool in fall prevention intervention research. In these cases, researchers located a population of participants who had already fallen, or had a high likelihood of falling. The participants went through a battery of fall risk assessments, many of which have already been mentioned. However, the researchers often included a novel OC as another measurement tool (Shimada & Uchiyama, 2003; Steadman, Donaldson, & Kalra, 2006). These obstacles courses were created by the researchers, and the details of the courses were not published. Despite the prevalence of the OC as an assessment method, there was a general lack of reference to its design or construction. This implies a need for an instrument such as an OC. Thus there is a need for a published layout of a valid and reproducible obstacle course.

In order to use an OC, a screening assessment and properly designed validity study are imperative. In order to determine the construct validity of a course, it must be correlated to the most commonly used assessment tools that are now in place. Because each of the previously mentioned assessments have all been validated to test individual components of balance and mobility and an OC is intended to test the summation of all of these components, if an OC shows a high correlation to the common tests than it can be considered efficacious as a holistic predictor of future falls and in diagnosing "fall risks."

As previously mentioned, the common fall risk assessments have provided moderate abilities at screening for fall risks. In many cases, this was determined by performing a construct validity study, in which the assessment of interest was correlated to other common assessments (Raiche, et al., 2000; Whitney, et al., 2004)

These assessments, however, may only measure a limited number of fall-related mechanisms. The result is often a one or two-dimensional perspective, which can be beneficial, but often misses the broader multi-dimensional causes of falls. Until research can show definitive and universal causes of falls, looking at single factors (in a multi-factorial disease) will provide poor predictions. Because information is still being gathered on all of the aspects of fall factors, it is less important to assess what may cause a future fall but, rather, to look at the summation of all impairments in a realistic setting, because falls do not happen in a closed setting, but within a changing and dynamic environment.

Background on Validity Studies

A validity study is an integral part of the research process. Before any instrument can be widely used in either clinical or research purposes, it is important that it has been validated. However, it is worth noting that the qualification for validity can be subject to each practitioner's standard. The assessments previously mentioned in this review have been tested in two validity paradigms: construct and convergent. In construct validity studies, the assessment of interest is correlated to other assessments that are in current practice and that have been previously validated in a manner to examine whether an assessment measures the construct it purports to measure. For example, a study that has been shown to measure construct *A* can be used, via correlation, to show that a second assessment measures the same construct. Convergent validity is determined by comparing the assessments of interest to the "gold standard." In the case of fall risk screening instruments, this would entail measuring the instruments ability to discern between fallers and non-fallers (Carmines & Zeller, 1979), through a variety of possible methods. In terms of performing fall risk assessments, this would require a follow up after the original testing to measure the frequency of falls in the sample.

Data analysis for this study entailed using Pearson Correlation with the MFOC and three other popular individual assessments to determine construct validity and test re-test reliability. Cronbach's Alpha was used to measure internal consistency.

Because the assessments are using continuous variables of measurement, Pearson is an adequate form of measuring how well the MFOC compares to the three highest standards of fall risk assessments. Each of these assessments has been validated to assess their target components. A more detailed description of the data analysis procedures is included in Chapter III.

Rationale for Creating an Obstacle Course

A systematic review of current fall risk assessments was performed by Oliver, et al. (2004). They found tests, such as the Activity Specific Balance Confidence Scale, Tinetti Balance Test, etc., examine self-efficacy, postural sway, or other single and exclusive components. However, most falls in the older adult population occur in open and dynamic situations while they are involved with activities of daily living. Currently, many of the conventional instruments used to assess fall risk have limitations, may require substantially expensive equipment, and/or have a narrow scope of focus. These types of assessments lack the pivotal environmental aspect, which may be a more effective way of identifying older adults who are at risk of falling (Simpson, et al., 2009).

A test that examines a single component of falls will continue to provide practitioners and researchers with a narrow view of this broad and complex issue. A fall risk assessment tool should not only look at the causes of falls, but how those causes limit the body's ability in novel tasks, as this is where many falls take place.

A properly designed obstacle course (OC) should have the ability to examine the effectiveness of muscular strength and power, proprioceptive ability, cognitive function, and even many socio-psychological parameters. An OC is a set area of challenging functional and practical tasks that are completed in immediate succession. For example, an OC that involves first standing from a seated position, as well as other obstacles further in the course, tests muscular strength and power. Other tasks such as walking over a slightly uneven surface test cognitive function, because a participant must be aware of the upcoming obstacle to make corrections in gait. This, of course, also tests sensory perception because a participant must be aware of the obstacle before any action begins. It also tests the proprioceptive system. An uneven surface and other related tasks are intrinsically new and novel to the participant and, therefore, negate stored motor programs, forcing the participant to rely on proprioceptive awareness to complete the task (Means, et al., 1996, 1998). These obstacles and others, such as climbing up and down stairs, are designed to be truly functional, because they are tasks that would be completed during everyday activities. For this reason, an OC also tests self-efficacy and balance confidence.

Summary

This literature review examined the effect of accidental falls on health care costs and the risk it poses to the increasing number of older adults in America, and what constitutes balance and mobility and their effect on fall risks. Included in the discussion of balance and mobility were common ailments that increase the rate of fall risk in aging. The discussion on balance, mobility, and their impairments was central to the main purpose of the study, which intends to look at the validity of a novel assessment to diagnose fall risks (Modified Functional Obstacle Course) by comparing it to three popular assessments.

CHAPTER III: METHODS

This chapter will review the methods used for recruiting study volunteers and provide a detailed explanation of all tests being used. In addition, protocol for the testing sessions and data analysis will be explained.

Participants

Prior to commencing the study, approval was obtained for the use of human subjects from the Institutional Review Board of Boise State University (January 2011). In order to participate, volunteers had to be: (a) ≥ 65 years old, (b) provided a signed informed consent, (c) given approval to participate by their primary health care provider, (d) free from severe macular and ocular degeneration, and (e) free of substantial cognitive impairments.

A convenience sample of community dwelling participants ≥ 65 years of age were recruited for the study. Volunteer participants were recruited through a variety of methods. These methods included: (a) flyers, (b) word of mouth, and (c) direct contact by the primary researcher. The primary researcher also visited community and retirement centers, as well as local programs for older adults. Interested participants were contacted by phone or in person by the primary researcher. See Appendix F for a written phone script. Volunteer participants were asked to attend an orientation session, where informed and medical consent documents were distributed. During the initial meeting, in conjunction with distributing consent forms, potential volunteers were further informed about all aspects of the study, including: inherent risks, benefits, time requirements, data management, participating research staff, and corresponding credentials. Seventy participants were sought for the study and a total of 63 older adults completed the study; the lower than expected participation was due to resource limitations, including: limited recruitment material and staff.

Instrumentation

Testing consisted of four separate instruments. Each assessment had different protocols, which are outlined below.

Modified Functional Obstacle Course (MFOC)

The obstacle course used in the study was originally created and later modified by Means and O'Sullivan (2000). The obstacle course that was modified for this study is primarily the design of the aforementioned authors, with slight alterations (see Table 3 for a complete description of the MFOC). The original authors on the MFOC provided verbal consent to use and modify their initial obstacle course for this study.

The MFOC has 12 different tasks that are intended to imitate common environmental hazards. Scoring is divided into two categories: time to complete (time score) and the participant's ability to cross an obstacle without assistance (performance score). There is a maximum of 36 points a participant can receive. The higher an individual scores, the better the participant's performance. For example, if a participant requires a handrail to balance him/herself, the researcher/practitioner deducts one point from the scoring on the obstacle. See Appendix A for complete scoring guide.

