# COMMUNITY MULTIDIMENSIONAL FALL RISK SCREENING

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by
CARMEN CASANOVA ABBOTT

Dr. Alex Waigandt, Dissertation Supervisor

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The undersigned appointed by the Dean of the Graduate School, have examined the dissertation entitled

COMMUNITY MULTIDIMENSIONAL FALL RISK SCREENING

Presented by Carmen Casanova Abbott

A candidate for the degree of Doctor of Philosophy

And hereby certify that in their opinion it is worthy of acceptance.

Professor Alex Waigandt

Professor Steven Osterlind

Professor David Bergin

Professor Marybeth Brown

Professor Marilyn Rantz

*……..to Pete, Jonathan, and Katie*

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ABSTRACT

O**bjective:** The purpose of this study was to compile a multidimensional fall risk screening tool that would be used to establish preliminary reference values for modifiable fall risk factors tested in independent community dwelling adults. Research hypotheses were investigated to determine if there would be significant differences in testing due to aging factors prior to the age of 65. A secondary objective sought to determine if age group, sex and physical activity were predictive of total physical performance. **Methods:** Evidence based compilation of a 16 component test multidimensional fall risk screen (MFRS) and subsequent community screenings of 190 adults aged 20-79 were carried out. Test results provided fall risk stratification of each participant. This cross sectional study utilized multivariate analysis and multiple regression to test the null hypotheses at p-values of <.01. **Results**: The MFRS proved to be an efficient measure of modifiable fall risk factors. Adults aged 20-79 demonstrated significant age related differences in physical performance on most of the component tests and on the MFRS total score of impairment. Sex and physical activity had a relationship to age associated changes but not as primary predictors. **Conclusions**: Community screening was able to identify fall risk and preclinical disability in young, middle aged and older adults. Fall risk stratification following routine multidimensional screening of modifiable physical fall risk factors can be used as a primary prevention strategy to provide the high functioning adult with information and direction on how to minimize impairments and age healthy.

# TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

# CHAPTER I

# Introduction

## Rationale for the Study

The United States population is aging rapidly. In 2004, one in eight Americans was 65 years or older; by 2020 the ratio is expected to be one in six. The number of fall related injuries will rise along with the rising numbers in the older age groups. Falls can be seen as markers of poor health, declining function and are associated with morbidity. Epidemiological reports point out that increasing numbers of adults over the age of 65 suffer falls, 30 percent of whom are community dwelling, and 50 percent are nursing home residents (Province et al., 1995). Falls are the leading cause of injury related visits to emergency departments (CDC, 2006).

Fall related injuries among older adults, especially among older women, present a significant economic burden to society. Fatal injuries in 2000 cost 0.2 billion dollars and non-fatal injuries totaled 19 billion dollars. Costs to the individual include significant morbidity, loss of independence, early admission to nursing homes, and mortality, as the result of fall related injuries. Falls are experienced by more than a third of older adults each year. Twenty to thirty percent of fallers suffer moderate to severe injuries that reduce mobility, independence, and increase risk of institutionalization and premature death. In 2002, over 12,900 older adults died as a result of falls (CDC, 2006; Tinetti, Liu, & Claus, 1993). Mortality rate for falls increases substantially with age in both sexes and all ethnic groups. Seventy percent of accidental deaths in the 75 or older have been related to falls (J. A. Stevens, Corso, Finkelstein, & Miller, 2006).

Approximately 40 percent of fall related injuries identified in acute care settings resulted in hospital admissions (Sattin, 1992). The most frequent fall related injuries include hip and wrist fractures, head trauma, and internal organ damage. In the older adult, 87 percent of fractures result from falls. Older adults who survive hip fractures experience great trauma from disability and loss of independence. Twenty five percent of hip fracture patients, who were independent community living adults, are discharged to a nursing home.

Nonfatal fall rates and hip fracture rates are higher in women (Grisso et al., 1991). Medical expenditures for women are 2-3 times higher than for men. Stevens reports fractures accounted for 35 percent of non-fatal injuries, but fractures incurred 61 percent of the medical costs. In adults 75 years and older, fallers are 4-5 times more likely to be institutionalized for a year or longer when compared to the younger decade age group (NCIPC, 2002).

Falls can cause people to lose confidence in their ability to function safely. Psychological trauma, another consequence of falling, causes loss of confidence and fear of falling which then leads to self imposed restriction of activity, precipitates loss of functional mobility, and eventually loss of independence (Tinetti, Speechley, & Ginter, 1988; Vellas, Caylov, Bucquet, de Pemille, & Albarede, 1987). Approximately 50 percent of individuals who fall admit to restricting activities, which leads to periods of immobility. Decreased activity level leads to physical complications similar to the aging process itself, e.g., muscle weakness, osteoporosis, and increased fall risk (Legters, 2002). Fall survivors experience a greater decline in activities of daily living (ADL), physical and social activities.

Research has identified fall risk factors that are predictive of future falls and fall related injuries. Risk factors have been identified from conceptual domains that have been demonstrated to be strongly associated with falls. These categories consist of: recent fall history; demographic characteristics; psychosocial characteristics; self perceived health status; physical activity; symptomatic risk factors; and physical performance risk factors from strength, power, balance, and mobility impairments (Covinsky et al., 2001; Tinetti et al., 1988). Impairments in the vestibular, somatosensory, and visual systems increase risk of falling.

Falls are described as being due to intrinsic and or extrinsic risk factors. Intrinsic fall risk factors are typically considered physiologic changes associated with aging, acute and chronic disease conditions, and the side effects of medications. Extrinsic risk factors refer to environmental hazards that create a risk for falling. Once a fall has occurred there is a significant increase in the fall risk (Robbins, Rubenstein, Schulman, Osterweil, & Fine, 1989; Rubenstein, 2006).

Anyone who has ever slipped on a patch of ice knows how unnerving it can be to lose your balance. Balance, the ability to control and maintain your body's position as it moves through space, is an integral, ever-present part of daily life to which most people rarely give conscious thought. Due to the complexity of balance, a systems approach to assessment of balance and mobility requires a variety of tests and measures to document functional abilities, determine underlying sensory, motor, cognitive, and psychological impairments contributing to falls and functional disabilities (Hu, Roth, & Ferrell, 1994).

Much of the deterioration in balance associated with aging is simply due to a sedentary lifestyle as well as fear of falling (Grisso et al., 1991; Legters, 2002; Tinetti, Mendes de Leon, Doucette, & Baker, 1994; Vellas et al., 1987). Most of the adult population in the United States is not active enough. Prevalence in meeting the minimum recommendations for physical activity decreased from 59.6 percent among younger adults to 39.0 percent among older adults (Haskell et al., 2007; Nelson et al., 2007; Pate et al., 1995). Evidence is present for a negative correlation between physical activity and fall risk. A study of 704 community dwelling women found that the individuals taking part in planned exercise and being active for seven or more hours each week had fewer falls (S. R. Lord, Ward, Williams, & Anstey, 1993). Physical activity levels for adults for the maintenance of health are well researched. Exercise guidelines for health and fitness have been developed by the American Heart Association and American Academy of Orthopaedic Surgeons. Specific prescriptions for regular strengthening, aerobic conditioning, and balance work are delineated for the older adult (Haskell et al., 2007; Nelson et al., 2007).

Intervention aimed at identified risk factors has proven to be effective. Research shows that balance exercises combined with strength training are associated with a decreased risk of falling. Studies demonstrated retention of balance abilities and decreased incidence of falls following these types of exercise with a six to nine month carry over into functional activities when exercise was stopped. Multifactorial assessment and targeted interventions for community dwelling older adults have shown a reduction in fall risk up to 39 percent, dependent on whether an adult has fallen once or more than once (Gillespie et al., 2003; Province et al., 1995; Shaw et al., 2003; Shumway-Cook, Gruber, Baldwin, & Liao, 1997; Steadman, Donaldson, & Kalra, 2003; Tinetti, Baker, McAvay, & Claus, 1996; Tinetti, Baker et al., 1994).

Identification of the cause of a fall is critical to prevention of future falls. A person experiencing several falls can attribute their postural instability to multiple impairments rather than one isolated deficit. Multiple impairments interact or have cumulative effects that lead to a fall (A. J. Campbell & Robertson, 2006). In order to identify all factors contributing to increased fall risk requires a systems approach. The more risk factors a person has, the greater the likelihood they will fall. Research has shown that if there are 4 or more fall risk factors present, there is a 78 percent chance of falling in an older adult (Studenski et al., 1994; Tinetti, Williams, & Mayewski, 1986). Fall risk screening earlier in the aging process can lead to identification of preclinical disability. Fall prevention strategies can then be utilized to reduce risk factors that are modifiable.

Falls and fall related injuries are a serious public health problem (Healthy People 2010). The incidence of falls and fall related injuries continue to increase as the population at highest risk is expanding and will sharply increase in the future. The increasing average age of adults sustaining a fall related injury is likely to present more difficulties in treatment and management because of increased personal, medical and societal costs. In addition to these concerns, older adults often do not report problems with gait, balance, and falls for fear of institutionalization. As a result, falls are under reported and may not be detected until after a preventable injury has occurred.

Government and professional fall prevention guidelines are available for the older adult population. Implementation of fall prevention methods remains limited in the United States (A. J. Campbell & Robertson, 2006). Prevention efforts need to be assimilated into primary care for the populations that are clearly at the highest fall risk. A need exists to be able to quickly screen at risk populations in order to focus primary prevention strategies that will diminish the number or severity of fall risk factors. Prevention strategies need to address younger age groups under 65 years of age; as age-related changes, sedentary lifestyles, preclinical disability and unreported difficulty with gait and mobility have been found to occur several decades earlier. Risk stratification across all adult age groups would be a logical strategy to use in primary and secondary prevention. Multidimensional fall risk screening and resultant targeted interventions have been shown to result in improved survival, reduced hospital and nursing home stays, and improved functional status (Province et al., 1995; Shumway-Cook, Brauer, & Woollacott, 2000; Tinetti, Gill, & Williams, 1995).

## Statement of the Problem

The focus of this study was specific to the compilation of individual fall risk tests into a multidimensional fall risk instrument that can be used to assess independent community dwelling adults 20-79 years of age. The instrument, called the Multidimensional Fall Risk Screen (MFRS) was derived from a review of evidence-based research literature on fall risk tests in use by health care practitioners and recommended for assessment of adult age groups. The study sought to identify a subset of modifiable risk factors / impairments associated with decline across domains of functioning that can precipitate falling and result in fall related injury. The MFRS was used across adult age groups starting with the young and middle aged, 20-50s, and extended into the older adult (60-79) decades. In order to identify the multiple factors contributing to fall risk, the MFRS is a multidimensional, with components of the screen used to assess major physiological systems and predictors of falls and fall related injuries. Administration of the screen can occur in a community or office setting, requiring minimal equipment, space, and time.

This study sought to develop a preliminary set of reference values across six age decades for the MFRS total score and for each of the six component tests. Fall risk stratification of the independent community dwelling adult can then be made from these reference values. Data analysis of the MFRS component test scores seeks to describe a trend of increasing fall risk that starts at ages earlier then 65 years of age. Preclinical disability will be identified by the multidimensional MFRS. Referrals can then be made for comprehensive evaluation and targeted intervention based on the fall risk stratification. Adults at low fall risk will be advised to follow general fall prevention guidelines. Current guidelines stress the importance of incorporation of interventions for the targeted deficits that have been identified during a routine screen. Cost effective fall prevention programs will need to be adopted at community levels to provide the means with which individuals decrease their risk of falling and sustaining fall related injuries as they age.

## Research Hypotheses

This investigation will test the following hypotheses:

$H_1$ The component tests scores on the MFRS will show age related differences across six adult decade age groups.

$H_2$ The mean MFRS total score will have a negative correlation with aging across the six adult decade age groups.

$H_3$ Sex and physical activity will have effect on the MFRS total scores.

## Delimitations

A convenience sample of independent community dwelling adults were recruited from the University of Missouri-Columbia campus and surrounding communities. These volunteers included 190 university faculty and staff, city, and county residents. This study administered the MFRS to a representative sample of both male and female adults ranging in age decades from 20 to 79 years of age. Each age cohort will contain approximately 30 subjects. Subject exclusion criteria consisted of significant cognitive, neurological, and orthopedic disabilities that disallow functional independence. Acute illness; unstable or limiting cardiac or pulmonary disease; and visual impairment which prevents person recognition at 10 feet also excluded participation in the study.

Components of the fall risk screen were chosen from known and reliable individual fall risk tests described in evidence based research literature in order to offer efficacious, multidimensional, and efficient testing. The domains that were examined included: functional vision, functional vestibular status, strength, power, mobility, static and dynamic balance, postural stability in transitional movements and functional performance. Impairments in these domains are modifiable risk factors. Multidimensional screening included the following tests: dynamic visual acuity, habitual gait speed, single leg stance, multidirectional reach, ankle dorsiflexion range of motion, timed up and go, timed sit to stand, and stance single heel rises.

The study will determine if there is an age related trend in fall risk predictors in the younger adult and middle aged decades. The scores from the components in fall risk screen were then used to determine a preliminary set of reference values by age decades.

Means, standard deviations and fall risk scores were derived to provide additional normative information across the adult age groups. The comprehensive nature of the age cohorts can add to the existing fall risk stratification body of knowledge.

## Limitations

The use of a sample of convenience for the study was not as powerful as randomization of subjects. The size of each age cohort was limited to approximately 30 subjects, the minimum number of subjects required for acceptable power of the statistical analysis. Many isolated tests and testing batteries for fall risk identification have been excluded from the MFRS. The objectives of keeping the screen simple, short, and specific to the independent community living adult required elimination of tests that are lengthy and that may have had a ceiling effect for the higher level physically functioning individual. Tests such as the Berg Balance Scale, Tinetti Performance Oriented Mobility Assessment, Dynamic Gait Index, and perturbation tests were not included as these tests have been reported to have a ceiling effect, although they are strong fall predictors in the already compromised adult. The major limitation of the study may have been that of subject motivation in performing to the best of their ability, especially during the test components that assess power.

## Basic Assumptions

Balance testing must incorporate a diverse set of tests to comprehensively address the physiological systems that control postural stability. As functional capacity is one of the intrinsic fall risk factors, functional measures of daily activities must also be incorporated into a fall risk assessment. Testing should identify impairments and functional limitations leading to increased fall risk and a loss of independence. The test results can then be used to customize an individual's intervention program. Remediation in the visual, vestibular, and somatosensory areas will enhance the adult's physical capacity to maintain a moderately active lifestyle (Tinetti, Baker et al., 1994). If fall prevention strategies are not integrated into society, the deleterious effects of falls and resultant sedentary lifestyle will continue to increase morbidity, chances of institutionalization, and mortality rates in the older adult (Aoyagi & Shephard, 1992; Landi et al., 2004; Pate et al., 1995).

Early detection of fall risk factors and identification of physical impairments and functional limitations can minimize or prevent falls and the injuries associated with falls. Fall risk screening in the independent community dwelling middle aged adult and high functioning older adult will determine the presence of preclinical functional limitations. Targeted intervention of these impairments and functional limitations would allow for healthier aging, maintenance of an independent lifestyle and enhanced quality of life as the individual ages (A. J. Campbell & Robertson, 2006; Tinetti, Baker et al., 1994). Fall risk stratification at an earlier age will allow adults, as they age, to actively attend to their fall risk factors. Targeted multifactorial interventions for the community dwelling adult has been reported to decrease fall risk up to 39 percent and higher, depending on the intervention (Gillespie et al., 2004; Rand Report, 2003; Tinetti et al., 1996). The older adult's vulnerability to disease and injurious falls will be minimized by aging at a higher level of function, higher quality of life, and reduction in economic pressures (L. P. Fried, Bandeen-Roche, Chaves, & Johnson, 2000; Steadman et al., 2003) .

## Definition of Terms

The following terms are key words necessary to the understanding of this study and are defined as used in the study.

*Fall*. A fall is an unintentional change in position of the body resulting in coming to rest on the ground or a lower level.

*Physical activity.* Physical activity is defined as bodily movement that is produced by contraction of skeletal muscle that substantially increases energy expenditure.

*Therapeutic exercise*. Therapeutic exercise is described as planned, structured, and repetitive movement that is performed to accomplish specific outcomes.

*Impairment.* An impairment is described as a loss or deficit of mental, emotional, physiological, anatomical structure, or function e.g., muscle weakness, depression, pain, poor postural control.

*Functional limitation.* A functional limitation describes a restriction or lack of ability to perform an action or activity in the manner considered to be normal e.g., unable to dress or feed one self, unable to stair climb.

*Static balance.* Static balance is the ability to maintain the center of gravity in position when there is no movement e.g., standing in place on one leg.

*Dynamic balance.* Dynamic balance is the ability to maintain the center of gravity without loss of stability during movement e.g., marching in place.

*Systems testing*. Systems testing stimulates visual, vestibular, or somatosensory system input to determine if these systems are operational.

*Impairment testing.* Impairment testing determines what deficits are present in the systems that control balance, e.g., muscle weakness, loss of visual acuity during head movement.

*Functional testing.* Functional testing observes performance of whole body movements necessary to complete daily physical activities such as: sit to stand, walking, and stair climbing.

*Disability.* Disability refers to functional limitations that result from impairments that limit an individual's ability to function in society e.g., loss of the ability to walk fast enough to cross a street before a traffic light turns red.

*Primary prevention.* Prevention of disease in a susceptible population using health promotion and wellness models or strategies.

*Secondary prevention.* Prevention efforts to shorten duration, severity and complications of disease or illness; accomplished by prompt diagnosis and intervention.

## Significance of the Study

Fall related injury and death are significant national health concerns. These issues present growing and costly societal problems. Fall survivors experience a greater functional decline in activities of daily living (ADL), physical and social activities, and have a greater risk of subsequent institutionalization. Prevalence of falls and the resultant cascade of events that occur following a fall make this issue a high priority primary prevention objective in the United States.

Research has shown that fall related injuries are multifactorial in nature. Falls and resultant reduced mobility in community dwelling adults result from accumulated effects of intrinsic and extrinsic factors. Intrinsic risk factors are related to physical aging changes and disease. Extrinsic risk factors arise from environmental hazards. Identification of fall risk factors can be performed through self report health status questionnaires and physical performance testing. Evidence based literature consisting of random controlled trials in the areas of multifactorial fall risk assessment is available but the test batteries are typically long and not easily reproduced in a community setting.

Strategies for the prevention of fall related injury in the older adult population have been described by national and professional organizations. Routine fall risk screening is recommended for individuals 65 and older. Assessment and targeted intervention in the older adult age groups have been extensively studied and are recommended to follow, as indicated, routine fall risk screening (A. J. Campbell & Robertson, 2006; Province et al., 1995; V. J. Stevens, Hornbrook, & Wingfield, 1992; Tinetti et al., 1996).

Geriatric research describes the concept of preclinical disability occurring in independent community dwelling older adults who have not yet fallen. Physiologic changes associated with aging and subsequent development of impairments leading to falls begin to occur in adults that are younger than 65 years (Isles, Choy, Steer, & Nitz, 2004). Review of the literature points to the fact that early signs of impairment in the middle-aged adult and healthy older adult should be able to be identified and targeted for specific interventions. Currently, there are no guidelines to address these issues in the younger and middle-aged adult. Normative information in the areas of balance and physical performance are available for the older adult population. However, only fragmented normative information is available for younger and middle aged populations.

Aging changes related to fall risk, previously considered inevitable aging processes, are now being recognized as preventable or treatable.

The data from this study was analyzed to determine if functional changes related to strength, balance, and mobility occur in the younger and middle aged adult groups. This study identified preliminary reference values for a multidimensional fall risk screen that can be used for identification of physiological and functional impairments in younger and middle aged community dwelling adults. Fall risk stratification, a process that fits well as a strategy in fall primary prevention, can then be used to identify preclinical disability. Positive findings will be able to be used to initiate referrals for further testing and targeted interventions. Addressing fall risk factors in the younger age groups can target intervention of single impairments and thereby allow for healthy aging. Increased independence and higher quality of life can follow as the adult nears the older age groups where aging changes, lifestyle transitions, and chronic diseases significantly make the older adult more susceptible to falls and fall related injuries.

# CHAPTER II

# Review of the Literature

## Introduction

Review of the literature provided an understanding of falls as a serious health issue at individual and societal levels. Fall prevention as a primary prevention target will be presented by utilizing risk factor stratification across the adult life span. Evidence based rationale for multidimensional modifiable fall risk screening of adults younger than 65 years of age will be explored in this chapter. A systems review of the literature will follow that will delineate the primary systems that govern the ability to be physically active with minimal risk of falling. A battery of component tests will be compiled that will include assessment of evidence based domains in the area of mobility from each physiological system. Each test will be chosen for its efficacy in the area of fall risk assessment and identification of primary modifiable impairments and functional limitations. Simplicity of administration in the community will be a second determinant for inclusion in the test battery. Description from the review of literature of each component test will be outlined in terms of administration, purpose, domain, reference values, and statistical analysis in order to provide the efficacy of testing.

## Fall Demographics

Falls are the leading cause of unintentional injuries in the United States. These injury rates are highest in the older (over 65) and younger (0-14) age groups (CDC, 2006; Sterling, O'Connor, & Bonadies, 2001). Falls are seldom lethal but have debilitating long term effects for individuals and families. Significant social costs are spent in the form of lost work days, lost school days, and high healthcare costs. Falls are tracked annually by several national surveys; the National Health Interview Survey of US residents, the National Ambulatory Medical Care Survey of physicians, and the National Hospital Medical Care Survey from emergency and outpatient centers. Fall injuries constitute 36.2-45.7 percent of visits to health care providers (Runyan et al., 2005).

Falls are common and the leading cause of injury in older adults. Approximately one third of older adults will experience a fall annually. Twenty to thirty percent of these adults will sustain moderate to severe injuries which can lead to mobility limitations, nursing home admission, and an increased risk of mortality (CDC, 2006; National Blueprint, 2001; Tinetti, 1986). In 2003, the CDC reported that 13,700 adults 65 years and older died from falls. This same age group totaled at 1.8 million individuals who received treatment in emergency departments for nonfatal fall injuries. Individuals that fall are two to three times more likely to sustain a recurrent fall. The risk of falling is shown to have an exponential increase with aging. Gender differences exist for falls in the older age groups. Nonfatal fall injury rate for the female is 49 percent higher than the male. Fatal fall rates increased significantly in 1994 through 2003; mortality was 49 percent higher in the male gender. During 2001-2005, fatal fall rates increased significantly among both genders but continued to be higher in males. This upward trend was true of all ethnic backgrounds, with the white race experiencing the highest fatal fall rates. The increase in fatal fall rate during this period has been explained by two factors: increased longevity in our country with a resultant greater number of older adults living with chronic diseases, and the increased incidence of injurious falls. Survival after an injury related fall would be more difficult for this susceptible population (J. A. Stevens et al., 2006).

In 2006, the CDC analyzed data from the Behavioral Risk Factor Surveillance System (BRFSS). Interviews with 92,808 adults aged over 65 years were performed. The survey reported that 15.9 percent of the adults had had more than one fall in the previous three months; 23.1 percent reported falling three or more times. A fall related injury was reported in 31.3 percent of the fallers irrespective of age group. Most falls do not result in injury or lead to medical care. Previous falls do place an individual at an increased risk of recurrent falls. Studies have shown that older adults may not remember minor falls or are not willing to report falls due to embarrassment or fear of losing autonomy in their living situations. The actual fall figures are therefore underreported because of the difficulty with inability for comprehensive surveillance (Cummings, Rubin, & Black, 1990; M. C. Nevitt, Cummings, Kidd, & Black, 1989; Rubenstein et al., 2004; Tinetti et al., 1988).

Speechley et al (1991) in a study of 336 community older adults, observed incidence of falling as being the highest in the frail group (52 percent), and lowest in the vigorous group (17 percent). Groups were classified as frail or vigorous by physical, psychological, and demographic characteristics. Serious injury results occurred in 22 percent of the vigorous adult group and only six percent of the frail group. The vigorous group fall mechanisms describe displacement activities, environmental hazards, and stair climbing as circumstances leading to injury, all at a greater likelihood than in the frail group. Recommendation from this study stated that fall and injury prevention should target all adults, the active vigorous adult and the frail older adult.

## Fall Consequences

Stevens and Sogolow (2005) analyzed data from 22,560 emergency department cases made available through the National Electronic Injury Surveillance System (NEISS-AIP). The authors estimated that 1.64 million older adults were treated for fall related injuries within a twelve month period in 2001. Nonfatal unintentional fall related injuries included fractures, contusions and lacerations which made up three fourths of all these injuries. Approximately 70.5 percent of the cases were women. Women's fracture rate was 2.2 times higher than that for men. The most frequently injured body parts in the order of the greatest to the lower rates were the lower extremity, upper extremity and lower trunk. Hospitalization for the women was 1.8 times that for the men. Although the trend in hospitalizations for hip fractures has been consistently higher in women, in 2001, hospitalizations for women started to decline with the hip fracture rate in men over 80 years old increasing slightly as of 2003.

Fractures were the most common and the most expensive type of nonfatal injuries. Fractures accounted for 35 percent of nonfatal injuries, but 61 percent of the total costs of injury. Hip fractures, at 95 percent, presented as the most common fractures sustained from falls. Colle's wrist, spinal compression, and proximal humerus fractures follow hip fracture incidence. Hip fracture rates show an increase with age. In the United States, 44 percent of the direct health care costs for hospitalization are for hip fractures (CDC, 2006). Incidence of falls and severity of complications, resultant functional impairments and disability all increase with age. The costs of nonfatal fall injuries doubled between age group 65-74 and 75-84 (J. A. Stevens & Sogolow, 2005).

Injuries that represented the most common and most costly fatal fall injuries in 2000 were traumatic brain injuries (TBI) and injuries to the hip, legs, and feet. These injuries made up 78 percent of the fatalities and 79 percent of the costs incurred from fatal fall related injuries. Development of a pulmonary embolism has been found to be strongly associated with death following a fall related injury. Long lies on the floor after a fall can increase the risk for dehydration, rhabdomyolysis, renal failure, decubitis ulcer, and death (Moylan & Binder, 2007).

Fatalities from TBI are highest among the oldest old, adults aged greater than or equal to 85 years. In 2005, 7,946 fall related TBI deaths in the 65 and older adult group were recorded by the National Center for Health Statistics' National Vital Statistics System and the Agency for Health Care Research and Quality's Nationwide Inpatient Sample. Death from TBI make up more than half of the unintentional fall deaths in the U.S. Internal organ injuries precipitated 28 percent of fall related deaths and made up 29 percent of the costs. It is not completely clear as to the reason why older adults are dying from these injuries. In the TBI older adult, combined aging changes and medication effects contribute to fatal brain bleeds. Recurrent falls or resultant head injuries may alter the risk-benefit ratio of taking anticoagulants. The heightened risk of intracranial hemorrhage, with the most common being subdural hematoma, is a reason for reviewing indications for drugs and their dosages (Moylan & Binder, 2007; J. A. Stevens et al., 2006).

Severity of these brain injuries is not always apparent after the fall. Confusion, dizziness, and loss of consciousness develop over time, accompanied by signs and symptoms of progressive deterioration of neurological status. The majority of TBI patients were hospitalized for two days to two weeks. Hospital discharge data reveal that 46-51.5 percent of the TBI patients were transferred to intermediate or nursing home facilities. These figures and the resultant economic burden on society have continued to rise and are expected to increase significantly with the "graying of America" as the baby boomer generation reaches the susceptible older adult age groups (CDC, 2006; National Blueprint, 2001; Sattin, 1992; Thomas, Stevens, Sarmiento, & Wald, 2008).

Fall related injury severity was described by Sterling et al. Two age cohorts, greater than 65 and younger or equal to 65 years, were compared based on fall mechanism, injury severity score, and mortality. Falls were reported in 68 percent of the older group and in seven percent of the younger group (n = 1,512 trauma patients). Serious injury ocurred in 32 percent of the older group and 11 percent of the younger group. Same level injury resulted in more serious sequelae in the older age group, 30 fold more severe in the older age group. Frequency of fall related injuries for the older adult was greater in all areas of injury: head/neck (31 vs. 15 percent); chest (23 vs. 1 percent); and pelvic/extremity (27 vs. 15 percent). The older age group sustained the same severity of injury despite same or multilevel falls. Mortality due to falls was higher in the older group, and was seven times more likely to be the cause of death. Mortality due to same level falls was ten times more common in the older age group. From several studies it is apparent that severity and mortality are greater in the over 65 age group. Pattern of injury is also different between the younger and older age groups (Sterling et al., 2001; Wenjun et al., 2006).

Fall related sequelae in the older adult include longer recovery with resultant deconditioning and anxiety that decreases normal activity level due to a fear of falling again. The psychosocial consequences of falls, fear of falling and self imposed isolation, along with physical deconditioning, produce a cumulative effect that contributes to further deconditioning of all physiological systems. The consequences of falling continue to perpetuate into impaired gait and balance, continued loss of confidence, and further restriction of activity level. The National Health Interview Survey reports that falls account for 18 percent of the restricted activity days among older adults, the largest single cause of restricted activity. Decreased activity level in turn leads to physical deficits similar to the aging process itself, e.g., muscle weakness and osteoporosis. Physical inactivity is associated with greater loss in muscle strength and increased mortality (Metter, Talbot, Schrager, & Conwit, 2002; Paffenbarger et al., 1993). Fall survivors experience greater functional decline in activities of daily living (ADLs), physical leisure time pursuits, and social activities. Recurrent falls and serious injury become more likely to occur with the accumulation of these additional significant fall risk factors (Grisso et al., 1991; Rubenstein, 2006; Tinetti, 2003; Tinetti et al., 1988; Vellas et al., 1987).

Impaired gait and balance are major problems that evolve from restricted activity and loss of confidence in resuming an active lifestyle due to fear of falling. Gait deficits that may be seen are: increased variance in gait pattern, increased base of support; shortened strides and diminished gait velocity, and stiffer posture and clutching or grabbing for support. These gait abnormalities cause postural insufficiencies and balance deficits that interfere with maintenance of upright posture accommodation to perturbations that occur in daily life. These deficits are primary risk factors for decreased functional capacity, onset of disability, and premature mortality (L. P. Fried et al., 2000;

Maki, Holliday, & Topper, 1994; Montero-Odasso et al., 2005; Murphy, Williams, & Gill, 2002).

A study by Stevens et al, in 2006, provided national estimates of incidence and direct medical costs associated with fall related injuries among older adults in the United States. Data was used from the 2000 National Vital Statistics Systems, 2001 NEISS-AIP, 2000 Health Care Utilization Program National Inpatient Sample, and the 1999 Medical Expenditure Panel Survey. National fall related injury costs of over 31 billion dollars reported each year, in year 2000 dollars, have been cited in government CDC reports. These fall related injury costs do not take into account the long term sequelae of fall related injuries which include loss of independence, loss of confidence, susceptibility to recurrent falls, and increased mortality. Among older adults who sustained a fall related injury, 38 percent required assistance for ADLs and 58.5 percent of these elders have been estimated to continue to require assistance for at least an additional six months.

Economic costs associated with fall related injures in the United States are substantial. A breakdown of direct medical costs among adults over 65 years of age by Stevens, found that in 2000, point two billion dollars were spent for fatal falls and 19 billion for nonfatal fall related injuries. Of the nonfatal injury costs, the costs were 63 percent for hospitalizations; 21 percent for emergency room visits; and 16 percent for outpatient treatments. Medical costs for women, who made up 58 percent of the older adult population in 2000, were two to three times higher than for males for all the treatment settings. The direct medical costs cited in the literature for falls do not take into account for the costs associated with lost wages, caregiver assistance, adaptive equipment, insurance costs, and the reduced functional capacity and quality of life. These personal and societal consequences will profoundly affect activity and life style of the older adult, especially if the changes become permanent (J. A. Stevens et al., 2006).

## Fall Prevention

The focus of health promotion is to maintain a healthy, physically active lifestyle with the hope of preventing chronic disease and improving the quality of life. Leading causes of death and health indicators can be traced to lifestyle related problems. National initiatives, including funding of research, are a part of national prevention activities. Healthy People 2010, our national vision for improved health care, identified ten leading health indicators that are used to measure our country's health status. Physical activity and injury from falls are two of the health indicators. Healthy People 2010 challenges individuals, communities, and professionals to take on the national objectives to increase quality and years of healthy life.

Health care costs will continue to rise without major changes in the health of the older population. Containment of health costs will be related to how successful health promotion and primary prevention are in minimizing age-related impairments and preventing disease (Schneider & Guralnik, 1990).

### *Primary Prevention*

Demographic and epidemiological information is gathered from statistical searches conducted by the Centers for Disease Control and Prevention under the auspices of the Department of Health and Human Services. Prevention of falls is one of the strategies identified under unintentional injury prevention (NCIPC, 2002). Health promotion efforts attempt to take evidence-based recommendations and translate research into actual practice in the community. Evidence is present and acknowledged that falls can be predicted and can be consequences of key risk factors. Fall prevention trials have made strides in determining strategies and interventions that can modify fall risk factors and promote prevention of extrinsic risk factors and minimize development of intrinsic risk factors. Falls among community dwelling older adults can be significantly reduced (Close et al., 1999; Gillespie et al., 2004; Province et al., 1995; Sattin, 1992; Tinetti et al., 1996; Tinetti, Baker et al., 1994).

An objective of primary prevention is the identification of population groups at risk for conditions that are common, associated by morbidity, and where strategies can be identified to decrease the occurrence of the targeted condition. In the area of fall prevention, incidence of falls rises steadily from middle age until the number of falls peaks in individuals over 80 years of age (CDC, 2006; Wenjun et al., 2006). Falls and fall related injuries have been identified at the national level as primary prevention targets (AGS, 2001; Healthy  People, 2000; NCOA, 2005). Primary predictors have been identified that can be used for prevention strategies in individuals who have not yet developed the targeted conditions. There is a long list of fall predictors. Primary modifiable predictors include sedative use, fear of falling, and lower extremity strength and power deficits. These risk factors can be assessed and if present, targeted interventions to modify or eliminate them can be put in place (Lord, Menz, & Tiedemann, 2003; Province et al., 1995; Tinetti, S.K. Inouye, T. M. Gill, & J. T. Doucette, 1995).

Fall related injuries are a significant health problem. Falls related injuries are among the most frequent and preventable sources of morbidity, health care utilization, and functional decline among older adults. Short and long term morbidity, mortality, and a consequent demand for health care service place a burden on the individual, family and society. High frequency, rate of morbidity, and evidence of preventability make falling meet the criteria as a prevention area (Gillespie et al., 2003). Research has identified fall risk factors and interventions that can reduce falls and fall related injuries. Government guidelines; professional, medical, and rehabilitation organizations; and state initiatives recognize the problem of falls and the resultant consequences to the individual and to society. Best practice in the area of primary prevention points toward multifaceted approaches where there are community and senior based strategies to develop and initiate fall prevention plans. To ensure a multifaceted approach to assessment, referral and intervention, there has to be "buy in" by stakeholders from several professional groups e.g., physicians, pharmacists, and physical therapists (NCOA, 2005).

Primary prevention has not kept pace with what is known about falls and fall related injuries. Rubenstein et al. (2004) reports, in a systematic study to evaluate physician quality of care in a community setting, that about half of falls with injury or cases of multiple falls were never documented in senior medical records. Quality indicators were utilized to evaluate compliance with best practice guidelines. Overall, possible road blocks to current primary prevention efforts are: age, frailty, and shortest life expectancy of the highest risk population; personal behavioral changes that need to take place; and the lack of a delivery system in initiating fall risk prevention (Campbell & Robertson, 2006; Wenjun et al., 2006).

Fall prevention programs need to be coordinated using best practice guidelines that have been developed at national and state levels. Fall prevention, studied by the

Briggs National Quality Improvement /Hospitalization Reduction Study of 2006, has been defined as a strategy that uses specific interventions to help community dwelling adults avoid risk of falling in order to reduce hospitalizations. Fall prevention programs will need to take into account special needs of targeted adults. Younger adults must also be targeted by fall prevention efforts. Primary prevention in areas of smoking cessation, exercise promotion, alcohol consumption, and identification of preclinical disability can decrease the onset of chronic disease and thereby minimize development of fall risk factors. Programs will need to incorporate an interdisciplinary approach to planning, development and implementation. Strategies will need to be provided on how to change society's culture from a reactive to a proactive approach prior to fall incidence. Health care costs will continue to rise without major changes in the health of the older population. Containment of health costs will be related to how successful health promotion and primary prevention are in minimizing age-related impairments and preventing disease (HHQIOSC, 2007; NCOA, 2005; Schneider & Guralnik, 1990).

Dissemination and adoption of fall prevention strategies need to occur at the community and individual level in order to address all the areas necessary in primary prevention. Perception of falls as a health problem may promote increased awareness of personal risk and need for risk stratification. Some work has been done in this area. Braun, in 1998, reported that when community dwelling older adults were questioned regarding their perception of falls as a major health issue in our country, the subjects considered falls to be preventable. The older adults also understood the significance of fall related risk factors, but did not consider themselves to be susceptible to falling. Awareness of the consequences of falls and the need to take steps to reduce physical, behavioral, environmental and social risk factors are the first steps in health promotion and primary prevention (NCOA, 2005). The prevention program must personalize the fall consequences and intervention steps that need to be taken by each adult.