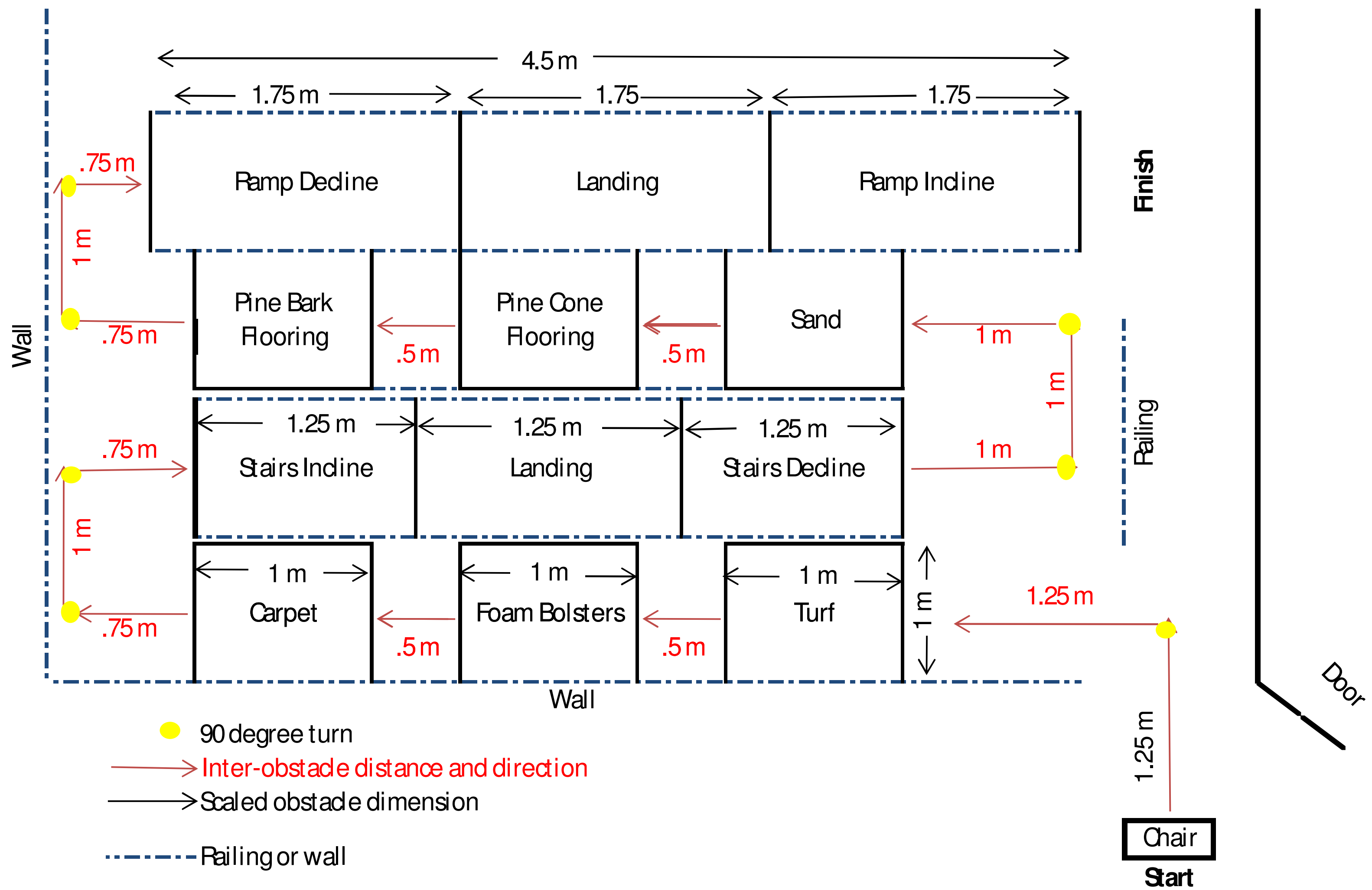
One of the tasks required dynamic activity while physically manipulating an object, which was the door opening task. Six of the tasks involved walking over various textures and four required walking up and down stairs and ramps. Figures 2 and 3 illustrate a number of these tasks. Six of the obstacles (chair stand, door opening, foam bolsters, carpet, sand, and up and down ramp) were all placed next to a wall, for safety. The stairs include handrails and the pinecones and pine bark obstacles were on the side of the staircase. The placements of all obstacles were chosen based on the proximity of handrails or walls in order to increase safety and allow for a greater range of analysis. The practitioner did not interact with the participant at any time, unless they asked for assistance. The "performance score" was based on the amount of assistance the participant needed. For example, if a participant used a handrail to cross an obstacle, that would equate to a lower score than if he, or she, did not need to use the handrail. If the participant requested assistance, the practitioner helped the participant cross an obstacle. However, if assistance was given, the participant received a score of zero for that particular obstacle.

The order and title of each obstacle is as follows: (a) chair stand, (b) door walk through, (c) artificial turf, (d) foam bolsters, (e) carpeted turf, (f) pinecone flooring, (g) stairs (incline), (h) stairs (decline), (i) pine bark flooring, (j) sand box, (k) ramp (incline), and (l) ramp (decline). All of the obstacles listed above have specific inter-obstacle distances. A description of the obstacles and sequential order are listed in Table 3; pictures of the course are shown in Figure 2. A diagram of the course is shown in Figure 3.

Figure 2. Modified Functional Obstacle Course (with and without a Participant)

Table 3. Description of Obstacles in Sequential Order

Number of Obstacle	Title of Obstacle	Description of Obstacle
1	Chair stand	Standard chair: no arm rests, seat 43-46 cm from floor, 20 cm seat length and 100 degree angle from seat base to back support
2	Door walkthrough	Supported and framed door with 6 cm round doorknob
3	Artificial turf	Landscaping turf: 50 cm x 100 cm
4	Foam bolsters	Cylindrical foam padding 2-6 cm in diameter of varied length; contained in a box 50 cm x 240 cm x 8 cm
5	Carpet task	Bulk continuous fiber carpet: 50 x 240 cm
6	Pinecone flooring	Pinecones of varied shape and dimensions; contained in a box 50 cm x 240 cm x 8 cm
7	Stairs (incline)	Three step stair complex with each step at 19 cm with a 19 cm rise
8	Stairs (decline)	Five step stair complex with each step at 19 cm with a 19 cm rise
9	Pine bark flooring	Pine bark mulch of varied length and dimensions; contained in a box 50 cm x 240 cm x 8 cm
10	Sand box	Fine grain s and; contained in a box 50 cm x 240 cm x 8 cm
11	Ramp (incline)	2.4 meter ramp with a 4.8 degree incline
12	Ramp (decline)	2.4 meter ramp with a 4.8 degree decline


4.5 m
1.75 m
1.75
1.75
Ramp Decline
Landing
Ramp Incline
Finish
Wall
.75 m
1 m
.75 m
Pine Bark Flooring
.5 m
Pine Cone Flooring
.5 m
Sand
1 m
1 m
1 m
Railing
1.25 m
1.25 m
1.25 m
Stairs Incline
Landing
Stairs Decline
.75 m
1 m
.75 m
1 m
Carpet
.5 m
1 m
Foam Bolsters
.5 m
1 m
Turf
1 m
1.25 m
1.25 m
Wall
Door
Chair
Start
90 degree turn
Inter-obstacle distance and direction
Scaled obstacle dimension
Railing or wall

Activities Specific Balance Scale (ABC)

The ABC Scale is a self-report questionnaire where respondents rate their level of self-confidence for performing specific activities in 16 questions (Hatch, Gill-Body, & Portney, 2003). See Appendix B for a complete scoring guide. The questions are scored on as 0-100%, with an average score created from the summed answers. Each of the 16 items is scored on a 0-100% scale, with 100% being fully confident at performing the task without a fear of falling (Myers, Fletcher, Myers, & Sherk, 1998). The ABC scale has been validated, and demonstrated acceptable test re-test reliability (r = .92) (Powell and Myers, 1995). The ABC Scale has been validated for several populations including older adults (Lajoie & Gallagher, 2004). Other than the paper questionnaire, no extra equipment was required.

Tinetti Balance Test (TBT)

The TBT is a simple qualitative assessment tool that does not require any equipment. An administrator scores the participant on a scale of 0-2 on 14 tasks that are broken into static balance and gait. The total scores are summed to make the complete score (Tinetti, 1986). Despite the qualitative nature of the assessment, it has high reliability (r = .85) (Lewis, 1993).

The TBT is broken into two categories. The first series of tests involves observing the balance of the participant. The second series of tests involve a participant performing continuous gait through a variety of tasks. The order is specified below.

Balance tests

Sitting balance. The participant sits in a hard, armless chair for thirty seconds, while the researcher observes the participant's balance.

Rises from a chair. The task measures the participant's ability to stand from a chair unassisted.

Immediate standing balance. The practitioner observes the participants balance during the first five seconds after standing from the chair.

Nudged. The practitioner gently "nudges" the participant in his or her sternum and observes the participant's ability to maintain balance.

Eyes closed. The practitioner observes the participant stand (static) with both feet on the floor, for 20 seconds with eyes closed.

Turn 360 degrees. Without deviating from a given space, the participant must make one complete circle.

Sitting down. The participant moves into a standard chair and completes the task at ≈ 90 degree knee flexion.

Gait Tests

Participant begins walking with normal gait. There are no scenarios within this task. The practitioner observes gait pattern and scores accordingly. The participant continues walking until all areas have been assessed. The areas of assessment include: (a) step length and height, (b) step symmetry, (c) step continuity, (d) gait path (deviation), (e) trunk sway, and (f) register of stance during normal gait (for a complete description and score form for the TBT see Appendix C).