*Disablement Model*

The disablement model, first described by Nagi in 1964, provides an organizational framework for the relationship of disease, impairment, and functional limitations leading to disability. This process helps to explain how acute and chronic conditions effect deficits and affect functioning in specific physiological systems, mental states, and activities of daily living. A practitioner can follow sequential steps along the pathway from disease to disability. Evidence based research and pertinent data from an examination or screening process will assist in determining which impairments are most closely related to functional limitations and thus require targeted intervention. Application of the disablement model can address practical issues of care and prevention and thereby have an impact on health outcomes (Verbrugge & Jette, 1994).

Progression from a healthy state to disease, impairment, functional limitation, and eventually to disability should not be considered inevitable. Identification of disablement risk factors can slow or stop the disablement process. Primary and secondary prevention can be used to identify and ameliorate risk factors as they are responsible for predisposing an individual to fall and triggering a cascade of events leading to functional limitations and disability. The disablement model works well within the health promotion concept by providing the structure to develop focused interventions in an effective, efficient and cost containing manner.

*Preclinical Mobility Disability*

Preclinical or incident disability describes a state of diminished or altered function that falls between impairment and disability, similar to functional limitation. An individual may perceive a reduction in frequency of and, or, alteration in their approach to performing their ADLs, instrumental activities of daily living (IADLs), or in general mobility. The individual does not report difficulty with the actual task performance (L.P. Fried, Herdman, Kuhn, Rubin, & Turano, 1991; J. M. Guralnik et al., 2000; Simonsick et al., 2001). Fried et al., in 1996, described preclinical disability as a "progressive but unrecognized decline in physical function". Gradual physical decline due to aging precedes and can be predictive of the onset of clinically detectable physical function decline. Physical decline typically precipitated by disease and chronic conditions develops as one ages.

An individual may adapt to preclinical disability by taking longer to complete a task; task modification; or by decreasing how often a task is performed. Realization of an actual problem with function may not occur until functional dependence is present. Preclinical disability in younger adults or healthy older adults does not present one main problem within a single system; but several small deficits or impairments across multiple systems which eventually interact to produce instability. Each of these impairments is a risk factor for falls. In combination, these risk factors can precipitate a fall (Newton, 1997). Routine fall risk screening has been recommended as a strategy in assessing the presence of preclinical mobility impairment and functional limitations. Fall risk screening incorporating self report and physical measures is a strategy that would satisfy public health and primary prevention objectives in the area of fall prevention. (Brach, VanSwearingen, Newman, & Kriska, 2002; Covinsky et al., 2001).

Measures of physical function can predict future disability in older adults. Guralnik et al (1995) reported test scores from 1,122 subjects of lower extremity function which were highly predictive of subsequent disability four years later in community dwelling adults who originally reported independence in ADLs, stair climbing, and in being able to walk one half of a mile without difficulty. Adults with the lowest scores were 4.2 - 4.9 times more likely to incur a disability. Physical measures of standing balance, comfortable gait speed, and chair rising were used. The summary performance score in this study demonstrated a gradient risk of nursing home admission and mortality with a smaller lower extremity function score.

Mobility is considered to be an important outcome measure indicative of health outcome. Deficits in mobility are precursors for physical dependency. Objective measures of function can predict dependency. Fried, in 2000, reported that performance and self report measures are both strong and independent predictors of difficulty with mobility. These preclinical indicators identified subjects from a high functioning group of older women who were at a high risk of mobility difficulty. The study by Fried provides the first evidence for the predictive validity of self reported preclinical disability. Self report and selected performance measures can be sensitive to early changes in function in the high functioning community dwelling adult (J. M. Guralnik et al., 2000; S. R. Lord & Fitzpatrick, 2001). Preclinical disability, whether considered subclinical disease or abnormal aging, should be identified as early as possible. Risk stratification as a result of the identified impairments can help point towards targeted intervention. Remediation of impairments can minimize future disability. Susceptibility to falls and fall related injuries can be diminished  and thereby prevent significant sequelae in terms of personal and societal costs (Grisso et al., 1991; M. C. Nevitt, Cummings, & Hudes, 1991; M.C. Nevitt et al., 2003; Seeman et al., 1994; Speechley & Tinnett, 1991). The process of combining the disablement model with primary prevention helps to not only improve an individual's status but also assists with public health at a global level.

*Fall Risk Stratification*

Risk stratification is a concept in use for health promotion in several medical areas. Cardiovascular disease risk factor stratification is widely understood and used to determine level of care including referral to a physician and indication for pharmacological management. In the area of fall prevention, risk stratification has been studied and utilized for over 15 years. Evidence based threshold values for fall risk factors are present for the older population. Physical performance fall risk factor values are sparse in the literature, based only on specific and at times small populations, with most of the reference values present only for older adult groups (Covinsky et al., 2001; J. M. Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995; S. R. Lord & Fitzpatrick, 2001; Pluijm et al., 2006; M. E. Tinetti, S. K. Inouye, T. M. Gill, & J. T. Doucette, 1995).

Fall risk stratification has been studied in the older adult by many researchers using a simple mobility screen or risk index (Covinsky et al., 2001; Cwikel, Fried, Biderman, & Galinsky, 1998; Studenski et al., 1994; Tromp et al., 2001). Stratification is usually categorized as high or low fall risk or faller-nonfaller designations are used. Pluijm et al, in 2006, report from a three year prospective cohort study of 1,365 community dwelling persons, aged 65 years and older that specific risk profiles can be developed from fall risk factors for recurrent falls and fall-related fractures. Functional limitation was found to be the only significant predictor of fracture risk. Risk indices that have been developed include performance tests for mobility, static and dynamic balance, and upper and lower extremity impairments (S. R. Lord & Fitzpatrick, 2001; Maki et al., 1994; Robbins et al., 1989; P. A. Stalenhoef, Diederiks, Knottnerus, Kester, & Crebolder, 2002; Studenski et al., 1994; M. E. Tinetti et al., 1995). Other domains included in these indices include fall history, demographic and psychosocial characteristics, health status, and physical activity.

A fall risk index used by Covinsky et al, in 2001, on 557 elderly community dwelling individuals is an example of fall risk stratification. Three easily screened risk factors were used to identify adults at high risk for falling over the following year. The risk factors were: a fall in the previous year; presence of a symptom suggestive of a high risk of falling, for example balance difficulty or dizziness; and, abnormal mobility picked up from a physical examination. Risk scores ranged from 0 to 5; a score of 5 being the highest risk designation. Positive fall history and abnormal mobility each earned two points and the presence of symptoms of unbalance or dizziness each received one point.

The wide variety of fall risk tests need validation in other populations before they are suitable for widespread risk stratification use. Validation in the general adult population would be needed in a major primary prevention effort. Fall risk stratification of younger adults would require similar simple and easy to administer risk indices as can be found in the older adult age groups. Tests that do not have a ceiling effect for the younger or more mobile older adults need to be used in the screening across all adult age groups. The evidence already exists that stratification would be an effective fall prevention strategy. Intervention studies have shown that interventions targeted at specific fall risk factors can reduce the risk of falling by 10 to 39 percent (Close et al., 1999; Gillespie et al., 2003; Rand Report, 2003; J. A. Stevens et al., 2006; Tinetti, Mendes de Leon et al., 1994).

*Fall Prevention Guidelines*

Current practice in the area of falls in the older adults focuses on fall related injuries. Minimal attention is given the underlying cause and functional consequences of the fall. Future fall prevention in the faller and in the individual who has not yet fallen is not routinely instituted. The American Geriatric Society, British Geriatric Society, and American Academy of Orthopaedic Surgeons published fall prevention recommendations in 2001.This panel developed guidelines for physicians that included asking their older patients for a fall history within the past year and a provision of a physical performance test, in most recommendations the Timed Up and Go Test, to assess mobility and lower extremity strength. A referral to a physical therapist or gerontologist to perform a complete evaluation would follow if there was a history of a fall, recurrent falls, or gait and balance impairments.

A fall evaluation would include a description of the circumstances prior to the fall including associated symptoms. The examination should include a review of medications and a review of systems. Cognitive, visual, cardiac, musculoskeletal, and neurological and syncope testing should take place. Mobility and functional status will be assessed by the performance of a couple of balance and functional tests, e.g., Single Leg Stance, and the Timed Up and Go test. Preliminary recommendations in the area of laboratory testing and diagnostic evaluation includes: blood count, thyroid function, electrolytes, blood, urea, nitrogen, creatinine, glucose, and vitamin $B_{12}$ levels. Differential diagnoses of anemia, dehydration, hypoglycemia, or hyperglycemia will assist in understanding the symptoms precipitating the fall incident.

National and professional organizations' recommendations incorporate a multifactorial evaluation followed by targeted intervention for identified fall risk factors in their best practice guidelines (AGS, 2001; NCOA, 2005). This sequence has been found to be the most effective strategy for fall prevention (Bottomley & Lewis, 2003; Close et al., 1999; Tinetti, Baker et al., 1994; E. H. Wagner et al., 1994; Wagner M.D., 1994). A routine fall risk screen is at the beginning of all the outlined fall identification measures.

Several government, professional organizations, and prominent researchers have developed similar algorithms that outline the approach to fall prevention in older adults (AGS, 2001; Moylan & Binder, 2007; NCOA, 2005; Tinetti, 2003). The routine fall screen should look for potentially modifiable risk factors. Multifactorial interventions have been shown to prevent falls in cognitively normal older people living in the community, and in those individuals who present to an emergency department following a fall. Several clinical studies have reported a drop of 25 to 40 percent in the fall rate among older community dwelling adults assigned to intervention groups when compared to control groups (Tinetti, Baker et al., 1994; E. H. Wagner et al., 1994; Wolf, Barhart, & Kutner, 1996).

## Fall Risk Factors

Evidence based literature concludes that falling results from the interaction or cumulative effect of multiple risk factors. Analyses of fall predisposing factors has determined that greater than 60 percent of falls in the older population result from interacting factors (A. J. Campbell & Robertson, 2006; M. C. Nevitt et al., 1989). Risk factors have been categorized as extrinsic, intrinsic, and behavioral in origin. A history of a single fall or occasional falls suggests extrinsic factors due to environmental hazards that are usually at the root of the fall, while recurrent falls are the result of intrinsic factors such as chronic disease and physical impairments. The single fall has not been associated with increased functional disability. Recurrent falls are significant predictors of disability (Dunn, Rudberg, Furner, & Cassel, 1992). A history of recent falls or status post hospitalization also predispose an adult to falling. Three or more falls imparts a greater risk for hip fracture (M. C. Nevitt et al., 1991). Studies have reported a three percent risk with no risk factors compared to 84 percent risk with the presence of five risk factors. The number of risk factors, whether it be greater than three, four, or five, is an additional statistically significant risk factor (Graafmans et al., 1996; Luukinen, Koski, Laippala, & Kivela, 1995; Tinetti, Baker et al., 1994; Tinetti et al., 1988).

Identification of those at risk for injurious falls requires an understanding of what kinds of falls result in injury and fracture. In a large study of 2,193 middle-aged and older adults, Wenjun et al report that falls occur more often outdoors among most of the age groups. Subjects who reported more leisure time activity had a higher risk for outdoor falls. Subjects in poorer health had a greater risk of indoor falls. Environmental factors such as uneven surfaces, sidewalks, curbs, and parking lots precipitated tripping and slipping as mechanisms of injury in 73 percent of the outdoor falls. Walking was reported to be the most common fall related activity at 47.3 percent for all groups except for the middle aged group. Adults in the younger age groups, 45-49 and 50-54, were most likely to fall while engaged in a vigorous activity. Falls occurred most often on a hard surface in a forward or sideways direction in both men and women. The third most common fall direction for the men was backwards and for the women the straight down direction. Analysis of risk factor profiles between the indoor and outdoor fall groups showed significant differences in the two groups. A higher level of physical activity was the independent predictor of outdoor falls, where as health related and physical problems were the independent predictors of indoor falls. Common independent predictors for both groups of fallers included lower extremity neuromuscular deficits, use of walking aids, cigarette smoking, and alcohol consumption. The overall recommendation from several studies notes that fall prevention should take into account the physically active adult whether they are middle aged or older adult (Sattin, 1992; Wenjun et al., 2006).

Intrinsic risk factors have been identified that impair the sense of balance and contribute to falls. Balance and gait characteristics such as unsteadiness during stand to sit, turning, sternal nudge, and single leg stance are associated with increased risk for falling (Tinetti et al., 1988). Among community dwelling older adults, muscle weakness or gait and balance disorders increase the risk of falling by three to four times (AGS, 2001). Mobility restrictions in the spine and neck, functional limitations in activities of daily living (ADL), and institutionalization are also risk factors for falls (M.C. Nevitt et al., 2003; Tinetti, 1986).

Diseases and chronic conditions are main causes of disability due to accompanying impairments and functional limitations. History of chronic lung disease, arthritis, Parkinson's disease, stroke, urinary incontinence, orthostatic hypotension, and cognitive impairment are significant medical factors that can lead to falls (Tinetti et al., 1986). Most common comorbidities associated with fall related injuries are syncope, conduction disorder/arrhythmias, chronic ischemic heart disease, anemia, diabetes, and hypertensive disease (Sattin, 1992). The risk of falling increases with the number of concurrent medical diagnoses (Tinetti, 1986; Tinetti et al., 1988). Chronic conditions such as vertigo and history of hip fracture are considered predictive of falls in the older adult. Cognitive impairment, fear of falling, and depressive conditions are sited as additional major concerns in a risk factor analysis (Prudham & Evans, 1981; P.A. Stalenhoef, Crebolder, Knottnerus, & Van Der Horst, 1997; Stel et al., 2003; M. E. Tinetti et al., 1995; Tromp et al., 2001). When sociodemographic, lifestyle, and psychological factors are present, there is an accumulation of risk factors for falling as well as a determination of disability (Dunn et al., 1992; Friedman, Munoz, West, Rubin, & Fried, 2002; M. C. Nevitt et al., 1989; Verbrugge & Jette, 1994).

Tinetti et al, from 1986 through 1990, studied fall risk factors and developed a grading system to document fall risk. Morale, distant vision, postural blood pressure, medications, ADLs, and mobility factors were some of the factors assessed. A fall risk of 0 was associated with no presence of a risk factor; 31 percent risk was associated with 4-6 risk factors; a 100 percent risk of falling was associated with the presence of greater than or equal to 7 risk factors. In a classic study by Tinetti et al in 1988, sedatives; cognitive impairment; lower extremity disability; palmomental reflex; abnormal gait and balance; and foot problems were listed as fall risk factors. The presence of these factors demonstrated a linear increase in fall risk with the number of risk factors present. They concluded that if there are four or more fall risk factors present, there is a 78 percent chance of falling in an older adult; *p* less than .0001.

The studies of falls in the elderly adult present concern for a high fall incidence and a high susceptibility to fall related injury. In this population there is a high prevalence of comorbidities and age related physiological changes that contribute to the higher susceptibility to falls and related injuries. The risk factors are similar to noninjurious falls. Independent risk factors for injurious falls that have been found are: history of more then one fall; cognitive impairment; arthritis, and inability to get up from lying on the floor (Bergland & Wyller, 2004; Rubenstein, Powers, & MacLean, 2001).

The interplay of fall risk factors is an important concept to understand in order to provide an organized assessment of risk factors, fall mechanics, and intervention strategies (Hayes et al., 1996; J. A. Stevens et al., 2006). Falls in the older population are said to be multifactorial events. Behavioral risk factors are descriptive of activity related factors.

The intrinsic risk factors are the factors that have been reported to be most significant in precipitating recurrent falls. In a study by Luukinen et al (1995) of 1,016 community dwelling elderly, a history of previous falls, peripheral neuropathy, psychotropic medication, and slow walking speed have been sited as independent risk factors for recurrent falls. Mobility factors make up the most important intrinsic factors leading to recurrent falls (A. J. Campbell, Spears, & Borrie, 1990; P. A. Stalenhoef et al., 2002; Tinetti et al., 1988; Tromp et al., 2001). Power output has been determined to be a major, if not the most, relevant predictor for fall risk (Perry, Carville, Smith, Rutherford, & Newham, 2007). In the frail elderly, primary causes include: stroke; Parkinson's disease, visual impairment, drug related hypotension, and the presence of an inflammatory disease (Lipsitz, Jonsson, Kelley, & Koestner, 1991). Functional limitations have been found to be important predictors of recurrent fall events in several studies (A. J. Campbell, Borrie, & Spears, 1989; A. J. Campbell et al., 1990; Tinetti et al., 1988; Tromp et al., 2001). When greater than two falls in the previous year and functional limitations are present, it has been shown that these two risk factors are significant predictors of recurrent falls and of hip fractures (Gregg, Pereira, & Caspersen, 2000; Pluijm et al., 2006).

Most of the major risk factors are modifiable by interventions that have proven to be effective. The U.S. Public Health Service reports two thirds of fall related deaths are preventable. Early identification and elimination of extrinsic factors and targeted intervention of intrinsic risk factors would constitute the most effective prevention strategies (AGS, 2001; Luukinen et al., 1995; Rubenstein, 2006). In order to make a screening process efficacious it has been recommended that modifiable risk factors be used in the screening process for fall risk (Moreland et al., 2003; Rubenstein, 2006). The CDC reported in 2001, that muscle weakness (relative risk = 4.4); gait and balance problems (relative risk = 2.9); vision problems (relative risk = 2.5); and psychoactive medications (relative risk = 1.7) are considered modifiable fall risk factors. Evidence based guidelines, from 2003, for the secondary prevention of falls in older adults separated the important potentially modifiable risk factors into two levels. Level 1 contained mental status and psychotropic drugs. Level 2 included multiple drugs, environmental hazards, vision, lower extremity impairments, balance, gait, and difficulty with activities of daily living (Moreland et al., 2003). The risk factors of older age, female sex, white race, chronic diseases, and mental impairment are not considered modifiable fall risk factors. The following risk factors are modifiable and are representative of intrinsic and behavioral risk factors that are commonly mentioned in the research literature as major predictors of falls.

*Fall Associated Aging Changes*

Aging is a complex process with interacting factors that influence health, functional capacity, quality of life, and independence. The effects of aging and age-associated disease effects are the most common causes of balance problems. Strength and coordination diminish and movements become slower. Age-related changes in function are believed to be due to disuse from a sedentary lifestyle and from intrinsic physiologic factors (Luff, 1998). Aging and disuse changes take place throughout the physiologic systems. Neuromuscular, cardiovascular, pulmonary, nutritional status, and metabolic systems age at different rates but in the older adult all of these systems are negatively affected by aging (Singh, 2002).

Skeletal muscle physiologic, anatomic, and histological processes decrease with aging, and the beginning of the decline is at 40 years of age (Aoyagi & Shephard, 1992). Estimates of 20-40 percent loss of maximal strength occurs by age 65 in the sedentary adult. Muscle mass and strength, especially in the proximal muscles of the lower extremities, decrease about 12 percent per decade after the age of 50 (Aoyagi & Shephard, 1992; Hughes et al., 2001; Ranatanen & Heikkinen, 1994; R. H. Whipple, Wolfson, & Amerman, 1987). Strength per unit of muscle mass is affected by age and gender; muscle group determines what type of effect is caused by aging (Lynch et al., 1999). The rate of decline in the lower extremity muscles was the same for men and women. The aging process accounts for 30-40 percent of the decline in strength. Strength is associated with loss of muscle mass (size and number of fibers), and control properties of motor units (Erim, Beg, Burke, & de Luca, 1999). Greater selective loss of the fast Type II fibers occurs. Resultant prolonged contraction time and half-relaxation time occur with a decrease in maximum contraction velocity. These changes are noticeable in the lower extremities. Decreasing hormonal and growth factor secretion is associated with decreasing protein metabolism necessary for muscle fiber growth. Osteoporosis and sarcopenia, age-related loss in muscle mass, are related due to diminished muscle tension and weightbearing effects on bone mineral density (Bottomley & Lewis, 2003; Nelson, Fiatatrone, & Morggant, 1994). The rate of loss of strength in men less than 60 years was determined to be more significant than the actual level of strength. In men 60 and older, strength level was more protective of all-cause mortality than rate of strength change (Metter et al., 2002; Proctor, Balogopal, & Nair, 1998).

Central neurological changes with age begin in the early decades. Central nervous system (CNS) delays are associated with decreased nerve conduction velocity and greater loss of myelinated fibers in the posterior spinal columns. These changes contribute to diminished reflex righting and equilibrium responses necessary to maintain postural stability in static and dynamic movement activities (Lynch et al., 1999). An average rate of motor neuron loss from the second to the tenth decade of life is estimated to be 25 percent. Aging of the nervous system has been described as a progressive neurogenic process. This process peaks at age 60. Eventually, as denervation exceeds reinnervation, muscle fibers are permanently lost and replaced by fat and fibrous connective tissue (Lexell, 1997; Vandervoort, 2002). The extent of loss of functional cells from the motor system is a function of the location in the body, age, and presence and extent of disease.

Locomotor capacity is compromised as a result of aging. Changes in muscle performance are causative in risk for falling. Deficits in hip, knee, and ankle strength and range of motion have been documented in community dwelling adults. Decreased power of the plantar flexors is the single most significant factor in loss of mobility and function (Aoyagi & Shephard, 1992; Metter et al., 2002). In active adults, it has been determined that muscle power decreases more than 50 percent between the ages of 20 and 80 (Runge, Rittweger, Russo, Schiessl, & Felsenberg, 2004; Skelton, Greig, Davies, & Young, 1994). Power, defined as the ability to perform work quickly**,** requires the integration of neural and muscular systems. Successful mobility, gait and other functional movements necessary in daily life depends on complex interaction of the physiologic systems. Each of these systems is impacted by degeneration, the effect of aging and or disuse. Gait performance decreases by age decade, with significant changes occurring in the age decade 50-59 and significantly decreasing by decade to the decade of 80-89 years (Lusardi, Pellecchia, & Schulman, 2003; Walker et al., 2007). Stepping voluntarily and reaction time slow with age. The ability to react and to weight shift laterally are predisposing factors to slower stepping (Luchies et al., 2002). Gait speed slows to below 98 cm per second, the necessary velocity to cross a lighted intersection (Ranatanen & Heikkinen, 1994). Head stability is diminished with aging, an important aspect of gait in the maintenance of a stable gaze (Cromwell, Newton, & Forrest, 2002). Lower extremity age-related joint angle changes are present during gait. These alterations in joint range of motion are more pronounced at slower gait speeds (Oberg, Karsznia, & Oberg, 1994).

Somatosensory system structural and functional declines, involving cutaneous sensation and proprioception, occur with aging. Preferential loss of the distal large myelinated sensory fibers and their receptors and resultant deficits in distal lower extremity proprioception, discriminative touch and balance are the results of aging. Proprioceptive and vestibular sensory receptors, central nervous system relays, and integration within the CNS experience loss of function with aging (S. Lord & Ward, 1994; Shaffer & Harrison, 2007). Sensory input about the status of the body within the environment comes from optimal functioning and interaction of these sensory systems. Deficits in these systems are serious situations as the adult will have to rely on vision for direction as to whether the environment is moving around him or he is moving in the environment. Visual-vestibuloocular responses are also diminished due to age-related changes in the sensory and neural components of the visual, vestibular, and oculomotor pathways. These functional changes with aging contribute to common reports of dizziness and disequilibrium observed in older adults (Baloh, Jacobson, & Socotch, 1993). Vision acuity deteriorates with aging due to several factors, e.g., development of cataracts, decreased depth perception and contrast sensitivity, making it an unreliable avenue for perception of movement (S.J. Herdman, 2000; S. Lord & Ward, 1994).

Aging changes such as cognitive impairments, restricted joint movements, gradual onset of chronic disease, along with deficits in strength, power, reaction time, and proprioception interact to foster a sedentary lifestyle which predisposes the older adult to falls and functional dependence (Gehlsen & Whaley, 1990; Robbins et al., 1989). Lower extremity dysfunction, visual impairment and barbiturate use not only predispose the individual to a fall but also to a hip fracture. Ninety percent of hip fractures result from a fall (Grisso et al., 1991). Age-related gait changes contribute to these injuries, e.g, preponderance of falling to the side has been reported to increase the risk of hip fracture six fold (Greenspan et al., 1998; Hayes et al., 1996).

Cognitive slowing is another significant risk factor of falling. Confusion, inattentiveness, decreased alertness, and poorer judgment are some of the changes that can predispose an older adult to a fall incident. Short cognitive tests are widely used to assess mental status in older adults. Two tests, the Mini-Mental State Exam (MMSE) by Folstein et al (1975) and the Blessed Orientation-Memory-Concentration (BOMC) Test developed by Katzman et al (1983) are used in fall prevention research literature. The BOMC is also referred to as the Short Blessed Test. Both tests are easily administered by a nonphysician. The six-item Short Blessed Test assesses orientation, memory, and concentration. Findings of cognitive impairment on the Short Blessed Test have been correlated with plaque formations in the cerebral cortex on autopsy. It is the simplest test of the two to administer in a screening situation and determined to be sensitive to milder forms of dementia when compared to the MMSE (Adelman & Daly, 2005; Brooke & Bullock, 1999; Dellasega, Lacko, Singer, & Salerno, 2001; Katzman et al., 1983; Moylan & Binder, 2007).

Risk of falling and serious injury increase significantly in the older adult population (M. C. Nevitt et al., 1989; Tinetti et al., 1988; Tromp et al., 2001). Subtle physiological changes that occur progressively with aging combine with disease and environmental hazards to increase fall risk in the older population. Sarcopenia and the pattern of strength reduction most evident in the lower extremities can lead to impairments in mobility, activities of daily living, and reduced work capacity. Heterogeneous characteristics of the adult add another component to the fall risk profile. An understanding of which of these aging changes are present versus impairments that are unique to an individual is difficult to ascertain. Translational research, effort to bring research into practice, recommends multidimensional evaluation of physiological systems to alter fall risk and fall injury events by the identification of impairments and functional limitations, particularly of postural control and lower extremity function.

*Fear of Falling*

Fear of falling is considered to be an independent predictor of falls. In a population based prospective study of 2,212 older adults, Friedman et al, determined falls at baseline were independent predictors of onset of fear of falling (FOF); odds ratio of 1.75; $p < .0005$; FOF at baseline was an independent predictor of becoming a faller; odds ratio of 1.79; $p < .0005$ (Friedman et al., 2002). The correlation between falling and FOF may be from common underlying risk factors, e.g., visual and cognitive impairments, older age, female gender, and ≥ 4 medications (Cumming, Salkeld, Thomas, & Szonyi, 2000; B.J. Vellas et al., 1997).

FOF has been postulated to be the recognition of being at fall risk and at risk for developing secondary sequelae from falls. FOF is a persistent attitude, causing an individual to limit activities which then precipitates functional decline and changing physiological status (Friedman et al., 2002; M. E. Tinetti et al., 1995). Self-imposed activity restrictions can lead to lower extremity muscle weakness and changes in gait patterns. FOF is associated with decreased stride length and speed, increased double limb support time; decreased clinical gait scores, and increased base of support during ambulation (Maki, 1997; B. J. Vellas et al., 1997). Several studies of older community dwelling adults have indicated a significant difference between high fear and low fear individuals on balance, lower extremity mobility and quality of life measures. Newton, in 1997, in a study of 251 African-American and Hispanic older adults, determined that physical activity level and comfort in performing activities without FOF significantly contributed to the scores on the Timed Up and Go and the Reach in Four Directions Test. Other studies have shown high fear individuals had significantly poorer scores on gait, balance, physical activity, and functional performance testing utilizing well known tests and measures, e.g., Berg Balance Score, Timed Up and Go, Habitual Gait Speed, Functional Reach, Dynamic Gait Index (Li, Fisher, Harmer, McAuley, & Wilson, 2003). A spiraling effect is created where FOF contributes to the addition of several significant fall risk factors, thereby making the fearful individual at a high risk for future falls.

Much of the deterioration in balance associated with aging is due to a sedentary lifestyle secondary to a fear of falling. Thirty percent of older adults with no fall history have fear of falling while, 60 percent of fallers have fear of falling. It has been estimated that 20-30 percent of hip fracture patients develop FOF. Lack of confidence leads to activity restriction with a resultant decreased quality of life (Legters, 2002). Lack of confidence is measured by assessing fall related self-efficacy. Self-efficacy has been determined to mediate the effects of fear of falling (Li, Fisher, Harmer, & McAuley, 2005). FOF and self-efficacy have similarities but are not the same constructs. Fall-related efficacy has been shown to be an independent correlate of physical function and performance of ADLs. FOF did not show this correlation. Nonfallers who report FOF have an increased risk of institutionalization (Cumming et al., 2000; Tinetti, Mendes de Leon et al., 1994).

There are several sensitive self-efficacy scales, including the Falls Efficacy Scale (FES) developed by Tinetti (1990), and the Activities-Specific Balance Scale (ABC) validated by Powell (1995). Fear has been defined for these scales as "low perceived self-efficacy at avoiding falls during essential, nonhazardous activities of daily living" (Tinetti, Richman, & Powell, 1990). These scales have been validated but differ in the type of population with which they can be used. Studies have also used a dichotomous response to a single question to determine FOF, and if positive, a second question is used to determine self-efficacy. The single question approach, although not as powerful as the measurement scales, has been useful in determining significant relationships of FOF and fall history or incidence of future falls (Friedman et al., 2002; Murphy et al., 2002; Newton, 1997).

Individuals who have an impairment in any of the fall risk factors are at risk for developing another risk factor, with a resultant cascade of increased fall risk, fear of falling, and functional decline (Tinetti, Mendes de Leon et al., 1994). A lower quality of life due to FOF represents impairments in mental health, social, and leisure time pursuits. Actual prevalence of FOF is underestimated, as older or frail adults are not willing to confess to falling because they fear the incident may precipitate loss of their independence and require caregiver support or institutionalization.

*Medications*

A prescription medication is a significant fall risk factor, especially when multiple medications are taken. Drug classes that are implicated in fall histories are:

benzodiazepines, antidepressants, antipsychotics, antihypertensives, cardiac medications, analgesics, anticonvulsants, antihistamines, and GI-histamine antagonists (NCIPC, 2002; M.E. Tinetti, T.M. Gill et al., 1995). Hilmer et al developed a drug burden index using data from the Health, Aging, and Body Composition Study of 3,075 community dwelling older adults. The results found anticholinergic and sedative medications associated with significant diminished physical performance at a $p < .001$ and diminished cognitive performance at a $p = .045$ and .01 for anticholinergic and sedative exposures (Hilmer et al., 2007) (Hilmer et al., 2007). Associations were stronger when exposure was calculated by exact dose response. An increase of one unit on the drug burden index was associated with specific deficits on the physical function and cognitive performance scales.

The literature is also consistent in stating that if an older adult has multiple drug use, also referred to as polypharmacy, there is an increase in fall risk and incidence of falls and recurrent fall incidents. Polypharmacy has been defined as the use of four or more drugs. A cross-sectional study of 6,928 individuals, aged ≥ 55 years, determined that there is a significant increased risk of falling with the number of drugs used on a daily basis, $p < 0.0001$. The study also determined that polypharmacy with at least one high risk drug, e.g., central nervous system drug or diuretic, was associated with increased risk of falling (Leipzig, Cumming, & Tinetti, 1999).

Central nervous system (CNS) active medications, also referred to as psychotropics, have been studied to determine fall fracture risk. These drugs produce psychomotor impairment and gait abnormalities which can lead to falls (Draganich, Zacny, Klafta, & Karrison, 2001). In a longitudinal study of 8,127 older community dwelling females, 1,256 experienced nonspine fractures. Medications in this class included benzodiazepines, antidepressants, anticonvulsants, and narcotics. Follow up at 4.8 years determined that taking narcotics and antidepressants (tricyclic antidepressants and selective serotonin reuptake inhibitors) placed the subjects at greater risk for nonspine fractures (Ensrud et al., 2003; Tinetti et al., 1988). The use of multiple CNS active medications also demonstrates a higher adjusted odds ratio of 2.37 when compared to the use of one medication with an adjusted odds ratio of 1.54. This type of dose response relationship produces one of the determinants in causality of falls by the use of certain medications (Weiner, Hanlon, & Studenski, 1998). Benzodiazepines are predictors for any type of fall (Tinetti et al., 1988; Tromp et al., 2001). In a large cohort study of 125,203 older adults enrolled in a Medicaid program, the association of benzodiazepine with hip fracture, at a 54 percent higher rate, was confirmed. The hip fracture incidence rate was greatest during the first 15 days of commencing benzodiazepine use. Fracture rate incidence decreased by 27.4 percent after the first two weeks of drug use. The results also determined that short half-life benzodiazepines carry a significant risk for hip fracture (A. K. Wagner et al., 2004). The psychotropics have shown to have about a two fold increased risk of falls and fractures when compared to individuals not using these drugs (Cumming, 1998; Tinetti et al., 1996).

A review of 29 studies show that these specific drug classes determined a weak association with falls when subjects reported the use of three or four medications of any type. Digoxin, type IA antiarrhythmic and diuretic use had the strongest associations with recurrent falls (Leipzig et al., 1999). Cardiac and analgesic drugs also bear an association with fall risk, although not as strong as the psychotropics.

A primary prevention strategy in the management of medications is a review of prescriptions and over the counter (OTC) drug use. A pharmacist or primary care practitioner should evaluate proper dosage, interactions, side effects and compliance with taking the medications. Reduction in the number of medications is associated with decreased fall risk when a combined risk factor reduction intervention is implemented (AGS, 2001; Tinetti et al., 1996; Tinetti, Baker et al., 1994).

*Vestibulo-Oculomotor Impairments*

Balance is a motor skill composed of static and dynamic properties. Balance provides steadiness, symmetry, and dynamic stability. These components allow for the three basic dimensions of balance: maintenance of a position, stability for voluntary movement; and reaction to external disturbances. Balance, the ability to control and maintain the body's position as it moves through space, is an integral, ever present part of daily life that most people rarely give conscious thought to until a fall occurs. Balance depends on the integration of sensory and motor physiological systems. Vestibular, somatosensory, and visual systems are the three primary sensory contributors to balance and functional independence. Function of each of these systems declines with aging, sedentary lifestyle, and /or disease. Impairments in a single system or in several systems will increase the risk of falling (S. R. Lord et al., 2003; M. E. Tinetti et al., 1995).

The vestibular system has central nervous system and peripheral nervous system components. Disorders of the peripheral system include pathologies of the semicircular canals and otoliths. These sensory receptors detect angular and linear acceleration of the head and trigger appropriate spatial orientation of the head in relation to gravity. This function is a critical piece of maintaining balance. The central vestibular system includes nuclei and motor outputs to the ocular muscles and spinal cord via the vestibulo-ocular reflex (VOR) and the vestibulospinal reflex (VSR) respectively. These reflexes control gaze stabilization and help maintain equilibrium and postural stability during head movements and locomotion. Central vestibular function is to process information from the peripheral system, visual, and somatosensory systems in the regulation of balance and posture. Disorders of the vestibular system can produce disequilibrium, dizziness, nausea, vomiting, and gait impairments (K.M. Gill-Body, 2000).

The vestibular system senses and helps integrate motion of the individual and of the environment around the individual. Vestibular function tests measure vestibular ocular reflex (VOR) function. The Dynamic Visual Acuity Test is a functional VOR measure that helps determine if vestibular hypofunction is present. Deficits associated with aging and fall risk of the vestibular system are: diminished VOR gain, shorter VOR time constant, and a decreased ability to enhance or suppress VOR with vision. These deficits present with functional limitations in maintaining a stable gaze and adjusting for sensory conflict during static and dynamic activities (Baloh et al., 1993; S.J. Herdman, 2000).

The VSR pathway is responsible for sensory and motor organization. This is the ability to use visual, proprioceptive, and vestibular input related to postural control. Musculoskeletal and neuromuscular impairments that are manifested involve joint range of motion, trunk and lower extremity strength, flexibility, and coordination. Clinical balance tests assess the VSR. Static and dynamic balance testing examine and quantify postural stability in standing, multidirectional reach, and during gait activities (Horak, 1987; Maki et al., 1994).

Aging changes in balance begin in the second decade. Test performance of postural stability, e.g., single leg stance and tandem stance, has been found to decrease with age beginning at age 35 (A. R. Fregly, Smith, & Graybiel, 1973). Postural balance has been cited as a major predictor of risk of falling (Maki et al., 1994; Scott, Votova, Scanlan, & Close, 2007; P. A. Stalenhoef et al., 2002). Postural stability of single stance in women is dependent on vision from the age of 40; vision is the dominant sensory system from the 50s during bilateral stance on foam; and vision reliance is complete from 60 years of age when tested on a firm surface (Choy, Brauer, & Nitz, 2003). This gradual degradation of visual, vestibular, and somatosensory system function requires specific assessment as to age, visual condition and support surface. The systems that contribute to postural stability are redundant. Compensation is possible by increasing dependence on systems that are functioning well. Balance can be preserved and restored through exercise emphasizing vestibular function and lower extremity strengthening (S.J. Herdman, 2000). The presence of multiple system impairments in the area of postural stability reduces the ability for an individual to compensate effectively, leading to increased risk of falling and injury. Balance impairments affect transfer skills of getting in and out of bed, chair, and tub; and on and off a toilet (Chu et al., 1999; M.E. Tinetti, T.M. Gill et al., 1995).