Dynamic Gait Index (DGI)

The DGI is an eight-item assessment tool that assesses a participant's gait during task-oriented activities: such as, 180-degree pivot, vertical and horizontal head turns, and walking up steps. The DGI requires a participant to perform eight functional tasks that require gait alterations. Each task on the index is scored on an ordinal scale of 0-3, with a maximum final score of 24. The test takes approximately 15 minutes to complete. This DGI has been validated as a measurement tool for fall risks (Chiu, 2006). The practitioner does not interact with the participant, other than to observe and measure the volunteer's performance. For a complete description and score form of the DGI, see Appendix D. The order of the tests is as follows:

Gait on Level Surfaces

The participant walks from the starting position to the next mark (20 feet). There is not a particular obstacle during this portion of the test.

Change in Gait Speed

The participant walks on a level surface for five feet and then increases speed to his/her fastest possible walk. After five feet, the participant slows back down to a normal gait speed.

Gait with Horizontal Head Turns

The participant walks in a straight path on a level surface. After five feet, the practitioner will ask the participant to look to the left while walking. After another five feet, the practitioner asks the participant to walk while looking to the right.

Gait with Vertical Head Turns

This portion is identical to the "gait with horizontal head turns." However, instead of changing looking left or right, the participant is asked to look up and down.

Gait and Pivot Turn

The participant begins walking on a level surface and the practitioner asks the participant to pivot 90 degrees, in any direction. Scoring is based off the time it takes to complete the full pivot.

Step Over Obstacle

The participant walks five feet to an eight-inch box. Without touching the box, the participant must step over the box and continue walking for another five feet.

Step Around Obstacles

The participant must make a figure eight around two cones placed six feet apart.

Stairs

The participant begins at the bottom of a standard set of stairs (8*8) and walks up five steps, then turns and walks back down. For this study, a modality staircase was used and participants did not need to complete a turn, but were able to walk in a continuous path.

Procedures

The purpose of this study was to (a) examine the construct validity of the MFOC, by measuring the correlation of the MFOC to current assessments, (b) examine the reliability, and (c) further determine construct validity and intra-obstacle discrimination via principal component analysis.

Several parameters for testing were incorporated to ensure strong data validity and decrease risks for the participants. The construction of the obstacle course was tested through a pilot study (*N* = 10) with participants prior to IRB approval. This was to ensure that the quality of each obstacle was safe for participants and to verify and practice the scoring system for each individual assessment before official testing began.

During the pilot study and testing, participants wore a four-inch wide gait belt and were closely followed by a researcher. The primary researcher, who was present during all testing, was certified in CPR and First Aid through the American Red Cross and had an EMT basic license and had extensive experience working with older adults in similar settings. The pilot testing was successful. Shortly after the pilot testing, IRB approval was obtained and participant recruitment began.

Testing was only performed by participants who had obtained a medical consent to participate, which had to be completed by the participant's primary care physician. The medical consent forms limited participants who may be at a substantial risk of falling, or injury due the physical nature of the assessments. Participants were notified that participation in the study was voluntary and they could withdraw at any time and for any reason.

Following recruitment, an orientation was held for informational and organization purposes. Several meetings were offered over several days to accommodate volunteer's schedules. These sessions began with a description of the study and what participants could plan to expect. All relevant forms (e.g., informed consent and medical consent to participate) were distributed at this time and anthropometric data (weight and height) was recorded and the participant's fall history was obtained (via self-report questionnaire). Testing schedules were also chosen at this time. The purpose of the first meeting was to provide all participants with the necessary information and documentation to ensure they were fully informed of the inherent risks of the study and what type of activity and commitment would be required.

Session One (First Day of Testing)

Two participants arrived at a time and began by performing the ABC. Participants were not told the sequence of the assessments before they were performed and the order in which the assessments were performed was randomized between participants. Each assessment took approximately 10-15 minutes to complete. With the exception of the ABC, one participant performed an assessment while the other rested in an outside waiting area. The total time for testing was approximately 45 minutes per two participants. A total of 63 participants completed this portion of the testing. The first 45 participants to complete the study were asked if they would like to return for a second session, and of the 45, a total of 30 participants agreed to return.

Session Two

This session involved a single test on the MFOC. Participants (N = 30) performed each test alone, and no other participants were allowed to be present. The approximate time to complete this session was 15 minutes per participant.

Data Analysis

The information gathered from the second session MFOC testing was used to determine test re-test reliability of the instrument. Pearson correlation was be used to determine the correlation between all three assessments (ABC, TBT, & DGI) and the MFOC. Cronbach's Alpha was used to determine the internal consistency of the MFOC.

Exploratory factor analysis was also performed, using principal component extraction. Kaiser's criterion was used to determine significant component, and Varimax rotation was used to determine factor loading. All analysis was performed with SPSS 19 (SPSS, Inc., Chicago IL).

Summary

This chapter explained the procedures that were used to recruit participants and the procedures that were used to complete the study. In addition, the safety protocol was discussed. Testing procedures were described along with how the data was to be analyzed.

CHAPTER IV: RESULTS AND CONCLUSION

The purpose of this study was to determine the construct validity and reliability of a Modified Functional Obstacle Course (MFOC). The MFOC was compared to three assessments that are currently being used in the clinical setting to screen for fall risks in older adults. The assessments are the Activity Specific Balance Confidence Scale (ABC), Dynamic Gait Index (DGI), and the Tinetti Balance Test (TBT). This chapter provides descriptive information and the results from the data analysis.

Descriptive Characteristics

Participants

A total of 63 participants completed the study and were recruited from seven community sites in the Boise, ID area, including a local physician's clinic, fitness facilities, current fall risk prevention exercise programs and studies, and local community centers. Table 4 provides the characteristics of the participants. The sample included 34 males and 29 females with a mean age of 73.30 (*SD* = 5.02) years. The mean age for males was 73.71 (*SD* = 4.96) years and the mean age for females was 72.83 (*SD* = 5.2) years. The mean BMI was 22.13 (*SD* = 1.88): specifically, 22.82 (*SD* = 2.03) and 22.13 (1.31 = *SD*) for males and females, respectively. A total of 15 participants reported, via a self-report questionnaire, having had one or more falls within one year previous to participating in the study. Independent *t* tests and Pearson Correlation indicated that gender had no effect on BMI or fall history and age was not related to BMI or fall history.

Table 4. Sample Characteristics

	N	Age (M ± *SD*)	BMI (M ± *SD*)	Number of Fallers
Gender				
Male	34	73 ± 4.97	22.82 ± 2.02	9
Female	29	72 ± 5.20	21.31 ± 1.31	6
Fall-History				
Faller	15	75 ± 5.68	21.59 ± 1.40	
Non-Faller	48	73 ± 4.80	22.3 ± 2.00	

Note. Gender was not related to age, BMI, or fall history ($p > .05$) and fall history was not related to BMI ($p > .05$).

Tests (ABC, DGI, & TBT)

All participants ($N = 63$) performed a single test on the four assessments (MFOC, ABC, DGI, and TBT). A comparison of means for all of the four assessments, grouped by fall history and gender, is provided below in Table 5. There was not a significant effect of gender or fall history on the ABC, DGI, or TBT.

Table 5. Performance Scores on ABC, DGI, & TBT

	N	ABC (M ± *SD*)	DGI (M ± *SD*)	TBT (M ± *SD*)
Gender				
Male	34	74.79 ± 20.27	19.74 ± 3.01	20.62 ± 3.56
Female	29	78.24 ± 18.28	20.31 ± 2.66	21.55 ± 3.05
Fall-History				
Faller	15	78.33 ± 24.67	21.33 ± 3.22	22.07 ± 3.51
Non-Faller	48	76.38 ± 19.30	20.00 ± 2.85	21.05 ± 3.34

Note. Gender was not related to age, BMI, or fall history ($p > .05$) and fall history was not related to BMI ($p > .05$).

<u>MFOC</u>

The MFOC is broken into two independent scores: performance and time. The mean for the performance score of the MFOC was 29.95 ($SD = 4.05$). Gender did not have a significant effect on the performance score ($t(61) = -.99$, $p = .32$) and neither did fall history ($t(61) = .08$, p = .93). There was a low-to-moderate correlation between MFOC performance and BMI ($r(63) = .27$, $p < .05$) and a lower correlation between MFOC and age ($r(63) = .16$, p = .20).

The mean for the time score was 42.68 ($SD = 6.62$) seconds. Gender did not have a significant effect ($t(61) = .864$, p = .39); nor did fall history ($t(61) = .08$, p = .38). There was also low correlation between the time to complete the MFOC and BMI and age ($r(63) = .26$ and $r(63) = .36$, $p = .52$, respectively). Table 6 on the succeeding page provides a comparison of the mean scores, factored by gender and fall history, for all assessments.