Gaze and postural stabilization are two necessary components of balance required for functional independence in the environment. Adults, especially older adults, rely on vision for successful head stabilization. Head stabilization provides head on trunk responses to lower extremity dynamics in order to maintain orientation of the head in space. Stability of lower extremity performance during dynamic activities is influenced by head stability in the presence of perturbations that can cause a fall. Gaze stabilization influences stepping behavior to the extent that with deficits in this area there is an increased risk of tripping and falling when climbing stairs. Correct stepping behavior relies on feed forward information from early visual input in order for planning of correct stepping behavior (Di Fabio, Zampieri, & Tuite, 2008). Head stability during rotations about the vertical plane demonstrates an age-related decline (Cromwell et al., 2002). Visual feedback is important to head stabilization in the older or younger adult with vestibular deficit.

Vision is used to compensate for deficits in the somatosensory and vestibular systems. Visual impairments that are significant in the risk for falling include: macular degeneration; diabetic retinopathies; visual field loss due to stroke; age-related changes associated with visual acuity, glare intolerance, depth perception, night vision; and not wearing appropriate prescription glasses (HHQIOSC, 2007). Visual acuity on its own does not represent the quality of vision. Acuity testing by itself does not provide information about seeing larger objects, objects with poor contrast such as curbs or stairs, or how clearly objects can be discerned when the head is moving or when the environment is moving about the head (S. R. Lord & Dayhew, 2001).

In The Blue Mountain Eye Study and the Study of Osteoporotic Fractures, reduced functional vision, a combination of visual acuity and contrast sensitivity, has been determined to be a predisposing factor to postural imbalance and falls in the older adult. Visual contribution to postural stability has been reported to be significantly greater in nonfallers compared to fallers (Coleman et al., 2004; Ivers, Cumming, Mitchell, & Attebo, 1998; S. R. Lord, Clark, & Webster, 1991; Turano, Rubin, Herdman, Chee, & Fried, 1994). In a study of 911 older adults who had sustained hip fractures, it was determined that poor binocular visual acuity, lack of depth perception, and time since last eye examination were associated with the hip fractures (Ivers, Norton, Cumming, Butler, & Campbell, 2000).

Clinical performance tests such as gait speed, Timed Up and Go Test, and Five Times Sit to Stance Test are associated with FOF scales and the Dizziness Handicap Inventory. Perception of disability is related to measures of mobility in individuals with vestibular dysfunction (Whitney, Wrisley, Brown, & Furman, 2004). Physiological and functional tests of balance are necessary in explaining disability from vestibular disorders (K. M. Gill-Body, Beninato, & Krebs, 2000). Correlation of fall risk tests e.g., functional reach and single leg stance, with vestibular disorders has been found to be significant (Mann, Whitney, Redfern, Borello-France, & Furman, 1996). Association of vestibular, visual, and somatosensory testing with each other facilitate the assessment of balance in each of its dimensions.

*Gait and Balance Impairments*

Balance in gait is defined as the ability to integrate postural adjustments with locomotor strategies to safely perform a wide range of activities. Postural adjustments in gait refer to changes in walking speed, cadence, stride length, and double limb support when perturbations occur during locomotion. Work by Shkuratova (2004) demonstrated that young and older adults produce changes in postural adjustments specific to the task at hand and vary according to the type of perturbation encountered.

Age-related gait adaptations attempt to minimize imbalances due to physiological and psychological factors. The typical gait adjustments associated with the older adult are: decreased walking velocity; decreased hip, knee, and ankle extension; decreased knee extension torque and push off power at the ankle. These changes serve a protective function under normal circumstances. Stride to stride variations, especially that of stride width used to control gait, have been determined to be independent predictors of falling. In situations of a hazardous environment, these adaptive changes may not result in appropriate postural responses and instead become key factors leading to increased fall incidence (Maki, 1997; L. Wolfson, 2001). The younger adult, in contrast, presents with a gait pattern that is less stable and as a result is able to shift their center of mass forward and laterally quickly and effectively with each step.

Ample evidence is present in the research literature demonstrating poor performance in lower extremity tasks associated with higher incidence of new falls in the aging adult (J. M. Guralnik et al., 1995; Tinetti et al., 1988). Balance and gait problems are significant fall risk factors (P.A. Stalenhoef et al., 1997). Gait characteristics associated with falls and a slower gait speed are: decreased stride length, increased bilateral stance time, decreased plantar flexion during push off, and decreased hip extension during terminal stance (Barak, Wagenaar, & Holt, 2006). Aging changes are seen in gait parameters associated with obstacle avoidance and stepping. Kinematic factors of toe clearance, heel clearance, and street crossing velocity degrade with age (Kovacs, 2005).

Lower extremity impairments may compromise several domains of function simultaneously. Lower extremity impairment is a powerful predictor of a decrease in function and increase in fall risk (J. M. Guralnik et al., 1995; Tinetti, Allore, Araujo, & Seeman, 2005). An increased need for help in getting up from the floor after falling is greater after one or more falls. This presents a significant concern in an older adult who lives alone. The risk of institutionalization and death are increased the longer an individual stays on the floor (Bergland & Wyller, 2004; M. C. Nevitt et al., 1991; Tinetti et al., 1993). Most functional activities, e.g., getting up from the floor, sit to stance, stair climbing, and gait speed required to cross the street before the traffic light turns red, require a minimal level of lower extremity strength and power.

Lower extremity muscle weakness in strength and power can increase the odds of falling fourfold (Rubenstein et al., 2004; R. H. Whipple et al., 1987).The ability to produce maximal power is required for many activities of daily living; to quickly get out of the way of an oncoming car while crossing a street, to climb stairs or a slope of grass, to recover balance when footing is lost (Suzuki, Bean, & Fielding, 2001). Power is defined as the ability to perform muscular work per unit of time. In normal gait, the soleus and gastrocnemius muscles of the calf provide vertical support for the trunk and leg in the mid-single-leg stance part of the gait cycle. During late single-leg stance through pre-swing, the calf muscles provide forward progression by accelerating the trunk center of mass in the horizontal direction. When compared to other lower extremity muscles, the gastroc-soleus muscle group contributes 40-60 percent of the power in gait (Neptune, Kautz, & Zajac, 2001).

Reduced ankle plantar flexion and ankle power generation during gait is present in the older population. The speed of torque development is associated with balance recovery of a stable upright posture more so than isolated torque measurements at the ankle. Leg power has been demonstrated to explain two to eight percent more of the variance in performance than other lower extremity physical performance measures, e.g., stair climb time, chair stand time, tandem gait, habitual gait, and maximal gait (Bean et al., 2002; Foldvari et al., 2000). Sixty to eighty percent of the variance in walking speed has been accounted for by knee and ankle power (Bassey et al., 1992; Foldvari et al., 2000). These changes in ankle function have been found to be due more to physical impairment versus an age-related factor (Kerrigan, Todd, Croce, Lipsitz, & Collins, 1998; McGibbon & Krebs, 1999; Robinovitch, Heller, Lui, & Cortez, 2002). A significant association between lower extremity power and physical performance, especially in gait velocity, is present in the older adult (Bean et al., 2002; Suzuki et al., 2001). Asymmetry in strength and power is present in fallers. A comparison of frequent fallers to non-fallers in a study of older women determined that women with a history of falls were 24 percent more impaired in power for their weight than the women that had not fallen (Skelton, Kennedy, & Rutherford, 2002). Chan et al (2007) found similar findings in the Osteoporotic Fractures in Men Study of 5,995 community dwelling men. This deficit in power in the faller is manifested by a less vigorous push-off in gait, less heel strike, and resultant flat footed landing: gait characteristics associated with decreased walking speeds and small stride lengths (Barak et al., 2006; Winter, Patla, Frank, & Walt, 1990). Judge et al (1996) hypothesize that strengthening ankle plantar flexors may maintain stride length as individuals age.

The interaction of balance and gait in falling is an important concept to understand. Impairments of balance and gait have been reported to carry a three fold increase in the risk of falling (Rubenstein, 2006) A tendency in individuals with balance deficits to fall to the side has been reported. The control of lateral stability shows a significant difference between fallers and nonfallers especially when a fall is precipitated by a perturbation (Maki et al., 1994). Medial-lateral balance in women begins to decline as early as 40 years of age. Lateral stepping, lateral reach, and lateral sway measures have been used to demonstrate aging changes in medial-lateral balance (Brauer, Burns, & Galley, 1999; Nitz, Choy, & Isles, 2003).  Excessive lateral sway during gait is associated with vestibular and cerebellar dysfunction. Fall severity, manifested by an individual's fragility and direction of falling are significant predictors of fall related injury, especially, that of hip fractures (Chou, Kaufman, Hahn, & Brey, 2003; Greenspan et al., 1998). Nevitt et al, in 1993, reported a 3.3 fold increased risk for hip fractures in community dwelling older women who fell sideways or straight down. Falling to the side with direct impact on the hip plays an important role in how an injury occurs (Bergland & Wyller, 2004; Hayes et al., 1996).

Rubenstein et al (2002) determined that the top three causes of falls in an older adult are a result of the interaction between mobility and the following factors: environmental accidents, balance and gait disorders, and dizziness/vertigo. Performance of physiological and functional balance testing can be affected by age, gender, physical activity level, and race. Results from the Timed Up and Go Test and Reach in Four Directions Test are examples of reference values changing with the afore mentioned older adult characteristics (Newton, 1997). Balance impairments in the older adult have been demonstrated to involve higher central nervous system integration. This is exemplified by a diminished capacity in the older adult to process conflicting sensory input (Judge, King, Whipple, Clive, & Wolfson, 1995; L Wolfson, Derby, Amerman, Murphy, & Tobin, 1992). Decline in function as one ages may be due to the additive effect of impairments in sensory, central processing, and motor components of mobility. Selective attention and choice reaction time are cited as significant balance control components predictive of falls (Woolley, Czaja, & Drury, 1997).

*Physical Inactivity*

Physical inactivity, a modifiable fall risk factor, plays a significant role in the determination of health outcomes. Inactivity is associated health problems such as decreased cardiovascular status, muscle weakness, mobility and balance, premature chronic disease, weight gain, and functional limitations. These health problems have a great negative impact on the individual as well as costing the U.S. health care system. Morbidity and mortality are increased with poor physical fitness, an outcome of physical inactivity (Chad et al., 2005; Chan et al., 2007; Kujala, Kaprio, Kannus, Sarna, & Koskenvuo, 2000; Province et al., 1995).

The Centers for Disease Control and Prevention (CDC), American College of Sports Medicine (ACSM), and American Heart Association (AHA) have published preventive recommendations in the area of physical activity for every U.S. adult (Haskell et al., 2007; Nelson et al., 2007). Adults in this country, as revealed in data from 2005, are not active enough. Less than half of U.S. adults met earlier CDC/ACSM activity recommendations to achieve health benefits. Men met the recommendations more than women; 50.7 percent versus 47.9 percent, respectively. In addition to gender differences, age, ethnicity, and educational level also demonstrated significant effects on level of physical activity (Pate et al., 1995). Activity levels show an age related decline. CDC data show older adults grouped into 65-74 and 75 and older have no leisure time activity; at 28-34 percent and 35-44 percent, respectively. An additional group of older adults, 30-40 percent, were found to be insufficiently active.

Evidence based research has contributed to this body of knowledge over the past 30 years from the areas of physiology, epidemiology and clinical research. In addition to exercise, physical activity was determined to be significantly beneficial in the provision of health and fitness effects. Caloric expenditure and total time of physical activity showed an inverse correlation with cardiovascular disease (CVD) incidence and all cause mortality. Pate et al reported 12 percent of deaths in the U.S. were attributable to lack of regular physical activity.

Physical activity assessments usually involve questionnaires that include calculating total activity by considering the duration, intensity, and frequency of structured and non-structured exercise bouts. Common components assessed are: walking for exercise; non-exercise walking for daily and instrumental activities of daily living. Leisure time activity is looked at in the areas of sports and recreation. Occupational activity is another component singled out under non-structured exercise. Walking and household related activity are the largest contributors to physical activity in age groups starting with 50 year olds (Chad et al., 2005; Chan et al., 2007). An adult's physical activity recall has been found to be adequate and accurate with studies demonstrating moderate to good test-retest reliability (Winters-Hart, Brach, Storti, Trauth, & Krisk, 2004).

In a prospective cohort study of 5,995 men, Chan et al. followed up four and a half years later. The association of activity with fall risk was related to household activity and not to leisure or occupational activity. The most active quartile was more likely to fall when associated with lower levels of leg power, grip strength, and narrow walk pace. There was still a higher level of fall risk even in the more active group who possessed higher leg power. Another large prospective study followed 3,262 men for 21 years from the age of 44 to determine the association of physical activity and osteoporotic hip fractures. The results provided evidence of an inverse association between level of physical activity at baseline and future hip fracture risk (Kujala et al., 2000). Campbell et al. in several randomized control studies have determined that older women who participated in balance, strength training, and walking programs reduced fall incidence over a two year period by 30-40 percent (A. J. Campbell & Robertson, 2006; A.J. Campbell, Robertson, Gardner, Norton, & Buchner, 1999). The interaction between activity level, physical performance, and fall risk is not completely understood. Fall prevention will need to look at the physically active and physically inactive adult separately to identify strategies to keep both groups safe.

In 1995, it was reported that a change from a sedentary lifestyle to an active lifestyle provided benefits despite when these changes occurred. Risk reduction figures of 20-50 percent in coronary heart disease and CVD were described. Dose-response benefits of physical activity are also experienced with changes in anxiety, depression, physical function, independent living in elders, feeling of well-being, work performance, recreational and sports activities. These inverse, at times linear, dose-response relationships are evident in men and women, and in young and old age cohorts (Pate et al., 1995; Singh, 2002). Declining level of high intensity activity with aging has been determined to be an independent predictor of mortality (Metter et al., 2002).

The CDC, ACSM and AHA have recently published physical activity and public health recommendations for populations aged 18-65 and over 65 years of age. The updated recommendations are similar to the 1995 guidelines which emphasized a minimum of 30 minutes of daily moderate intensity aerobic physical activity. Common to both age group recommendations is the allowance for accumulated 10 minutes bouts of exercise in a day. A ten minute bout of aerobic exercise has been found to provide an aerobic training stimulus. The frequency of exercise in 2008 is set at five times a week with the performance of moderate and/or vigorous intensity aerobic activity. Strength and endurance training exercises containing 8-10 different exercises has been added to the prescription.  A recommended caloric expenditure in physical activity of 200 kcal per day is enough to receive health benefits. In the older adult, flexibility and balance exercises are part of the physical activity recommendation as impairments in these two areas have been identified as major risk factors in falls and decreased functional mobility (Haskell et al., 2007; Nelson et al., 2007).

Once impairments are diminished, regular physical activity will contribute to healthy aging (Liao, McGee, Cao, & Cooper, 2001). A low-moderate intensity program of strength, endurance, balance, and mobility exercise (components of physical fitness) has been reported to increased physical activity and reduce fall rates (Rubenstein, Josephson, & Trueblood, 2000). Evidence is present that physical activity decreases fall incidence and increases functional capacity leading to greater independence and quality of life (Chad et al., 2005; D. O. Clark, Stump, Hui, & Wolinsky, 1998; S. R. Lord et al., 1993; Pate et al., 1995). The CDC has reported that for every dollar spent on physical activity programs in older adult hip fracture patients, a $4.50 return was experienced. When correlational and prospective longitudinal studies are reviewed, the most consistent outcome was that long term physical activity is related to postponed disability and dependence in the old-oldest population. This age group has the highest risk for falls and serious fall related injuries (Chan et al., 2007; Kujala et al., 2000; Singh, 2002). Spirduso et al. report that individuals with chronic disease also show enhanced physical function following adherence to a physical activity. The active older adults reported higher levels of well being and physical functioning (Spirduso & Cronin, 2001). Primary and secondary prevention strategies in fall prevention contain recommendations for physical activity. The objective of these recommendations is to optimize risk factor profiles from the positive effect of physical activity on most of the declining physiologic systems due to aging and disuse.

## Screening for Modifiable Fall Risk Factors

### *Rationale for Early Screening*

Negative aging influences become apparent several years to decades earlier than are indicated in current fall prevention guidelines (A. R. Fregly et al., 1973; Isles et al., 2004; Shaffer & Harrison, 2007). Goals of primary prevention are to cause a shift towards normal or optimal function for adults who experience normal age-related declines in balance and concomitant decline in functional tasks. Healthy adults are heterogeneous in physical and psychological characteristics that may predispose early age-related changes and impairments that will eventually lead to physical declines. Multidimensional examinations with an emphasis on balance and mobility help differentiate between age effects and disease states.

Routine multidimensional fall risk screening can be a major strategy in fall prevention. Review of work in the area of health promotion and primary prevention brings to the forefront work by William Haddon. He has stated that “the event leading to an injury is separate from the injury itself'. Injury prevention strategies attempt to prevent injury by making changes in the person, e.g., preventing lower extremity weakness and joint restrictions. Successful prevention strategies are made up of a combination of active and passive behavioral components. Screening, a passive component, could be included in routine medical examinations (Rivara, Grossman, & Cummings, 1997). Adults in our society will be able to learn to appreciate their own fall risk stratification as a result of a fall risk screen. Screening can become a part of routine medical examinations or become a part of a community's primary prevention program. Fall risk screening can serve to identify an individual's fall risk. Fall stratification can be understood and practiced similar to cardiopulmonary disease risk stratification recommended by the American Association of Cardiovascular and Pulmonary Rehabilitation in 1999. Fall risk stratification can provide an individual with evidence-based recommendations for fall risk management.

Studies have examined fall risk factors, determined impairments that were present, and then have led to the development of a variety of physical and performance tests to identify fallers and nonfallers. Lower extremity strength, power, and functional performance have been correlated with the timed chair rise, stair climbing, walking, manual muscle testing, dynamometry, isokinetics, maximum gait speed, mobility interviews, Timed Up & Go Test, Berg Balance Scale (BBS), and Dynamic Gait Index scores (Bassey et al., 1992; Berg, Wood-Dauphinee, Williams, & Maki, 1992; R. W. Bohannon, 1998; R.W. Bohannon & Eriksrud, 2003; Newton, 2001; Podsiadlo & Richardson, 1991).

Functional performance has been assessed by functional reach, fear of falling, physical activity scales (e.g., PASE and SF-36), Timed Up and Go Test, BBS, muscle function, 360 degree turn, and bending over test (Aoyagi & Shephard, 1992; R. W. Bohannon, 1995; Newton, 2001; Rantanen et al., 1998; M.E. Tinetti et al., 1990). Several researchers have developed multidimensional batteries to include assessment of vision, vestibular ocular gain, visual contrast sensitivity, sensation, muscle strength, reaction time, postural sway on firm and on compliant surfaces, cognition and affect (Di Fabio, Greany, Emasithi, & Wyman, 2002; S. R. Lord et al., 2003; Tinetti et al., 2005). Each battery of tests has been shown to be valid in measuring risk for functional dependence and falls.

The National Fall Reduction Initiative has required that ten core elements be included in a fall risk assessment: age over 65; three or more co-existing diseases; prior fall history within past 3 months; incontinence of bowel or bladder; visual impairment; impaired functional mobility; environmental hazards; four or more prescription medications referred to as polypharmacy; pain sufficient to affect level of physical or mental function; and cognitive impairment. The presence of four or more of these core elements considers a person at risk for falling. Fall prediction accuracy of this assessment has been found to be 88 percent (HHQIOSC, 2007).

It has been shown that simple clinical screening tests can identify older adults who will be more likely to fall (CDC, 2006; S. R. Lord & Clark, 1996; Shumway-Cook et al., 1997; Studenski et al., 1994; Tinetti et al., 1988; Tromp et al., 2001). Most clinical testing thus far has focused on the older adult. A review of the physiological aging changes and balance test results show important fall risk impairments begin to occur much earlier in the adult, as early as the second decade of life (Choy et al., 2003; Isles et al., 2004). A fall risk screen needs to reliably identify modifiable risk factors for which targeted interventions can be initiated. The use of such a multifactorial fall prevention strategy has been demonstrated to significantly reduce fall risk and multiple fall incidence (Studenski et al., 1994). Application of this strategy, earlier in adulthood and routinely thereafter, will identify impairments, focus on appropriate interventions, and allow the adult to age with less fall and disability risk. Routine screening can therefore be recommended earlier in adulthood that will provide fall identification and collect evidence that can contribute to the study of falls (Gill, Hardy, & Williams, 2002; Gillespie et al., 2004; Scott et al., 2007; Tinetti et al., 2005).

*Fall Risk Screen Development*

General psychometric test properties include: reliability; degree of correlation of one test to another; validity measures of construct, criterion, and prediction of an expected outcome or performance; and responsiveness to detect clinically meaningful changes over time. In the area of fall risk detection, certain considerations need to be made when choosing tests that will make up a multidimensional measure (S. R. Lord & Clark, 1996). The test needs to have been validated on a population that is similar to the target population to be assessed by the new tool. Appropriateness of the test for the impairments and functional abilities that are being tested must be present. Ease of administration is important in a screening tool. In this study a portable test with few environmental specifications will satisfy part of the objective in making a screening tool that can be used in a variety of locations (AGS, 2001; Moylan & Binder, 2007). The scored measurements should be easily determined and have a standard to which the score is compared. Test domains will need to evaluate physiological capacity and functional performance (Perell et al., 2001).

Clinical tests of balance will identify balance impairments and functional deficits that explain resultant physical limitations and disability. The test items should mimic balance positions and movements required to complete daily physical activities. Static and dynamic balance tests provide a more accurate representation of balance (Newton, Alhanti, Creese, Golden, & Gregory, 1997). Visual, vestibular, and somatosensory components of postural stability must be addressed during performance of static and dynamic activities. The complexity of postural control requires utilization of more than one test of balance. Whipple (1997) described three balance-challenge domains that need to be addressed in measurement and intervention. The first domain describes predictable challenges occurring during bipedal activities, e.g., decreased bipedal base during reaching, ambulation, vertical movements like sit to stance, and stair climbing. Postural transitions during ground-level activities make up the second domain of challenges. These include transitional activities such as sit to stand, squatting, and half kneeling. The third domain describes environmentally induced or extrinsic destabilizations while in the erect position. The categories in this domain include destabilizing conditions that provide unstable support, decreased area of support, obstacles, and diminished or distorted visual input.

Balance and mobility activities vary in degree of difficulty as seen in the descriptions of challenges to postural stability. A hierarchical challenge to the postural control system is required to assess the complex integration and interaction of sensory and motor systems (Choy et al., 2003; Speers, Ashton-Miller, Schultz, & Alexander, 1998). Intensity of response to a stimulus requires assessment in terms of amplitude, speed, imposed resistance and duration of required movement (R.H. Whipple, 1997). The postural response is dependent on integration of the following systems: muscle strength, power, sensorimotor, joint range of motion, endurance, vestibular-ocular processing, and psychosocial status.

Balance deficits appear to have the most direct causal relationship to falls (B. J. Vellas et al., 1997). If an individual has not fallen in the past 12 months, gait and balance impairments predicted future falls more often than any other domain (Ganz, Bao, Shekelle, & Rubenstein, 2007). One of the most important steps in fall risk prevention may be the identification of persons who need targeted intervention for mobility impairments. Assessment of aging, nutritional status, disease state, and medications are important cofactors of balance deficits that affect fall risk (Aoyagi & Shephard, 1992; S. Lord & Ward, 1994; M. C. Nevitt et al., 1989). A complete fall risk screening will need to include a history of the presence of these factors along with physical testing.

Evaluation of fall risk factors is an approach that deals with impairments irrespective of their cause. Direct assessment of sensorimotor abilities occurs in physiological and functional performance testing. Screening results of major deficits or a combination of minor deficits may identify an individual at risk for falling (S. R. Lord et al., 2003; S. R. Lord, Ward, Willams, & Anstey, 1994). Performance of a multidimensional screening tool will provide assessment of each of the physiological systems that contribute to balance and functional mobility. No single fall risk factor is accurate enough to be relied upon as a sole predictor of falling.

Geriatric physical function measures are usually long and complex, making them impractical to administer during a primary care visit to a physician or therapist, whether the visit is in the home, community center, or hospital setting (Fleming, Evans, Weber, & Chutka, 1995; Scott et al., 2007). A fall risk screen will need to not only provide direct measures of physiological systems and functional capacity but, will also need to be succinct and applicable in primary prevention strategies (Gill, Williams, Richardson, & Tinetti, 1996; S. R. Lord et al., 2003; Tinetti, 1986; Tinetti et al., 1988). One simple test cannot assess the complex interaction of systems functional in an independent community ambulator (Province et al., 1995; Scott et al., 2007). Several single tests and summary scores used together can provide risk stratification and prediction of future falls and disability for the consumer (J. M. Guralnik et al., 2000; S. Lord & Ward, 1994; Robbins et al., 1989). Performance standards are available for fall risk screening tests but normative reference values have not been developed across the adult lifespan for most of the tests for the independent community dwelling adult.

*Recommended Test Components for the Multidimensional Fall Risk Screen*

A fall risk assessment tool is used for primary prevention of falls. Primary predictors of falls are to be incorporated into the instrument (AGS, 2001; Friedman et al., 2002; Gillespie et al., 2001; NCOA, 2005). A screening instrument must take into account the heterogeneity of age associated declines in function in healthy community dwelling adults across a wide range of ages (J. M. VanSwearingen & Brach, 2001). Usefulness of a screening instrument in fall prediction may vary depending on the level of function of the adult undergoing testing. Ceiling effects from tests that do not pick up potential fallers because of their high level of functioning need to be recognized

(Boulgarides, McGinty, Willett, & Barnes, 2003; Walker et al., 2007). Gradual development of physical impairments and functional limitations can prove to be markers of treatable fall risk factors before a fall occurs.

A fall prevention program is multifaceted in that individuals at risk need to be identified; environmental hazards need to be identified; and modifications and interventions need to be instituted to reduce the probability of falling. The Multidimensional Fall Risk Screen (MFRS), a series of individual fall risk tests, has been developed to address the first facet of a fall prevention program which is fall risk stratification. Utilization of a yearly fall risk screen for adults should be able to detect early aging changes, sedentary lifestyle changes, or changes in health status due to disease or trauma (AGS, 2001; M.E. Tinetti et al., 1990). The MFRS compilation of tests follows the recommendations found in research literature for a simple predictive model used to quantify fall risk.

A fall and health status report is customary as a complement to physical performance screening to identify fall risk. A prior fall and or for example, diagnosis of osteoporosis often lead to fear of falling resulting in self-restricted physical activities and an evolution of balance and mobility impairments. An individual is questioned about: falls within the past 12 months, mobility and ADL limitations, activity level, co-morbidities, medications, dizziness, fear of falling, cognitive status, and perceived health status (Ganz et al., 2007; Tinetti, 2003). These fall risk factors are considered significant predictors of fall risk. Evidence in the literature has demonstrated that tests that combine primary predictors are able to improve predictive capability (Morris et al., 2007). Performance measures and self-report health status surveys complement each other and should not be used in isolation if a multidimensional screening is to be performed (J. M. Guralnik et al., 1994; Lee, 2000; Shumway-Cook et al., 1997; Sibbritt, Byles, & Regan, 2007)

The component tests in the MFRS were selected from currently used reliable tests from evidence based literature and from best practice guidelines developed by professional and government agencies to evaluate the domains of fall risk assessment. Independence in ADLs, IADLs and maintenance of an active lifestyle require basic mobility skills that are proficient in balance and gait maneuvers, for example: getting up and down from a chair; in and out of bed; reaching in a variety of directions; walking fast enough to cross a street before the light turns red; and able to climb 7-8 stairs (Rubenstein et al., 2001; Tinetti et al., 1988). Functional vision and vestibular status; static and dynamic balance; movement strategies and center of gravity stability during transitional movements necessary in functional mobility; lower extremity strength, power, and mobility related to independent community ambulation will make up the domains of the MFRS (S. R. Lord et al., 2003; Lusardi et al., 2003; L. Wolfson, Whipple, Amerman, & Tobin, 1990). Age related changes predictive of fall risk are also incorporated into the MFRS. The primary fall risk predictors from the aging literature are vision, speed of movement, muscle strength, and physical activity.

The MFRS, an eight item multidimensional battery of physical performance tests, will be used to assess the major balance systems, within a short period of time (about 10 minutes), without requiring sophisticated testing equipment or designated clinical space. The clinical balance outcome measures that were chosen from the evidence-based literature presented above are: Habitual Gait Speed, Multidirectional Reach Test, Horizontal Dynamic Visual Acuity, Single Leg Stance, ankle dorsiflexion range of motion, Timed Up and Go Test, Five Times Sit to Stand Test, and Stance Single Heel Rises. The domains of static and dynamic balance; functional vision and vestibular function; lower extremity strength, power, and range of motion; and functional performance in the areas of gait and transitional movements are assessed in these eight performance tests. These measures can be used to compare performance with that of a target reference group; develop baseline status; and track fall risk and multidimensional performance status. The MFRS will be studied and recommended for use as a practical and meaningful measurement tool essential in primary prevention (Jack M. Guralnik & Ferrucci, 2003).

*Habitual Gait Speed (HGS)*

*Description.* The HGS test is a timed walk test performed for 10, 15, or 20 feet at a functional velocity. The distance of choice for the HGS test should be feasible in the home or primary care setting. Length of the walkway should allow at least 3-4 walking cycles in order to be able to capture changes in gait patterns exhibited by low or high functioning individuals (Berg, Maki, Williams, Holliday, & Wood-Dauphinee, 1992; Montero-Odasso et al., 2005). The time to complete the test is associated with power of the ankle dorsiflexors and balance (J. M. Guralnik et al., 2000). Impairments of power and balance during gait are associated with fallers (R. H. Whipple et al., 1987). Slower gait speeds are found in individuals with vestibular pathology when compared to healthy age matched individuals (Hall & Herdman, 2006; Whitney et al., 2004). Aging causes a decrease in gait velocity and small step length (Bottomley & Lewis, 2003). Elderly fallers demonstrate various gait abnormalities; slow walking speed, decreased stride length and arm swing (L. Wolfson et al., 1990).

The subject is asked to walk at their normal, comfortable speed for 20 feet. Timing is started at the 5 foot mark and stopped at the 15 foot mark. The five feet at the beginning and end of the walk will be used to accelerate and decelerate from the walk. The test will be repeated once. The fastest gait speed will be recorded. Gait speed will be calculated by dividing the distance of 10 feet walked by the time in seconds it took to complete the task.

*Domain.* HGS is used to assess mobility, dynamic balance, and lower extremity power. Gait velocity is a measure of how well multiple systems, such as neurological, musculoskeletal, cardiopulmonary, are integrated into lower limb function.

*Purpose.* HGS is used to identify status of ambulation. In individuals with stroke, gait speed can determine household versus community ambulation status. Slow gait velocity is indicative of the need for referral for a complete physical evaluation. Specific changes in normal gait characteristics result in reduced gait speed that is predictive of falls. Impairments in the domains of mobility, balance, and strength required for normal gait speed can be used as signs of diseases, frailty, and preclinical disability. Gait velocity is also used as a strong predictor of risk for future adverse effects in the high functioning older adult. Several large studies of lower extremity function and gait speed found gait speed an important predictor of incident disability and adverse events. Recommendations by these studies are to use this test as a screening tool (Cesari et al., 2005; J. M. Guralnik et al., 2000; Lusardi et al., 2003).

*Reference Values.* Normative values for HGS are reported by gender and age decades. Mean gait velocities of 4.24-4.6 feet/second are reference values for the age decades 20-79 (R. W. Bohannon, 1997). Gait speeds of < 1.8 feet/second are reported as a higher risk for recurrent falls. Adverse events such as hospitalizations, requirement for a caregiver, future fractures, institutionalization, and death are predicted by gait velocity < 2.3 feet/second (Montero-Odasso et al., 2005; J. VanSwearingen, Paschal, Bonino, & Yang, 1996) (Wolfson, 1980). A large study consisting of 2,031 older participants demonstrated a gait speed cut off point of < 3 feet/second as high risk for incident major health related events; outcomes of persistent lower extremity limitation, hospitalization, and death (Cesari et al., 2005).

*Statistical Analysis*. Gait speed measures are highly reliable with coefficients of approximately .903. Age, height, and lower extremity strength correlate significantly, $P = .05$, with Pearson correlation of .190-.251.Weight, gender, and hip abduction on the nondominant side explain most of the changes at $r = .360$ by regression analysis (R. W. Bohannon, 1997; Hall & Herdman, 2006; Steffen et al., 2002). Sensitivity and specificity have been reported at 72 and 74 per cent respectively for determining individuals at risk for recurrent falls (J. VanSwearingen et al., 1996). Gait velocity has proven to be a better predictor of new falls than history of previous falls. Logistic regression analysis showed odds ratio of 10.9 from gait velocity versus 1.4 odds ratio from previous fall history (Montero-Odasso et al., 2005). Individuals with low gait velocity scores are reported to be 2.5 times more likely to have at least one adverse event.

### *Multidirectional Reach Test (MDRT)*

*Description*. MDRT is a measure of self-imposed movement that challenges limits of stability. An individual is required to maintain postural stability and lean and reach in the medial, lateral, anterior, and posterior directions without shifting the feet. Postural stability requires the body to maintain its center of mass within its base of support. The MDRT is an expansion of the Functional Reach Test (FRT) in which the individual is only asked to reach in a forward direction. Postural strategies and maximum center of gravity displacements have been shown to be different in the performance of the four directions in the MDRT when compared to the FRT. (S. Clark, Iltis, Anthony, & Toews, 2005; Duncan, Weiner, Chandler, & Studenski, 1990). Lateral and backwards displacements of center of mass are involved with falls causing hip and wrist fractures respectively (Hayes et al., 1996; M. C. Nevitt & Cummings, 1993). Lateral sway has been reported to be the single predictor of future falls when compared to anterior or posterior sway and clinical balance tests for fallers and adults with no history of falls (Bergland, Jarnlo, & Laake, 2003; Brauer et al., 1999; Chou et al., 2003; Greenspan et al., 1998; S. R. Lord et al., 1993; Maki et al., 1994). Backwards disequilibrium or retropulsion is commonly seen in the older adult or in someone who has a vestibular lesion. This tendency to fall backwards is especially evident when an individual has difficulty in bending the trunk forward due to joint movement restrictions, abnormal vestibular input, or fear of falling. Falls in the posterior direction are likely to occur when sitting down or taking a backwards step (Pfitzenmeyer, Mourey, Mischis-Troussard, & Bonneval, 2001). Several studies recommend that testing in only one direction, as in the FRT or Lateral Reach Test, not be used in isolation. The information from these balance tests is not interchangeable as they assess distinct components of postural stability (S. Clark et al., 2005; DeWaard, 2002).

The MDRT is performed by asking the subject to stand next to a wall where a yardstick or tape measure is taped horizontally at the level of the acromion. The subject is asked to stand with his heels four inches apart, raise arm of choice forward to shoulder level. Instructions follow asking subject to reach as far as he can along the yardstick, without moving his feet. The backwards direction is accomplished by asking the subject to lean back as far as possible without taking a step. The test is then continued to the right and the left directions. The investigator measures the starting position of the middle fingertip and then when the subject has stopped the test movement. The start and end positions are recorded and the difference is the recorded total reach for each direction tested. A second trial is performed for each direction. The test is terminated if the feet are moved or come off the ground. The sequence of directions tested should remain as described above (Newton, 2001; Steffen, Hacker, & Mollinger, 2002).

*Domain.* Postural stability and functional performance

*Purpose.* MDRT assesses limits of stability and the movement strategies used to maintain balance in stance. Assessment of lateral, anterior, and posterior sway with the arm in the reach position are used to predict fall risk and fractures (Brauer et al., 1999; Maki et al., 1994).

*Reference Values*. Reference values are available for adults aged 50-80 years of age. No significant difference has been reported between right and left direction scores. Age is a significant variable showing decreasing MDFT scores with increasing age. Height has an effect, but not significant, in several studies with the exception of increased height associated with increased backward reach scores (Brauer et al., 1999; DeWaard, 2002; Steffen et al., 2002). Newton, in a large community based study, reported older adult mean scores on the MDRT of: FR = 8.89 ± 3.4 in.; BR = 4.64±3.1 in.; RR = 6.86 ± 3.00 in.; LR = 6.61 ± 2.88 in. (Newton, 2001).