Table 6. Means for the ABC, DGI, MFOC, and TBT (M ± SD)

	Male	Females	Non-Faller	Faller	Total
ABC	75 ± 20.26	78.24 ± 18.2	78.33 ± 24.7	75.77 ± 17.57	76.40 ± 6.24
DGI	19.73 ± 3.00	20.31 ± 2.66	21.3 ± 3.22	19.58 ± 2.616	20.00 ± 2.85
MFOC					
Performance	29.5 ± 4.24	30.5 ± 3.82	30.03 ± 1.5	29.92 ± 4.11	29.95 ± 4.05
MFOC Time	42.68 ± 6.62	41.31 ± 5.8	40.53 ± 5.1	42.52 ± 6.54	42.05 ± 6.24
TBT	20.62 ± 3.56	21.56 ± 3.05	22.06 ± 3.5	20.73 ± 3.26	21.05 ± 3.51

Hypotheses Testing

This study contained two separate hypotheses: (a) the MFOC will demonstrate high construct validity, via high Pearson correlation to three currently validated instruments, and (b) The MFOC will demonstrate high test re-test reliability and internal consistency.

Construct Validity of the Modified Functional Obstacle Course

Construct validity was determined by calculating the Pearson Correlation (r) between the MFOC scores (performance and time) and the ABC, DGI, and TBT. Results are displayed in Table 7. Based on previous research, a correlation of $r \geq .80$ demonstrates adequate validity (Lewis, 1993). The performance score of the MFOC demonstrated a higher correlation to the other three assessments (ABC, DGI, and TBT) than the time score. The performance value showed moderate to high correlations with the ABC, DGI, and TBT ($r(63) = .76, .76$, and .75, $p < .05$, respectively). The time value showed relatively low correlation to the ABC, DGI, and TBT ($r(63) = -.38, -.43$, and .37); there was also a moderate correlation between the performance and time scores, ($r(63) = -.585$' with $p < .05$).

Table 7. Pearson Correlation (r)

	ABC	DGI	MFOC (Time)	MFOC (Performance)	TBT
ABC		0.77	-0.38	0.76	0.76
DGI			-0.43	0.75	0.84
MFOC (Time)				-0.58	-0.36
MFOC (Performance)					0.75
TBT					

Note. Correlation is significant at the 0.05 level for all values.

Table 8 provides the Pearson Correlation values for the MFOC performance and time scores in comparison to the ABC, DGI, and TBT, factored by gender and fall history. There was a small variation in the correlations between males and females; however, men tended to show a slightly higher (r) value.

Table 8. Correlation (r) Between MFOC Performance and Time and ABC, DGI, & TBT Factored by Gender and Fall History

	ABC	DGI	TBT
MFOC Performance			
Male	0.78	0.79	0.78
Female	0.72	0.68	0.73
Faller	0.76	0.94	0.81
Non-Faller	0.75	0.71	0.61
MFOC Time			
Male	-0.37	-0.45	-0.31
Female	-0.43	-0.43	-0.28
Faller	-0.46	-0.71	-0.31
Non-Faller	-0.32	-0.34	-0.29

Note. Correlation is significant at the 0.05 level for all values.

The MFOC performance score demonstrated moderate to high correlation to the ABC, DGI, and TBT ($r(63) = .75\text{-}.76$, $p < .05$ and > .80) when factored by those with a history of falling ($r(63) = .81, .94$, $p < .05$, for the DGI and TBT) thus, the construct validity was accepted for the MFOC. This was exclusive, however, to the performance score. The time score did not demonstrate adequate validity. Further explanation is provided in future sections.

Intra-Obstacle Discrimination

An intra-obstacle correlation was performed on the 12 obstacles in the MFOC in comparison to both total score sub-groups (time and performance). Table 9 provides the correlation (*r*) and descriptive statistics of the individual obstacles. The pine cone and bark flooring had the highest correlation to the performance score ($r(63) = .70$ and .73, respectively). The carpet and turf had the lowest correlation,($r(63) = .31$ and .28, respectively). Correlations were significant ($p < .05$) for all variables.

Table 9. Intra-Obstacle Correlation

Obstacle	M ± *SD*	MFOC Time (*r*)	MFOC Performance (*r*)
Chair	2.698 ± .612	-0.31	0.59
Door	2.651 ± .481	-0.441	0.54
Carpet	2.746 ± .538	-0.61	0.31
Turf	2.873 ± .336	-0.28	0.28
Ramp (up)	2.753 ± .429	-0.21	0.66
Ramp (down)	2.674 ± .450	-0.26	0.51
Pine Cone Flooring	2.039 ± .886	-0.32	0.7
Pine Bark Flooring	2.571 ± .500	-0.467	0.73
Foam Bolsters	1.769 ± .954	-0.24	0.62
Sand	2.404 ± .581	-0.25	0.63
Stairs (up)	2.404 ± .614	-0.35	0.56
Stairs (down)	2.365 ± .624	-0.378	0.58

Principal component analysis (*PCA*) was used to further analyze intra-obstacle discrimination within the MFOC for the performance score. *PCA* was used to analyze independent measurement constructs within the MFOC. The first component in *PCA*, using orthogonal transformation, is represented by those obstacles that account for the largest portion of the variance in the score. Preceding components are then listed in descending order of their accountability to the total score, with each component showing little to no correlation to the others (Jolliffe, 2002). Using Kaiser's criterion and Varimax rotation, principal component analysis demonstrated that five components accounted for 78% of the variance. Figure 4 provides the Scree plot and the drop in the eigen values after the fifth factor and Table 10 provides the factored components.

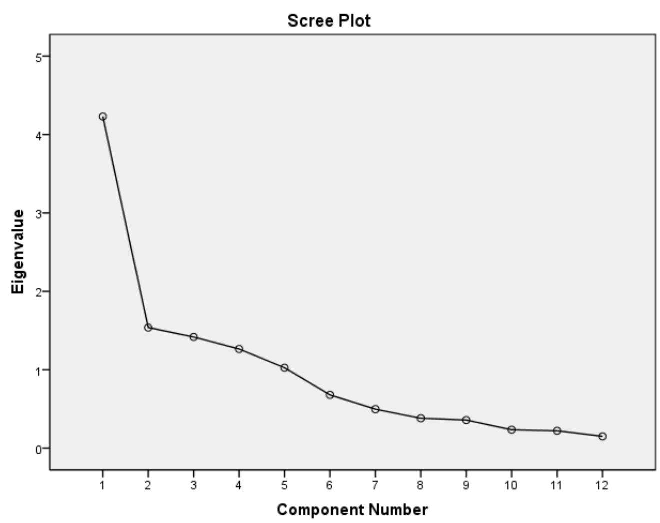


Figure 4. Scree Plot

Factor scores from the five components were saved and tested for their correlation to ABC, DGI, and TBT. Results revealed that the first two components (ocular/vestibular and intrinsic/self-efficacy) were moderately correlated with all three standard measures, with the ABC demonstrating the highest correlation ($r(63) = .63$, $p < .01$). Table 11 provides a summary of the correlation (r) scores between the convergent measures and factor scores.

Table 10. Rotated Component Matrix

			Environmental		
	Ocular / Vestibular	Intrinsic/ Self-Efficacy	Dynamic Movement	Surface Tasks	Object Manipulation
Chair			0.844		0.895
Door					
Carpet				0.887	
Turf	0.705			0.774	
Ramp (up)	0.867				
Ramp (down)	0.811				
Pinecone					
Flooring	0.608				
Pinebark					
Flooring	0.718				
Foam Bolsters					
Sand					
Stair (up)		.0913			
Stair (down)		.0887			

Table 11. Correlation (r) Between Components and Convergent Measures

	ABC	DGI	TBT
Ocular/Vestibular	0.54**	0.51	.49**
Intrinsic/Self-Efficacy	.63**	.55**	.53**
Dynamic Movement	0.17	0.19	.30*
Surface Tasks	-0.14	-0.08	-0.04
Object Manipulation	0.09	0.24	0.11

Note. *. Correlation is significant at the .05 level. **. Correlation is significant at the .01 level.

Reliability

Pearson's correlation for the participants' (N = 30) original performance and time scores in relation to their return value was high ($r(30)$ =. 99 and .893, with $p < .05$, respectively). Internal consistency was determined via Cronbach's alpha and was high for both the original performance and time scoring values, in relation to the reciprocal return scores, Cronbach's Alpha was .993 and .943, respectively.

Due to the high internal consistency of both the original and return scores and the correlation between the two, the MFOC demonstrated high test re-test reliability.

Summary

This study tested whether the Modified Functional Obstacle Course (MFOC) could demonstrate high construct validity, which was determined by correlating the MFOC to three convergent measures (ABC, DGI, & TBT). The MFOC demonstrated moderate to high correlation ($r(61)$ = 75-.75, p <. 05), high test re-test reliability ($r(30)$ =

.99-99, $p < .05$), and internal consistency. Validity was further determined through principal component analysis, which demonstrated five distinct components (measurement constructs). Two of these components demonstrated moderate correlation to the three convergent measures (ABC, DGI, & TBT), and three unique components.