*Statistical Analysis*. The MDRT has been validated and found to be reliable in community dwelling older adults. Cronbach's alpha was reported to be 0.842 , at p ~ .0004 by Newton. Cronbach's alpha was not improved when each direction was taken out of the analysis; indicating the importance of testing each direction. Concurrent validity has been supported by moderate correlation with Berg Balance Scale; FRT, and TUG. An inverse relationship has been demonstrated with the TUG (DeWaard, 2002; Duncan et al., 1990; Jette, Giorgetti, & Harris, 1998; Newton, 2001). Construct validity with laboratory measures of center of pressure limits of stability are significant, with $r = .650$ (Brauer et al., 1999; Duncan et al., 1990). The MDRT will predict the nonfaller at an ICC of greater than .92. Activity level contributed to the scores for forward, right, and left directions at $p < .0004$. Fear of falling contributed to the backward direction score (Newton, 2001; Newton et al., 1997).

*Horizontal Dynamic Visual Acuity Test (hDVA)*

*Description.* Dynamic visual acuity reflects visual resolution during motion of the head or of the visual target. There is a normal loss of acuity to a moving image on the retina. This type of movement is said to demonstrate performance of the vestibule-ocular reflex (VOR). The VOR is the primary reflex responsible for stabilizing the eyes during head movement. When the VOR is dysfunctional, the image slips over the retina during head rotation and a retinal slip is produced (Aznar-Casanova, Quevedo, & Sinnett, 2005;

Tian, Shubayev, & Demer, 2002). Head movements diminish dynamic visual acuity for a stationary target in this instance. Testing will assess functional gaze by examining vestibular function during static head position and passive head movements. Positive result denotes vestibular hypofunction (S.J. Herdman, 2000; S. J. Herdman et al., 1998; S. R. Lord & Dayhew, 2001; S. R. Lord et al., 2003).

Assessment of the functional VOR system for gaze stabilization is performed by testing visual acuity with the head stable and moving at a frequency of 2 Hz in a horizontal direction. At low velocities between 22 degrees/sec and 43 degrees/sec an individual should be able to maintain accurate ocular pursuit of an object (Reading, 1972). The subject is seated 10 feet from a visual acuity eye chart. He is asked to read the smallest possible line out loud. The investigator will then place their hands on either side of the head from behind the subject. The head will be placed in 30 degrees of neck flexion to maximize stimulus to the horizontal semicircular canal. Unpredictable passive head movements will be imposed at a frequency of 2 Hz and a displacement of 15 degrees to both sides. Unpredictable head movements mimic normal random head movements during daily activities that cause a functional degradation of visual acuity. The subject will be asked to read the lowest line that is possible during twenty head movements. Results of the *h*DVA are expressed as the difference between acuity measured with the head stationary and acuity measured with the head moving. The subject should be able to read either the same line or the adjacent larger line as read during the static acuity part of the test (S. J. Herdman, Schubert, & Tusa, 2001; Rine & Braswell, 2003). Dynamic visual acuity is an important screening tool not only as a functional visual measure but also because of the possibility of enhancing this capability with training (S. J. Herdman, Schubert, Das, & Tusa, 2003; S. J. Herdman et al., 2001).

*Domain.* The *h*DVA is used to measure functional vision and vestibular deficiencies.

*Purpose.* Identify loss of functional vision and presence of vestibular hypofunction throughout the lifespan. Dysfunction in these two areas is predictive of increased balance and mobility functional limitations and heightened fall risk (Di Fabio et al., 2002; S. J. Herdman et al., 2003).

*Reference Values.* Dynamic visual acuity will be recorded as the number of lines lost during the maneuver. A *h*DVA score ≥ 3 is indicative of test failure and of the presence of vestibular deficit.

*Statistical Analysis*. Similar test-retest reliability ICC of .94 and inter-rater ICC of .84 are reported for the computerized or visual eye chart *h*DVA test. Reliability was high for both normal subjects and patients with vestibular deficits. The test has been used on young as well as elderly populations with similar findings. Sensitivity and specificity range from 94.5 to 100% in a review of dynamic visual acuity testing. Regression analysis demonstrated a significant relationship ($p < .001$) between age and unpredictable *h*DVA scores in healthy subjects and patients with unilateral and bilateral vestibular lesions. *h*DVA was affected more by the presence of vestibular pathology than age. (S. J. Herdman et al., 2001; Rine & Braswell, 2003). These studies supported previous work that showed a general trend of larger DVA scores with increasing age.

*Single Leg Stance (SLS)*

*Description*. SLS measures higher level balance ability. A narrow base of support and removal of vision combine to provide a challenge to individuals at a fairly high level of function. Removal of vision allows assessment of how much the visual system is dominating the vestibular and somatosensory systems. Young children and older adults show a reliance on the visual system for static balance, single or bilateral stance(Newton, 1997). Individuals with a reliance on the visual system will experience difficulty with low light situations; when they will have to step over obstacles; and navigate on uneven terrain (R. W. Bohannon, Larkin, Cook, Gear, & Singer, 1984; B.J. Vellas et al., 1997). Single leg stance is incorporated into the stance phase of gait for the supporting lower extremity; is a part of stair climbing maneuvers; or is a part during recovery of balance during weight shifts forced over one lower extremity. Balancing over one extremity requires static balance and integration of visual, vestibular and kinesthetic sensory input. Muscle strength is required up the kinetic chain to maintain postural stability. Extensive work completed by Fregly in 1966 developed normative data for ages 17 - 71 by gender. SLS then and now is a timed balance test that is interpreted with respect to the adult's age. When young adults are timed without a terminal time, they were able to maintain SLS for 3-5 minutes. It showed the earliest differences in postural stability at age decades starting with age 40. SLS test has been recommended as a routine screening tool to be used for females aged 40-50. Bohannon et al report the Pearson product-moment and Spearman correlations of age and duration of one-legged balance were -.65 and -.71 with eyes open and -.79 and -.75 with eyes closed respectively. A mediolateral instability accompanied the drop in SLS scores in the 40 decade age group in women (Choy et al., 2003). SLS score correlated with amplitude and speed of sway during static balance. Deficits with SLS are associated with increasing difficulty in stair climbing; IADL deficit requiring assistance with transportation; and poor self assessment of health status. (Knutzen et al., 2002; B.J. Vellas et al., 1997).

SLS is performed on a noncompliant surface. Subject will be asked to stand on one leg with the nonsupporting leg flexed to 90 degrees at the knee. Test may be performed with or without shoes. Arms will be crossed across the chest with the hands touching opposite shoulders. Subject is asked to focus on a target about 3 feet in front of them while maintaining the position for 30 seconds. The test will be terminated if the subject shifts supporting foot position or the elevated foot touches down. The test is then repeated with the opposite leg. The test sequence will be repeated with the eyes closed. The subject will be asked to focus on a target prior to closing the eyes (R. W. Bohannon et al., 1984; Curb et al., 2006).

*Domain.* Static balance and lower extremity strength within a narrow base of support.

*Purpose.* The time an adult can maintain the SLS can be used to predict serious falls in the older adult as well as used to measure physical function level (Curb et al., 2006; B.J. Vellas et al., 1997).

*Reference Values*. Expect decreased ability to maintain SLS in age decades starting with age 40. (Giorgetti, Harris, & Jette, 1998). Score ranges for the SLS is dependent on the terminal time used to discontinue the test. Use of 30 seconds as the terminal time is common practice in the literature. Normal SLS time is 30 seconds and abnormal is < 5 seconds with no significant difference between right and left legs.

Normative data is provided for each decade age group from 20-29 to 70-79 (20-29: ranges of 29-30 eyes open and 21-28.8 eyes closed; 60-69: scores of 22.5 eyes open and 10 eyes closed; 70-79: scores of 14.2 eyes open and 4.3 eyes closed) (R. W. Bohannon et al., 1984; Curb et al., 2006). A recent meta-analysis showed slightly higher values and normative values for the 80-89 age group of 8.5 seconds (60-69: 27 seconds eyes open and 70-79: 17.2 seconds eyes open)(R. Bohannon, 2006).

*Statistical Analysis.* Validity and reliability of the SLS test has been demonstrated in several studies. Inter-rater reliability for SLS test has been found to be .75 and .85 respectively for a normal and a disabled adult (R. W. Bohannon et al., 1984; Gehlsen & Whaley, 1990). Test-retest reliability coefficients have been reported in the range .70-.96 for the eyes open SLS (Franchignoni, Tesio, Martino, & Ricuper, 1998; Giorgetti et al., 1998; Knutzen et al., 2002).

*Ankle Dorsiflexion ROM*

*Description*. Dorsiflexion range allows anterior translation of the tibia over the foot while the heel is kept on the ground during the mid-stance phase of gait. Restriction of ankle range of motion will change the dynamics of the kinetic chain during gait. Decreased time to heel off and decreased knee extension are two gait abnormalities that occur as a result of impaired dorsiflexion at the ankle (Johanson et al., 2006). Restricted ankle movement affects balance and functional activities. Safe ambulation, postural stability, and adaptations to movement of the center of mass over the base of support are possible with normal ankle range. In stance, ankle strategy, movement of the leg over the foot, is used to maintain postural stability and prevent loss of balance (S.J. Herdman, 2000). Stair climbing, sitting down, and standing up are other functional activities strongly influenced by range of motion at the ankle. In older adults, ankle dorsiflexion occura through a greater range of motion when compared to younger adults in sit to stand transitional movements. Healthy older adults maintain ankle range of motion, a significant difference from fallers in ankle flexibility (R. W. Bohannon, 1995; Gehlsen & Whaley, 1990; Gross, Stevenson, Charette, Pyka, & Margos, 1998). Moderate to strong correlations between ankle ROM and balance abilities on gait tests and Functional Reach Test exist (Mecagni, Smith, Roberts, & O"Sullivan, 2000).

Choy et al., in a study of 372 women within age decades of 40-80, reports a significant relationship between ankle range of motion and falls. A difference of at least eight degrees less ankle range was found in fallers versus nonfallers. Age showed a significant effect on ankle dorsiflexion with a demonstrated decline in range between age cohorts 40 through 70s. A significant three way effect between age, falls, and activity level was also seen.

Passive dorsiflexion ROM is measured in a nonweightbearing position. The subject can be seated or lying down. The knee can be held in flexion or full extension to isolate the soleus or gastrocnemius respectively. In a quick screen of functional range of motion, the most conservative method in terms of positioning and range of motion was chosen. The subject will be asked sit in a chair with the knee in extension (Magee, 1997). The investigator will grasp the heel with one hand and pull distally on the calcaneus, passively moving the ankle and foot into maximum dorsiflexion. Measurement is taken with a goniometer that is placed laterally over the calcaneus, with one arm extending towards the fibular head and the second arm extending along the fifth metatarsal (Hoppenfeld, 1976).

*Domain.* Gait and functional activities

*Purpose.* Ankle range of motion allows safe and efficient ambulation. Greater range is required for the performance of functional activities such as stair climbing and rising from a chair.

*Reference Values.* Ankle dorsiflexion range of motion of 10 degrees is necessary for normal locomotion. Normal range with the knee extended is 20 degrees past the anatomic position (Magee, 1997).

*Statistical Analysis.* Intra-rater and inter-rater reliability for passive ankle range of motion are high at $r$ = .90 – .99. Ankle range and falls have a significant relationship at $p$ = .025 (Choy et al., 2003).

*Timed Up and Go Test (TUG)*

*Description*. The TUG is a test of basic functional mobility, balance, lower extremity strength, and gait; ICC=.99 (Podsiadlo & Richardson, 1991). The test has undergone variations in procedure and is associated with functional dependence and functional mobility (Mathias, Nayak, & Isaacs, 1986; Shumway-Cook et al., 2000). Currently it is being recommended to serve as a fall risk assessment tool by medical and health promotion professionals (AGS, 2001; NCOA, 2005; Okumiya et al., 1998). The subject is asked to rise from a standard chair (≈ 18 inches); walk at a comfortable gait speed to a line on the floor three meters away; turn around and return to the chair and sit down. The score given is the time taken in seconds to complete the test. The test measures mobility in individuals that are able to walk on their own with or without the assistance of a cane or walker. The time taken to complete the task has a strong inverse relationship to level of functional mobility and independence in ADLs.

Work by Podsiadlo and Richardson indicated that medically stable individuals showed little variation in their TUG score. It was then presumed that poor performance on the TUG could reflect subtle changes in fall risk factors as a result of medication, disease, and acute medical conditions. A study of 157 older adults aged within the same decade found that the TUG could differentiate clearly between the nonfallers versus the one time and frequent faller groups. The TUG was moderately associated with both mobility and lower extremity power. The test was also able to correctly classify 72 percent of the individuals regarding fall status, with 98 percent of the fallers correctly classified (Gunter, White, Hayes, & Snow, 2000). The TUG also has shown correlation with the Berg Balance Scale, Gait speed, Barthel Index, and Multidirectional Reach Test with moderate to high reliability. Physical activity level and fear of falling have been found to contribute to score on the TUG (Newton, 1997; Podsiadlo & Richardson, 1991).

*Domain.* Functional mobility

*Purpose.* The TUG identifies elderly individuals who are physically independent; individuals who are dependent or frail and not able to transfer or walk without assistance. Several studies have demonstrated that the TUG is able to identify individuals prone to fall in the next six months to five years (Kristensen, Foss, & Kehlet, 2007; Okumiya et al., 1998).

*Reference values*. The normal range of time to complete the TUG is 7-10 seconds. A meta-analysis of 21 studies presented mean reference values at 95% confidence intervals by three age decades (60-69: 8.1 seconds; 70-79: 9.2 seconds; 80-89: 11.3 seconds) (R. Bohannon, 2006). There are no significant gender differences reported in the literature. These scores are similar to the original findings by Podsiadlo and Richardson.

The test score can be predictive of high risk for falls at an 80 percent sensitivity and 100 percent specificity with a score of greater than 13.5 seconds (Okumiya et al., 1998; Steffen et al., 2002). A score of greater than or equal to 30 seconds corresponds with functional dependence in adults and is associated with falls (Bischoff et al., 2003; Kristensen et al., 2007; Podsiadlo & Richardson, 1991). These values were found in older adults with and without neurological diseases. A score of > 12 seconds on the TUG has been determined as a cut-off value for community dwelling elderly women who should receive early evaluation and intervention (Bischoff et al., 2003).

*Statistical Analysis.* The TUG predicts falls in elderly community dwelling adults at a very high inter-rater reliability (*r*) of .98; sensitivity of 87 percent; and specificity of 87 percent (Kristensen et al., 2007; Shumway-Cook et al., 2000). Content validity is present as the TUG assesses common transitions and skills used routinely in daily life. Concurrent validity is demonstrated by significant correlations with more formal tests of balance, gait speed, and functional ability (Mathias et al., 1986; Podsiadlo & Richardson, 1991).

*Five Times Sit to Stand Test (FTSST)*

*Description.* The FTSST is a measure of lower extremity strength, power, coordination, and postural stability during a transitional activity. The sit to stand task is a basic mobility skill that is required in daily life and for physical independence. Transition from sit to stance requires lower extremity strength, power, and coordination in terms of timing and maintenance of center of mass over a stable base. Postural stability is required for the static and dynamic portions of the FTSST (Foldvari et al., 2000; Lindemann et al., 2007).

The procedure for administering the FTSST requires the subject to be seated with their backs against a chair, 18 inches in height, with their arms crossed at the chest. The subject is instructed to stand five times as quickly as possible from the chair when the investigator says “go”. He is to sit completely down between each repetition without leaning back in the chair. The subject will be allowed to practice one sit-stance-sit repetition in order to adjust feet placement comfortably underneath them and to get a feel for the height of the chair. The investigator will commence timing on “go” and stop timing when subject completes the five repetitions and the buttocks touch the chair. The duration for the five repetitions will be recorded in seconds. One trial is recorded. The FTSST is considered easy to administer and has been widely used as part of a performance battery of tests. The specific procedure varies in the literature. The procedure described here is the same one used to validate the FTSST (S. R. Lord, Murray, Chapman, Munro, & Tiedemann, 2002; Whitney et al., 2005).

Literature review shows extensive work in understanding the relationships of how to measure strength, power, and functional performance as well as how much these variables affect the final functional activity. Knee extension strength is correlated with independence in sit-to-stand performance (R.W. Bohannon & Eriksrud, 2003). Lower extremity power is significantly associated with physical performance. Ankle power is a primary predictor of FTSST time, even more so than leg strength. (Bean et al., 2002; Suzuki et al., 2001). Measurement of strength and power by other means than functional performance is not seen as a correlate of performance, although an association of all these testing techniques is present (Lindemann et al., 2007). Several studies have reported a weak association between FTSST and adult age groups with balance deficits, with exception of individuals over 80 years old. Age became a strong predictor of FTSST performance in individuals without balance dysfunction (S. R. Lord et al., 2002; Whitney et al., 2005). FTSST scores demonstrate moderate correlation with measures of gait and dynamic balance: gait speed, TUG, Dizziness Handicap Inventory, Dynamic Gait Index (DGI), and Activities-Specific Balance Confidence Scale (ABC). As the scores improved in the FTSST, improvement was seen in the other tests (Meretta, Whitney, Marchetti, Sparto, & Muirhead, 2006). Sit-to-stand is influenced by a variety of sensorimotor, balance, and psychological processes. Visual contast sensitivitiy, proprioception, reaction time, postural sway, pain, anxiety, knee and ankle strength are reported to be significant and independent predictors of performance on the FTSST. The FTSST is not a simple assessment of one physiological system but requires integration of all these systems in order to perform the transitional skill of sit-to-stand. Deficits in these physiological systems are strong fall risk factors (S. R. Lord et al., 2002). Utilizing the FTSST in a fall risk screen is logical since a good number of falls occur during the sit-stand-sit transfer. The FTSST does not demonstrate a ceiling effect with younger and higher functioning older adults (Lindemann et al., 2007).

*Domain.* Functional lower extremity performance in terms of strength, power, and dynamic balance during transitional activity

*Purpose.* The *FTSST* is a measure of lower extremity strength, power, and balance. Transitional movements of sit to stance and stance to sit can be assessed during the FTSST. Postural stability during the transitional movements and in stance can be evaluated as well. The FTSST serves to quantify lower extremity performance (R. W. Bohannon, 1995). This test is used to discriminate individuals with balance dysfunction when performing transitional movements important to daily life. Discriminative properties of the FTSST are greater with individuals younger than 60 years of age.

*Reference Values.* FTSST time of 10 seconds is identified as the cutoff value for predicting balance dysfunction at the best combination of sensitivity and specificity in individuals younger than 60 years old. In adults older than 60 years of age, 14.2 seconds has been reported as the cutoff for optimal sensitivity and specificity. FTSST score of 10 seconds is the reported cutoff for the younger adult (Whitney et al., 2005).