CHAPTER V: DISCUSSION

The purpose of this study was to (a) examine the construct validity of the MFOC, by determining the correlation of the MFOC to three currently validated instruments, (b) examine the reliability and internal consistency, and (c) measure intra-obstacle parameters within the MFOC. This chapter will discuss the major findings of the study along with limitations and suggestions for future research.

Major Findings

The MFOC performance score demonstrated moderate to high correlation to the convergent assessments: Activity Specific Balance Confidence Scale, Dynamic Gait Index, and the Tinetti Balance Test (ABC, DGI, & TBT) used to determine the construct validity (r =. 75 - .76, $p < .05$). The narrow range of Pearson values ($r = .75 - .76$) indicates that the MFOC performance score is equally adept at examining the sum components of the three assessments combined. This illustrates that inferences can be made, with moderate to high confidence, that variation in the MFOC scores are representative of each of the three assessments (ABC, DGI, & TBT). The time score, however, showed only low correlation to the three convergent measures, as well as to the performance score.

These findings are comparable to the research by Means and O'Sullivan (2000) that showed moderate to high correlation between the original version of the functional obstacle course (FOC) and the TBT. Means, et al., (1996) demonstrated a high correlation of both performance and time scores to the TBT (r = .78, -.77, p <. 001, respectively). The current study however, contradicts the research by Means, et al., (1996) where the time score was positively correlated to the performance score on the original and modified version of the obstacle course and performance scores on the TBT. Their research also showed a significant difference in the time to complete the obstacle course between fallers and non-fallers (1998). The discrepancy between the current study and those previous two is in the length of the time to complete the course. Due to the larger size of the original obstacle course, the average time to completion was three minutes (Means, et al., 1998). The average time to completion for the MFOC was under one minute. This creates a lower range in possible scores for the MFOC, reducing its ability to discern between fallers and non-fallers. Table 12 provides a summary of the validity of the MFOC in comparison to previous studies by Means et al.

Table 12

Comparison of Means, et al., and Current Study

Test	Author / Year	Purpose	Results
The obstacle course: a tool for the assessment of functional balance and mobility in the elderly.	Means / 1996	Exploratory (original version)	High intra-rater reliability $r >$ .98 (time and performance)
Comparison of a functional obstacle course with an index of clinical gait and balance and...	Means, Rodell & O'Sullivan /1998	Validity (correlated to TBT)	$r = .78$, $p < .05$
Modifying a functional obstacle course to test balance and mobility in the community	Means & O'Sullivan / 2000	Exploratory (modified version)	No significant difference in time or performance scores between original and modified
Validity of a Modified Functional Obstacle Course as a tool to screen for fall-risks in older adults	*	Validity	$r = .75$-$.76$, $p < .05$ (performance score)

Table 12. Comparison of Means et al., and Current Study

Another significant finding of this study was the high correlation between the MFOC performance and time scores between the original round of testing and the return score, used to determine the test re-test reliability. The test re-test reliability measurements for the performance and time scores (r = .99 & .98) were concurrently verified by the internal consistency, which was also high. This indicates the internal reliability from the MFOC will likely remain consistent through multiple trials. Table 13 provides a summary of the MFOC validity and reliability results in comparison to the three convergent measures.

Table 13. Comparison of MFOC and Convergent Measures

Test	Inter-rater Reliability	Test/Re-Test Reliability	Validity
Tinetti Balance Test	*	.85 (*r*)	52-73% sensitivity; 52% specificity
Dynamic Gait Index	64 (*κ*)	.85 (I*CC*)	X^2=11.27 (p = .0001) (statistically significant) with a score < 19 compared to scores > 19
Activity Specific Balance Confidence	N/A- Self-report questionnaire	.92 (*ICC*)	$F(1,123) = 132$, $p < 0.01$
MFOC	*	$r > .98$	r = .75-.76

An interesting result of this study was the findings from the principal component analysis (*PCA*), which demonstrated that the 12 obstacles within the MFOC had five distinct measurements constructs, which accounted for a majority of the variance within the MFOC performance score. There appeared to be congruity between a majority of the obstacles within the MFOC, with the exception of the sand obstacle, which did not account for a significant portion of the total variation in the performance score. *PCA* is commonly used to identify distinct measurement constructs within a total measurement system (Jolliffe, 2002). In the case of the MFOC, *PCA* identified five separate measurement constructs, or components. Each of these components measured a dimension that was independent of aspects the other four components measured. Grouping of the obstacles demonstrated commonality in a component. This indicates that these obstacles were all measuring the same construct.

The large amount of factor loading within the first two components were identified as: a) ocular/vestibular (represented by the turf, incline and decline ramps, and pine bark and pine cone flooring obstacle), and b) intrinsic/self-efficacy (represented by the stairs). Factor loading of separate obstacles within a single component (such as pine bark and turf flooring), indicates a common measurement construct and correlation between the tasks. The high accountability for the total performance score variability within these two components indicates they could potentially be combined to create a subset of items, as they demonstrate a moderate correlation with all other measures. As a result, it may be possible to reduce the number of these obstacles as they each represent the same variation in the total score. In his retrospective article on the use of the obstacle course, Means (2005) noted that such commonalities between the obstacles most likely did exist; however, there were no studies that further investigated the topic.

Additionally, based on the *PCA*, the four obstacles (chair, foam bolsters, carpet flooring and the door task) represent distinct constructs that were identified as component 3, dynamic movement (chair and foam bolster flooring); component 4, surface tasks (carpet task); and component 5, object manipulation (door). These obstacles constructs were found to perform unique measurements not covered by the other constructs. It is interesting to note that the first two components, ocular/vestibular and intrinsic/self-efficacy, correlated to the construct assessments (ABC, DGI, & TBT), which indicate that they account for a large portion of the total correlation of the MFOC to these measurements. However, the latter three components did not correlate to these measurements, and can be seen as measuring a wholly new and unique construct. They have been labeled together as representing “environmental” tasks.

Additional information provided by the *PCA* indicates that Component 1 (ocular/vestibular) is the most representative of the variation within the MFOC score, and is represented by the turf, ramp (incline & decline), and the pinecone and bark flooring obstacles. This indicates that there is common measurement among these obstacles. Component 1 also showed moderate correlation to the ABC, DGI, and TBT. Research has found similar results between ocular and vestibular deficiencies and complication in adapting to floor surfaces. Deficiencies in either the ocular or the vestibular system have been shown to decrease the ability of an individual to adapt his or her gait to altered flooring surfaces (e.g., turf, pinecone and bark flooring, and the ramp obstacles) (Spaulding, et. al., 1994). This connection between the findings in the current study on floor surfaces and ocular/vestibular deficiencies and previous research demonstrates a strong measurement construct, represented by the turf, ramps, and pinecone and bark flooring.

Component 2, intrinsic/self-efficacy, demonstrated a higher degree of correlation to the ABC, while maintaining a similar correlation to the DGI and TBT. This indicates Component 2 is similar in its measurement construct to Component 1, but with an added measurement of self-efficacy. As referenced in earlier sections, self-efficacy (specifically measured via the ABC scale) has been shown to be strong predictor of falls in older adults ($ICC = .92$) (Cattaneo, Jonsdottir, & Repetti, 2006). Self-efficacy represents a unique, although conclusive, connection to falls that has only been measured via self-report questionnaires (Simpson, et al., 2009). This provides evidence that the MFOC is able to mold several measurement constructs together that would have required the use of multiple and separate assessments to measure otherwise. In addition to this distinct ability, this study indicates that the MFOC is able to measure new constructs that are not represented by the ABC, DGI, and TBT.

The environmental components (Component 3-5) made up of the chair, door, foam bolsters, and carpet obstacles represent the unique portion of the MFOC. The MFOC has already shown to correlate to the three convergent measures (ABC, DGI, & TBT), and the first two components account for this correlation. The latter three components represent a new and unique measurement construct. This indicates the MFOC is apt at measuring the same components represented by the ABC, DGI, and TBT, but it also measures new mechanisms that were not represented in the previous assessments.

Component 3, the first of the environmental components, titled dynamic movement, is represented by the chair and the foam bolsters obstacles. The foam bolster obstacle provided the participant with a novel and complex task that requires substantial gait and other mechanical alterations. Previous assessments, such as the DGI and TBT, used standardized gaits for all participants. However, in the obstacles such as the foam bolster, the participant is forced to choose the best gait adaptation via a new motor program to complete the obstacle. This method may be more representative of simulating tasks and challenges that an older adult would find via daily activities that may result in a fall.

Component 4 is constructed, solely, from the carpet task. The carpet task requires ankle moment stabilization as well as limited postural sway that can be brought on, or exacerbated, by the uneven surface of the carpet; this requires extensive proprioceptive function, in conjunction with other mechanisms (Manchester, Woolacott, Zederbauer-Hylton, & Marin, 1989) and has been aptly named "surface tasks." The door obstacle, Component 5, showed significant loading in the *PCA*. In this task, the participant was required to stabilize the upper body and reduce postural sway, while opening the door. It also required the participant to hold the door while walking through. The door obstacle, therefore, requires the most complex gross movement and muscular competency and represents "object manipulation." All of the tasks represented in these three components require skills necessary to successfully navigate through complex environmental situations. For this reason, they measure the participant's ability to navigate through a simulation of general and everyday tasks. As indicated in previous sections, falls happen in an open and dynamic environment. For this reason, the tasks represented in these three components provide a more detailed measurement of a person's risk of falling, as they account for these dynamic environmental hazards. This is important as previous research has shown environmental obstacles play a large part in falls (Hitcho, et al., 2004). Previous assessments (ABC, DGI, & TBT) have operated under the paradigm of removing the environmental component in hopes of isolating specific mechanisms that can be measured in a standardized form. Unfortunately, this modus operandi has limited the interrelationship of the fall-related mechanisms that can be viewed as the actual cause of falls.

Outside of the central findings related to the original hypotheses, the results provided information on the performance of each assessment (ABC, DGI, MFOC, & TBT, factored by participant characteristics. There was not a significant difference between males/females and fallers/non-fallers for the scores on the MFOC, and the three validation assessments (ABC, DGI, & TBT). Age was also correlated to the time but not the performance score on the MFOC. Research has closely shown a correlation between fall risk and age and it would be expected that a stronger correlation would be found in both scores (time and performance) if a wider range of ages for participants were used for the study (Stevens, 2008). It is important to note that the relatively low BMI ($M = 22.13$) for the sample may have resulted in less variation in the time score than would be found in larger or more diverse population.

Unique Contributions of the Study

The complex nature leading to falls has led to the origination of several different fall risk screening and diagnostic assessments (Heinze, et al., 2009). However, these assessments often look at single or limited factors, whereas the causes of falls are not typically characterized in such a limited scope. Common assessments (e.g. the ABC, DGI, & TBT) have attempted to quantify deficiencies in a limited amount of the previously mentioned mechanisms, and use their measurements as methods for predicting falls (Oliver, et al., 2004). However, these types of assessments lack the pivotal environmental aspect that may be a more effective way of identifying older adults who are at risk of falling (Simpson, et al., 2009). This is important because several studies have shown that obstacle courses that include the environmental component have significant potential as a fall risk-screening tool (Means, 2005).

The current study differed from previous research by Means et al., (1996, 1998, 2000) in two substantive components: 1) the MFOC was validated against *three* distinct fall risk assessments, and 2) intra-obstacle discrimination of the MFOC was examined. Previous research on the use of a functional obstacle course, mainly by Means et al., has been extensive. However, the validation study for the original design was correlated to the TBT, exclusively (Means, et al., 1998). By examining the construct validity of the MFOC via correlation to a variety of distinct assessments, a better-rounded view of the obstacle course's ability and scope was provided.

The wider variety of assessments used for this study also permitted a more precise view of the separate components being tested within MFOC's measurement constructs into separate and distinct components, which could be correlated to the convergent measures (ABC, DGI & TBT). The obstacle course, in both its original and modified version, has been noted as being lengthy (in time-to-completion) and large in size (Means, 2005). Subsequently, it lacked clinical applicability, despite its performance as a fall risk screening instrument. The current study began the process of thoroughly reviewing the need for each obstacle by finding redundant measures. This allows future researcher and practitioners to truncate the course, thereby decreasing it in size, cost, and time to completion.

Limitations

The major limitation of the study pertains to the use of the commonly used assessments as a method to determine validity, as opposed to using a follow-up study to examine the frequency of falls within the sample. A larger sample would also have presented a higher frequency of fallers as a method of comparison and validation by using a retrospective approach. This study had a relatively small sample size (N = 63) for a validity study. A follow-up study at set time interval, to ascertain up-to-date fall histories would have been the ideal method.

Secondly, the cohort was not a true representation of the intended demographic, as they lacked general diversity in socioeconomic status, ethnicity, and exercise history. It should be noted, however, that this information was obtained anecdotally. A majority of the participants were recruited from recurring fall-prevention and exercise classes, although a relatively large portion of the sample (24%) had indicated having had a previous fall. Many of the participants who reported have fallen within the last six months were enrolled in the interventions. For this reason, their performance may not have been truly characteristic of others who have a history of falls. The previous exercise history of the participants may be responsible for the low mean BMI (22.13), which was much lower than expected and indicates that the sample may have a higher physical fitness level than the national norm.

In relation to the data analysis, it is important to notethat Kaiser's criterion (used during the *PCA*) has been shown to overestimate eigen values and it is possible that fewer than five components could be used for analysis (Lance, Butts, & Michels, 2006). Under another interpretation of the results, as few as three components could be used, as opposed to five.

A further limitation was in the range in intra-participant effort and motivation. Participants were not informed of the precise scoring system of any of the assessments, for both the safety of the participant and for the integrity of the study. As a result, many participants may have believed time was the primary mode of scoring and they subsequently hurried through the assessments, resulting in lower performance scores.

Suggestions for Future Research

There is a discrepancy in the ability of the MFOC's time score to show a difference in fallers and non-fallers, between the current and previous studies. Future research should determine the measurement parameters necessary to successfully utilize the time score. For example, is timing each individual obstacle more predictive of fall risk over a simple time-to-completion?

While this study began the process of reviewing the principal components of the MFOC, future research needs to be conducted to take this process further, including a more detailed and conclusive outline of the exact measurement constructs of the MFOC components analyzed in this study via principal component analysis. *PCA* is an exploratory process and does not represent conclusive evidence. Future research should work to further detail the measurement constructs of the MFOC. This will help to increase the clinical applicability of the MFOC, as it will provide more information to the researcher/practitioner using the assessment, regarding the "take-home message."

Further research on the measurement construct of the MFOC should examine, specifically the nature of the environmental components. There is currently no research that indicates whether the obstacles (chair, foam bolster, door, and the carpet task) represent environmental obstacles better than the other eight in the MFOC. *PCA* indicated that they represent unique constructs, and future studies should focus on the exploration of the nature of these constructs.

A better understanding of the mechanisms being measured will provide a more detailed view of the fall risk pathology. The concept of the MFOC was to provide a screening assessment for fall risks that measures the sum impact of a variety of fall-related mechanisms. Future research, now, can look at whether the MFOC can discriminate between these mechanisms. In this way, the assessment will provide both a broad (holistic) measurement, as well as provide a practitioner with a more detailed outline of an individual/participant's fall-related pathologies.

Conclusion

This chapter covered the major findings of the study, which included the construct validity of the MFOC ($r(63) = .75\text{-}.76$, $p < .05$) and a discussion of the findings from the principal component analysis (*PCA*). *PCA* showed several distinct measurement constructs, including several that are not represented in the ABC, DGI, and TBT.

In conclusion, with a moderate to high construct validity and high test re-test reliability ($r(30) = .99$, $p < .05$) and internal consistency, the MFOC is a valid instrument to screen for fall risks in older adults, and is represented by distinct measurement constructs.

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APPENDIX A

Modified Functional Obstacle Course Scoring

Appendix A) Modified Functional Obstacle Course Scoring

Scoring is divided into two separate categories: a) Time to complete an obstacle, b) and performance. Time is the total time (in seconds) the participant requires to complete the entire course. Time begins at the moment of introduction and with a verbal "begin." Time ends when both feet are firmly planted on the ground after the last obstacle (decline ramp).

A performance score (0-3) is given for each obstacle, with the total score summed at the end. The details of providing performance scores for each obstacle are listed below. Performance scoring is measured while any portion of the participant's feet or hands are in contact with the obstacle, with the exception of the stairs and ramp obstacles (incline and decline). Instructions for when to begin and end performance scoring for these obstacles is listed below in **bold**.

Use the lowest score received for each obstacle. This is indicates the score for the obstacle. For example, in the first obstacle "stand from a chair," if a participant first uses one hand for support and then two; mark the score as 1 not 2. Wait until the participant has cleared the specific obstacle before scoring.
Instruct participant on how the obstacle course is performed and scored; including details on performance scoring and time

Ask participant to sit in the chair (first obstacle) and ask them to make a clear verbal sign when they are ready to begin.

After confirmation from participant Say "Begin." Begin timing at this point

Stand From Chair		
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Needs support to get up from the chair with two hands=**1** Needs support to get up from the chair with one hand=**2** No difficulty standing from chair, or walking to next obstacle=**3**	Score

Door Opening		
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Difficulty opening door; uses other h and for support or cannot clear doorway before *the* closing door swings back = 1 Minor difficulty opening door or clearing doorway ***in*** time =**2** No difficulty opening door or clearing doorway = **3**	Score

Artificial Turf		
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Hands actually touch *the* wall/person/object and/or are used for support after both feet are on *the* artificial turf or for 50 percent or more of *the* time = **1** Hands touch only when entering/exiting artificial turf or for <50 percent of *the* time = **1.5** Arm(s) abducted/elevated *in* "guarding" position but not touching *the* wall/person/object; and/or irregular body motion after both feet are on *the* artificial turf; or >50 percent of *the* time = **2** Guarding or irregular motion only when entering/exiting *the* artificial turf for <50 percent of *the* time = **2.5** Arms at sides; no touching of *the* wall/person/object; smooth motio*n* = **3**	Score
Foam Bolsters		
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Touches any object while attempting *to* step over = **1** Excessively high stepping (heel elevates beyond *the* opposite mid-tibia); or circumduction, but no foot-object contact =**2** Adequate clearance (heel below opposite mid-tibia); no touching = **3**	Score
Carpet		
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Hands actually touch *the* wall/person/object and/or are used for support after both feet have touched *the* carpet or for 50 percent or more of *the* time = **1** Hands touch only when entering/exiting carpet or for <50 percent of *the* time = **1.5** Arm(s) abducted/elevated *in* "guarding" position but not touching *the* wall/person/object; and/or irregular body motion after both feet are on *the* carpet or >50 percent of *the* time = **2** Guarding or irregular motion only when entering/exiting carpet for <50 percent of *the* time = **2.5** Arms at sides; no touching of *the* wall/person/object; smooth motio*n* = **3**	Score
Steps (ascending) **End scoring when participant enters landing**		
Performance Score	Participant refuses or is unable *to* complete this statio*n* = 0 Two or more of *the* following: hands touch railing; hands used for support unsteady, or apprehensive motion; "single stepping"(= trailing foot comes up *to* same step as lead foot) simultaneously or when going up and dow*n* = **1**	

	Two or more of *the* above occur but NOT simultaneously; or when going up or down, but not both = **1.5** Either hands make only initial contact with railing; or irregular motion with "single stepping" when going up and dow*n* = **2** Above occur(s) but only when going up or down, but NOT both = **2.5** No hands on rails; alternate stepping (trailing foot advances *to* step beyond lead foot) [No errors] = **3**	Score
	Steps (descending) **Begin scoring when participant exits landing**	
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Two or more of *the* following: hands touch railing; hands used for support; unsteady motion or hesitation; "single stepping" pattern (= trailing foot comes up *to* same step as lead foot before another step is taken) = **1** Two or more of *the* above occur but NOT simultaneously or when going up or down, but not both = **1.5** Either: hands make only initial contact with railing; or irregular motion or "single stepping" [One error only] – **2** Either: hands make only initial contact with railing; or irregular motion or "single stepping" [One error only] - 2 Above occur(s) but only when going up or down, but NOT both = **2.5** Smooth descent and arising; no use of upper extremities for support [no errors] = **3**	Score
	Pine Cones	
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Foot or assistive device touches any line; and touches cone(s) = **1** Foot or assistive device touches any line OR cone(s) [Not both] = **2** Feet and assistive device remains within lines; cones untouched [No errors] = **3**	Score
	Pine Bark	
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Hands actually touch *the* wall/ person/object and/or are used for support after both feet are *in the* pine bark or hands touch for >50 percent of *the* time = **1** Hands touch only when entering/exiting pine bark for >50 percent of *the* time = **1.5** Arm(s) abducted/elevated *in* "guarding" position but not touching *the* wall/person/object; and/or irregular body motion after both feet are *in the* bark for >50 percent of *the* time = **2**	

	Guarding or irregular motion only when entering/exiting bark for <50 percent of *the* time = **2.5** Arms at sides; no touching of *the* wall/person/object; smooth motio*n* = **3**	Score
	Sand	
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Hands actually touch *the* wall/person/object and/or are used for support after both feet are *in the* sand or hands touch for >50 percent of *the* time = **1** Hands touch only when entering/exiting and/or for <50 percent of *the* time = **1.5** Arm(s) abducted/elevated *in* "guarding" position but not touching *the* wall/person/object; and/or irregular body motion after both feet are *in the* sand and/or for >50 percent of *the* time = **2** Guarding or irregular motion only when entering/exiting sand for <50 percent of *the* time = **2.5** Arms at sides; no touching of *the* wall/person/object; smooth motio*n* = **3**	Score
	Ramp (incline) **End scoring when participant reaches landing**	
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Hands actually touch *the* wall/ person/object and/or are used for support >50 percent of *the* up-ramp = **1** Hands touch only when entering ramp or when exiting; or for <50 percent of *the* up-ramp **= 1.5** Arm(s) abducted/elevated *in* "guarding" position but not touching *the* wall/person/object; and/or irregular body motion >50 percent of *the* up-ramp = **2** Guarding or irregular motion only when entering ramp or turning; or for <50 percent of *the* up-ramp = **2.5** Arms at sides; no touching of *the* wall/person/object; smooth motio*n* = **3**	Score
	Ramp (decline) **Begin scoring when participant exits landing**	
Performance Score	Participant refuses or is unable *to* complete this statio*n* = **0** Hands actually touch *the* wall/person/object and/or are used for support = **1** Hands touch only when entering or exiting ramp; or for <50 percent of *the* down ramp = **1.5** Arm(s) abducted/elevated *in* "guarding" position but not touching *the* wall/person/object; and/or irregular body motion >50 percent of *the* down ramp = **2** Guarding or irregular motion only when entering or exiting ramp; or for <50 percent of *the* down ramp = **2.5** Arms at sides; no touching of *the* wall/person/object; smooth motio*n* = **3**	Score

End timing when both feet are planted on the ground		Time:
	Sum of all scores:	

(Adapted, with permission, from Means, MD and O'Sullivan EdD, [2000])

APPENDIX B

Activities-Specific Balance Confidence Scale (ABC)

Appendix B) Activities-Specific Balance Confidence Scale (ABC)

For each of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale: 0% 10 20 30 40 50 60 70 80 90 100% (No confidence to completely confident)

	0% 10 20 30 40 50 60 70 80 90 100% (No confidence to completely confident)
Walk around the house?	
Walk up and down stairs?	
Bend over and pick up a slipper from the front of a closet floor?	
Reach for a small can off a shelf at eye level?	
Sit and on your tip toes and reach for something above your head?	
Sit and on a chair and reach for something?	
Sweep the floor?	
Walk outside the house to a car parked in the driveway?	
Get into or out of a car?	
Walk across a parking lot to the mall?	
Walk up or down a ramp?	
Walk in a crowded mall where people rapidly walk past you?	
Are bumped into by people as you walk through the mall?	
Step onto or off of an escalator while you are holding on to a railing?	
Step onto or off an escalator while holding onto parcels such that you cannot	
Hold onto the railing?	
Walk outside on icy sidewalks?	
Total of percentages	

(Adapted from Powell &Myers [1995])

APPENDIX C

Tinetti Balance Test

Appendix C) Tinetti Balance Test

Balance:
Instructions: Seat the subject in a hard armless chair. Test the following maneuvers. Select one number that best describes the subject's performance in each text and add up the scores at the end.

Balance Tasks

Task	Description of Scoring	Point for task	Score
Sitting Balance	Leans or slides in chair	0	
	Steady, safe	1	
Rises From Chair	Unable to stand without help	0	
	Able, but uses arms for help	1	
	Able, with no arms used for help	2	
Attempt to Rise	Unable to rise without help	0	
	Takes at least two attempts to rise, but does fully rise	1	
	Able to rise on first attempt	2	
Immediate Standing Balance (first five seconds)	Unsteady (swaggers, moves feet, trunk sway)	0	
	Steady but wide stance (medial hills >4 inches apart) and uses cane or other support	1	
	Steady	2	
Nudged (subject at max position with feet as close together as possible, examiner LIGHTLY pushes on subject's sternum with palm of h and three times	Begins to fall	0	
	Staggers, grabs, catches self	1	
	Steady	2	
Eyes closed (at maximum position #6)	Unsteady	0	
	Steady	1	
Turn 360 degrees	Discontinuous steps	0	
	Continuous steps	1	
	Unsteady (grabs, swaggers	0	
	Steady	1	
Sitting Down	Unsafe (misjudged distance, falls into chair)	0	
	Uses arms, or not a smooth motion	1	
	Sade, smooth motion	2	

Total Points Possible/ Balance Score	***14*** /

Gait: Instructions: The subject stands with the examiner and then walks down hallway or across room, first at the usual pace and then back at a rapid but safe pace, using a cane or walker if accustomed to one.

Gait Tasks			
Task	Description of Scoring	Point for task	Score
Initiation of gait (immediately after told to "go")	Hesitation	0	
	No hesitation	1	
Step Length and Height	Right swing foot does not pass left stance	0	
	Right foot passes left stance foot	1	
	Right foot does not completely clear floor	0	
	Left swing foot does not pass right stance foot with step	1	
	Left foot passes right stance foot	0	
	Left foot does not completely clear floor	1	
	Fails to pass right stance foot with step	0	
	Left foot completely clears floor	1	
Step Symmetry	Right and left step length approximately not equal	0	
	Right and left step length appear equal	1	
	Staggers, grabs, catches self	0	
Step Continuity	Stopping or discontinuity	1	
	Steps appear continuous	2	
Path (Observe excursion of either left or right foot over about 10 feet of the course)	Marked deviation	0	
	Mild/Moderate deviation (or requires walking aid)	1	
	Straight gait, no deviation	2	

Trunk	Marked sway (or requires walking aid)	0	
	No sway but flexion of knees or back, or spreads arms out while walking	1	
	No sway, no flexion, no use of arms and no use of walking aid	2	
Walking Stance	Heels apart	0	
	Heels almost touching while walking	1	
Total Points Possible/ Gait Score			***12***
Total Points Possible/ Balance + Gait Score			***26***

(adapted from Raiche, Hebert & Price [2005])

APPENDIX D

Dynamic Gait Index Scoring

Appendix D) Dynamic Gait Index Scoring

Task	Instructions	Scoring	Points	Score
Gait Level Surface	Walk at your normal speed from here to the next mark (20').	**Normal:** Walks 20', no assistive devices, good speed, no evidence for imbalance, normal gait pattern.	3	
	Grading: Mark the lowest category that applies.	**Mild impairment:** Walks 20'	2	
		Moderate impairment: Walks 20'	1	
		(**Severe impairment:** Cannot walk 20' without assistance	0	
Change In Gait Speed	Begin walking at your normal pace (for 5'), when I tell you "go," walk as <u>fast</u> as you can (for 5'). When I tell you "slow," walk as <u>slowly</u> as you can (for 5').	**Normal:** Able to smoothly change walking speed without loss of balance or gait deviation. Shows a significant difference in walking speeds between normal	3	
		Mild impairment: Able to change speed but demonstrates mild gait deviations	2	
		Moderate impairment: Makes only minor adjustments to walking speed	1	
		Severe impairment: Cannot change speeds, or loses balance and has to reach for wall or be caught	0	
Gait With Horizontal Head Turns	Begin walking at your normal pace. When I tell you to "look right," keep walking straight,	**Normal:** Performs head turns smoothly with no change in gait.	3	
		Mild impairment: Performs head turns smoothly with	2	

	but turn your head to the right. Keep looking to the right until I tell you "look left," then keep walking straight and turn your head to the left. Keep your head to the left until I tell you, "look straight," then keep walking straight but return your head to the center.	slight change in gait velocity (*i.e.*, minor disruption to smooth gait path or uses walking aid).		
		Moderate impairment: Performs head turns with moderate change in gait velocity, slows down, staggers but recovers, can continue to walk.	1	
		Severe impairment: Performs task with severe disruptions of gait (*i.e.*, staggers outside 15° path, loses balance, stops, reaches for wall).	0	
Gait With Vertical Head Turns	Begin walking at your normal pace. When I tell you to "look up," keep walking straight, but tip your head and look up. Keep looking up until I tell you "look down," then keep walking straight and turn your head down. Keep looking down until I tell you, "look straight," then keep walking	**Normal:** Performs head turns with no change in gait.	3	
		Mild impairment: Performs task with slight change in gait velocity (*i.e.*, minor disruption to smooth gait path or uses walking aid).	2	
		Moderate impairment: Performs tasks with moderate change in gait velocity, slows down, staggers but recovers, can continue to walk.	1	
		Severe impairment: Performs task with severe disruption or gait (*i.e.*, staggers outside 15° path, loses balance, stops reaches for wall	0	

	straight but return your head to the center			________
Gait and Pivot Turn	Begin walking at your normal pace. When I tell you to "stop and turn," turn as quickly as you can to face the opposite direction and stop	**Normal:** Pivot and turns safely within 3 seconds and stops quickly with no loss of balance.	3	________
		Mild impairment: Pivot turns safely in >3 seconds and stops with no loss of balance.	2	________
		Moderate impairment: Turns slowly, requires verbal cueing, requires several small steps to catch balance following turn and stop.	1	________
		Severe impairment: Cannot turn safely, requires assistance to turn and stop.	0	________
Step Over Obstacle	Begin walking at your normal speed. When you come to the shoe box, step over it, not around it and keep walking.	**Normal:** Able to step over box without changing gait speed; no evidence for imbalance.	3	________
		Mild impairment: Able to step over box, but must slow down and adjust steps to clear box safely.	2	________
		Moderate impairment: Able to step over box but must stop, then step over. May require verbal cueing.	1	________
		Severe impairment: Cannot perform without assistance.	0	________
Step Around Obstacles	Begin walking at your normal speed. When you come to the	**Normal:** Able to walk around cones safely without changing gait speed; no evidence of imbalance.	3	________

	first cone (about 6' away), walk around the right side of it. When you come to the second cone (6' past first cone), walk around it to the left.	**Mild impairment:** Able to step around both cones, but must slow down and adjust steps to clear cones.	2	______
		Moderate impairment: Able to clear cones but must significantly slow speed to accomplish task, or requires verbal cueing.	1	______
		Severe impairment: Unable to clear cones, walks into one or both cones, or requires physical assistance.	0	______
Stairs	Walk up these stairs as you would at home (*i.e.*, using the rail if necessary). At the top, turn around and walk down.	**Normal:** Alternating feet, no rail.	3	______
		Mild impairment: Alternating feet, must use rail.	2	______
		Moderate impairment: Two feet to stair, must use rail.	1	______
		Severe impairment: Cannot perform safely.	0	______
			Points Possible/Total of Score	***24*** /

(Adapted from Shumway-Cook A, Wollacott M [1995])

APPENDIX E

Recruitment Flyer

Appendix E) Recruitment Flyer

Participants Needed

Background

Research participants are needed to help conduct a study that is looking at the ability of a new testing method to determine whether an older adult is at risk of falling. Participation is completely free and only requires about three hours of your time over two to three visits.

Eligibility

Participants must be at least 65 years old and have a signed approval from a health care provider to participate in the study.

Benefits

Participants will be provided with a comprehensive fall-risk assessment free of charge.

Boise State University
Kinesiology Department

CONTACT- 208-841-7457

www.fall-risk.org

APPENDIX F

Telephone Script

Appendix F) Telephone Script

Hello. My name is Daniel Gragert and I am a graduate student at the Boise State University Kinesiology Department. We currently have a study you previously expressed interest in. If you have some time, I would like to explain the study to you. Do you have a few moments right now?

If no:

Okay, is there a day and time when I can call you back? Date:_______ Time:_________

Thank you for your time.

If yes:

Great! Thank you for your time, this won't take long.

This study is part of our research about a new diagnostic method for older adult fall risks. This study involves testing a new assessment tool that resembles a short obstacle course for diagnosing fall risks. If you choose to participate you will be asked to come to an initial meeting in which we will discuss a few details of the study and provide you with an informed consent and a consent to participate that needs to be signed by your primary health care provider. In addition to the signed consent forms we will also have you fill out a quick form called the physical activity readiness questionnaire. If you choose to participate we will collect the signed consent forms and schedule your meeting times.

You will be asked to come to campus four separate times for testing. The first time will take about two hours and the next three will take about one and half hours. During the first session we will ask you to perform four assessments that take about fifteen minutes, each, to complete. During the next three sessions you will only perform three of these first tests. For each testing session you will be testing with another participant. As he or she performs the assessment you will be provided time to rest and socialize and vice-versa.

At your request we will provide you with the scores of any assessment you like. All of your information will kept in a locked filing cabinet that can only be accessed by necessary staff members.

Do you have any questions at this moment?

Is this something you may be interested in?

If no:

Thank you for your time and I hope you have a good day. If you have any questions you can contact me at 208-841-7457

If yes:

Great! The first session is_________ at the _________ from ________ to_______. I look forward to seeing you there.

Do you have any questions at this moment?

If you'd like, I can email you a breakdown of what we will be doing the day of the study. Would you be interested in that?

Thank you for your time today as well as your willingness to be a part of our study. Please to not hesitate to contact me if you have any further questions or concerns. Again, my name is Daniel Gragert and I can be reached at 208-841-7457. Thank you for your time and I look forward to meeting you.