*Statistical Analysis.* Intra-class correlation is reported at .89 reliability in testing older community dwelling adults (S. R. Lord et al., 2002). Convergent construct validity is high due to significant correlations between knee extension manual muscle test scores, dynamometer measurements, and the sit to stand test (R. W. Bohannon, 1995). A positive identification of vestibular dysfunction has been reported at 61 percent. The FTSST, Activities-specific Balance Confidence Scale, and Dynamic Gait Index together and separately are able to discriminate between adults with and without balance dysfunction at 85 percent discriminative ability (Whitney et al., 2005).

*Standing Single Heel Rises*

*Description.* Standing Single Heel Rise Test is a functional strength test of lower extremity strength and power. Body weight is used as the resistance to more closely simulate what happens during the stance phase of the gait cycle. The original standing heel rise test was administered to 203 individuals, aged 20-50 years with no known muscle weaknesses. The average number of heel rises was 27.9 for all age groups with no difference between genders. Several studies have been reported using the Standing Single Heel Rise test with similar findings (Lunsford & Perry, 1995; Svantesson, Osterberg, Thomee, & Grimby, 1998). Ankle plantar flexor power is associated with decreased step length and velocity in the older adult gait cycle. Power and strength at the ankle account for a significant variance in the 6 minute walk test. Hip and knee measurements of strength and power do not demonstrate significant association with the 6 minute walk test (Bassey et al., 1992; Judge, Ounpuu, & Davis, 1996). Ankle plantar flexor strength and power have been demonstrated to be predictive of gait performance in healthy and in mobility limited individuals. Heel rise from foot flat in the gait cycle is responsible for limiting center of mass displacement. Heel rise, a determinant of gait, contributes to an economic and normal gait pattern (Bean et al., 2002; Kerrigan, Croce, Marciello, & Riley, 2000).

The standing single heel rise test is performed by asking subject to stand on one leg with opposite leg flexed at the knee and foot off the ground. A finger tip touch for balance support is allowed on the opposite side as the weight bearing leg. The subject will be asked to plantar flex the supporting limb and raise the heel off the ground as completely as possible for 25 repetitions. A metronome will be set at 60 beats per minutes. The subject will be instructed to raise the heel on one beat and then drop down on the next beat. The test score will be the number of heel rises (from heel to the metatarsal heads) completed. Trunk and limb alignment, and finger tip pressure are monitored for excessive sway or pressure throughout the test. (Lunsford & Perry, 1995; Svantesson et al., 1998).

*Domain.* Lower extremity function in the areas of functional strength and power measured with ankle plantar flexion.

*Purpose.* Identification of strength and power in the ankle plantar musculature is performed in reference to their association with mobility limitations and gait performance. Impairments in plantar flexors increase energy cost and decrease safety during ambulation. Loss of strength and power also distinguishes fallers from nonfallers (Kerrigan et al., 2000; R. H. Whipple et al., 1987). Peak power of the ankle plantar flexors is an independent predictor of chair rise time at a $p < .0005$ (Suzuki et al., 2001).

*Reference Values.* A score of 25 repetitions will be required to receive a grade of normal strength. An individual that can not raise heel up but is able to hold heel up is given a fair muscle strength grade (Lunsford & Perry, 1995).

*Statistical Analysis*. Descriptive statistics are present for reference values of the standing heel rise test (Lunsford & Perry, 1995). Content validity and concurrent validity have been demonstrated in a variety of studies. No significant difference exists between age groups ($p = .906$) (Kerrigan et al., 2000; Svantesson et al., 1998; R. H. Whipple et al., 1987).

## Summary

This chapter presented a literature review based on individual randomized controlled trials (RCTs), meta-analysis and systematic review of RCTs, and community based longitudinal observational studies. Fall demographics and consequences are outlined from national government reports and longitudinal studies. A best evidence approach to this review lends strong support to the organization of this study. Research brings evidence of causal relationships of factors that put a person at risk for a fall. National government guidelines have used this approach to provide direction to fall prevention programs and strategies to minimize fall risk factors and thereby provide primary prevention of falls and their consequences in terms of individual and societal costs.

Health promotion, discussion of the disablement model, and how the identification of fall risk can be carried out as a primary and secondary prevention strategy were outlined. Fall risk stratification is a lifestyle change recommended for all adults, young and old. Health promotion can facilitate fall prevention through enhanced awareness of the problem; change of behavior in terms of modifiable risk factors; and creation of an environment that supports good health practices. It is important to keep in mind that falling in the older adult is a combined issue of high incidence and high susceptibility to injury due to prevalence of acute and chronic medical conditions and the natural aging process.

The natural aging changes that can predispose the adult to fall were reviewed. Fall risk factors and their correlation with falls and loss of functional independence were described. Due to the complex nature of determining which risk factors precipitate a fall, modifiable risk factors have been recommended as the variables to assess for fall risk. Modifiable risk factors, such as mobility, were highlighted in this chapter. Mobility, a primary intrinsic risk factor and a powerful predictor of fall risk, has been a major focus of prevention strategies.

Evidence-based test development was outlined. These principles were used for the establishment of a short, evidence-based clinical measure of physiological and functional performance for the community dwelling adult. Physiological tests serve to detect physical impairments in the somatosensory, vestibular, and visual systems. Functional or performance based tests examine activities of daily living. Measurement instruments that are comprised of these two types of assessments have been well researched and shown to identify older adults at risk for falling, functional decline, and institutionalization. Tests need to be chosen taking into consideration age, health status, and functional status in order to be efficacious. Psychometrics in use in the fall research literature were reviewed. Correlations of these test measures were compared with the physical performance tests in their ability to predict future falls. Primary modifiable predictors of fall risk will be taken into consideration as the performance parts of the fall risk screen are selected.

This study will endeavor to develop and use an evidence-based multidimensional instrument that is simple to administer in terms of time, space, and equipment. The components of the Multidimensional Fall Risk Screen (MFRS) will be comprehensive enough to assess the risk factors that research has identified as key predictors of fall and fall related injuries. The necessary domains of functional vision; static and dynamic balance; functional mobility; gait; and lower extremity strength and power are assessed by the eight component tests that make up the MFRS. The risk factors selected to assess each of the domains will be potentially modifiable by targeted interventions. A preliminary set of reference values for the MFRS and its components will be developed that range from the younger adult to the old-older age decades of independent community dwelling adults. The MFRS components will be used to identify community dwelling adults through out the adult life span who have positive preclinical mobility impairments and functional limitations. These adults will be predisposed to a risk for falling and functional dependence.

Fall risk stratification can be used to categorize adults by categories of fall risk. Fall prevention programs could then be utilized to educate and provide specific strategies at each fall risk level. Administration of the MFRS will help target types of prevention and specific treatment interventions to reduce identified impairments, functional limitations, and risk for falls. Long term effects of physiologic and performance based periodic screening and resultant intervention will help to decrease morbidity and mortality in a greater number of older adults by providing a basis for intervention earlier in life before they become functionally dependent. Review of the literature provides efficacy for establishment of reference values for the component tests for the adults younger than 65 years of age. The MFRS can provide a basis for earlier screening and prompt intervention. The MFRS should provide a practical, evidence based approach for screening in the community; identification of impairments and preclinical disability; and stratification of fall risk to provide direction for targeted intervention.

# CHAPTER III

# Method and Procedures

## Introduction

Cognitive, physiological, and psychosocial factors have been shown to be associated with falls. A major purpose of this descriptive cohort study was to compile a short instrument to identify physical impairments and functional limitations that can lead to fall risk in community dwelling adults. Research has shown that combined multifactorial assessment and management program are effective in reducing the risk of falling in the older adult (Chang et al., 2004; Tinetti, Baker et al., 1994). The American Geriatric Society, American Medical Association, and the Falls Free Initiative, professional and national organizations, recommend fall risk screening as a primary fall prevention strategy. Currently, implementation of these recommendations is incomplete. If screening can occur in the community or even initiated by the consumer, there would be two other avenues open to fall prevention strategies.

The Multidimensional Fall Risk Screen (MFRS), the instrument developed for this study, is a simple eight category screen for physical impairments and functional limitations (Appendix A). The screen, a compilation of sixteen test components that can identify modifiable fall risk impairments, will determine the need for further examination by a medical professional or if community based fall prevention strategies will be adequate for the individual. The individual subtests were chosen purposefully as reliable and valid tools that provide multidimensional fall risk examination which can be administered within a few minutes with minor instrumentation and space. This study sought to provide expanded performance reference values for six adult age decades. The reference values will be of immediate use to fall prevention practitioners in comparing client data.

The second objective of this study was to offer the MFRS as a primary prevention strategy to provide fall risk stratification in the younger and middle aged adult. The MFRS will be able to be used to target specific modifiable impairments and functional limitations for intervention prior to fall incidence in the adult, thereby weakening the combined causal relationship of aging and disease with fall risk. Statistical analysis of each component test was performed to determine the effects of age to fall risk throughout six age decade groups, from 20 through 79 years old.

The study provided the type and degree of impairment in each of the six age decade groups. The third objective was to be able to recommend routine fall risk stratification throughout the adult lifespan and not just to those adults 65 and older. The relationship of physical activity, gender, and aging on the component scores was also be studied.

## Study Population

One hundred-ninety independent community dwelling adults, 20 years to 79 years of age, were asked to volunteer for this cross sectional study. Subjects were recruited from church, community centers, school districts, and business groups to ensure diversity of educational and socioeconomic backgrounds were represented in the sample. The investigator personally contacted the centers and groups to enlist their assistance in recruitment. They were assigned to one of six age groups based on their chronological age. The six age groups were: I-20-29; II-30-39; III-40-49; IV-50-59; V-60-69; VI-70-79.

Approximately thirty subjects made up each decade age group. Close to equal representation of males and females made up each decade age group. Each subject signed an informed consent and HIPPA confidentiality form approved by the University of Missouri-Columbia Internal Review Board. Subject exclusion criteria consisted of significant cognitive, neurological, and orthopedic disabilities that disallow functional independence. Acute illness, unstable or limiting cardiac or pulmonary disease, and visual impairment that disallow person recognition at ten feet also excluded participation in the study (Tromp et al., 2001). Participants in the study volunteered for a one time screening that involved consent, completions of health status questionnaire, and physical performance battery of tests. All participants were tested independent of others in the study. On completion of the study, each participant received a summary of the MFRS impairment results (Appendix D). Recommendations for remediation of modifiable fall risk factors were included with information on each subject's fall risk. Testing took place at a variety of community settings. Churches, library meeting room, school cafeteria, school gymnasium, and work settings made up most of the testing sites.

## Study Variables

This study used a self-report Health Status Questionnaire (HSQ) and the Multidimensional Fall Risk Screen (MFRS), a performance based measure of fall risk. The MFRS is a collection of sixteen fall risk component tests. Age was the independent variable and the MFRS component tests scores served as dependent variables. Physical activity and sex were analyzed as additional independent variables and covariates to aging in subsequent analyses in this study.

*Health Status Questionnaire*

Demographic and health status information was be collected by interview and by completion of the self report HSQ. Each subject was asked to identify the presence of intrinsic and extrinsic fall risk factors that were present in their fall history within the past year. Falls were described as a loss of balance and subsequent unintentional fall onto the ground or other supporting surface (Kellog, 1987). A history of ≥2 falls would denote fall risk. The investigator inquired about the presence of limitations in mobility, activities of daily living (ADLs), and instrumental activities of daily living (IADL). Presence of protective sensation on the plantar surfaces of both feet was determined by testing five common zones (great toe, $5^{th}$ toe, $1^{st}$ and $5^{th}$ metatarsal heads, and heel) with a 5.07 Semmes Weinstein monofilament. Physical inactivity constituted less then 5 days/week moderate activity accumulated for 30 minutes in excess of normal ADLs, IADLs; or vigorous activity less then 3 days/week of 30 minutes. Presence of medication use known to be fall risk factors or polypharmacy was noted. Comorbidities, especially diseases of the musculoskeletal, neurological, and cardiovascular systems were interpreted as fall risk factors. History of dizziness, muscle weakness, and pain were also interpreted as risk factors. Fear of falling and falls efficacy were examined by single question approach recommended for fall risk screening. Their presence was each counted as a fall risk factor (Friedman et al., 2002; Murphy et al., 2002; Newton et al., 1997). Mental status was determined by orientation to person, place, time, and date. If the subject had difficulty with these questions, cognitive impairment would have been screened by administration of the Short Blessed Test (SBT) (Appendix C). A score of ≤ 6/28 was to have been considered normal cognition (Brooke & Bullock, 1999; Katzman et al., 1983). Cognitive status from this questionnaire was recorded on the HSQ. The number of fall risk factors from the HSQ were tabulated (Appendix B). Four or more risk factors identified on the HSQ categorized the subject as  high risk for falling (HHQIOSC, 2007; M. C. Nevitt et al., 1989).

Resultant information from the HSQ and MFRS determined nature of impairments / fall risk factors and functional limitations. The MFRS component tests mean scores served as preliminary data for decade age groups reference values. Fall risk stratification of each of the participants was possible as a result of this process from tabulation of HSQ and MFRS risk factors.

*Multidimensional Fall Risk Screen Component Tests*

Subjects were asked to complete the HSQ and then to undergo physical performance testing with the MFRS. The MFRS, a sixteen item screening tool (Appendix A) was constructed from commonly used evidence physical performance measures. Test components on the MFRS were organized to be performed without excessive position change and fatigue. Total time for administration of the battery was approximately fifteen minutes. The MFRS consists of the following component tests:

*Habitual Gait Speed.* Habitual Gait Speed is associated with the functions of mobility, dynamic balance, and lower extremity power. Subjects are asked to stand with their feet behind a starting line marked on the floor and then to walk 20 feet using a typical comfortable pace. Timing commences at 5 feet and is be stopped at 15 feet to account for acceleration and deceleration of the gait speed. The test is repeated one time. A 10 foot walk is used to determine habitual gait velocity. Velocity is calculated by dividing the distance in feet by the time in seconds it took to complete the walk. Gait speed of < 3.3 ft/sec was used as the threshold value for a fall risk factor (R. W. Bohannon, 1997; Cesari et al., 2005; J. M. Guralnik et al., 2000; Suzuki et al., 2001).

*Multidirectional Reach Test.* Multidirectional Reach Test measures self-imposed movement that challenges limits of stability in an anterior, posterior, right, and left direction. Movement strategies are assessed during a functional performance. The subject stands with arm of choice raised at shoulder height with an outstretched hand for the forward and backwards tasks; similar starting position are used for right and left reaches while using the respective arms. A yardstick is positioned level with the out stretched arm. The subject is asked to lean while reaching as far as they are able to in a forward, backward, right & left direction while maintaining their feet flat on the floor. The out stretched arm and hand will need to stay level with the yardstick. The start and end positions of the middle finger are used to determine reach. Reach is recorded in inches. One practice trial is permitted for each direction. There are no fall threshold values available in the literature, except for forward reach with a threshold value of < 10 inches (Brauer et al., 1999; Newton, 2001).

*Horizontal Dynamic Visual Acuity (hDVA).* Horizontal Dynamic Visual Acuity testing assesses functional gaze with respect to vestibular function during unpredictable passive head movements. Static and horizontal dynamic visual acuity are tested using a Visual Acuity Eye chart. The subject is seated 10 feet from the eye chart. Static acuity is recorded as the last line that can be read clearly. A metronome set at 120 beats per minute (frequency of 2 Hz) guides the investigator in oscillating the subject's head to the right and to the left with each beat. The head is held from behind in 30 degrees of neck flexion and rotated side to side 20 times about a 30 degree arc. The subject is asked to read the lowest line possible during the passive head movements. The investigator will count how many lines were lost during the head rotations. Dynamic visual acuity is recorded for unpredictable passive head movements as the number of lines lost during the maneuver. A loss of ≥ 2 lines is indicative of vestibular dysfunction (Hall & Herdman, 2006; S. J. Herdman et al., 2001; S. J. Herdman et al., 1998; Rine & Braswell, 2003).

*Single Leg Stance.* Single Leg Stance is a test of lower extremity strength and static balance within a narrowed base of support. Subject is asked to cross their arms across the chest touching shoulders; stand on one leg with the opposite leg bent at the knee and foot held off the floor. Subject is then asked to focus on a target about three feet in front of him/her. Right and left lower extremities are tested individually with eyes open and then with eyes closed. The time in seconds up to 30 seconds is recorded. The test is to be stopped if the subject demonstrates inability to hold the position or lets the opposite foot down. A threshold value of < 5 sec is indicative of significant impairment in balance (R. W. Bohannon et al., 1984; Choy et al., 2003; A.R. Fregly & Graybiel, 1966; B. J. Vellas et al., 1997).

*Ankle Dorsiflexion Range of Motion.* Passive ankle dorsiflexion is a component of a normal gait pattern and is required for movement strategies used to maintain balance. Subject is seated in a chair. Right and left passive ankle dorsiflexion is measured with a goniometer. The knee to be measured is placed in extension. Right and left passive ankle dorsiflexion are measured with a goniometer. The measurements are to take place from the lateral side of each ankle. The arms of the goniometer are lined up with the fibula, calcaneous, and fifth metatarsal head. Ankle range of motion with the knee extended requires 10 degrees for normal locomotion (Johanson et al., 2006; Ostrosky, VanSwearingen, Burdett, & Gee, 1994).

*Timed Up and Go Test.* Timed Up and Go Test is a measure of basic functional mobility where balance, lower extremity strength, and gait patterns can be screened. Ability to perform transitional movements is also evaluated during this task. The subject is seated in a chair, with their back resting on the back of the chair. When the investigator says "go", the subject is to stand up from a standard height straight chair (18 inches without arm rests), walk forward to a line 10 feet in front of them, turn around, walk back to the chair, and sit back down in the chair. This is to be performed at a comfortable and safe pace. The subject walks through the test once before being timed in order to become familiar with the test. The time is recorded in seconds from the point the subject leans forward in the chair until the subject returns to the seated position and their back touches the back of the chair. An assistive walking aide such as a cane or walker can be used. A score of > 12 seconds is indicative of disability and risk of falling (Podsiadlo & Richardson, 1991; Shumway-Cook et al., 2000). A meta-analysis by Bohannon in 2006 presented mean normal values up to 10 seconds in the 70-79 age group.

*Five Times Sit to Stand Test.* The Five Times Sit to Stand Test is a measure of lower extremity power and of the ability to transition from one position to another. The subject will be seated in a chair (18 inches without arm rests) with their back against the chair. Subject is instructed to rise from a chair five times as fast as possible with their arms folded across their chests. Subject is instructed to stand up completely between repetitions. Subject is advised not to touch the back of the chair during each repetition. The subject is asked to perform one practice trial of sit to stand to get the feel of posture and comfortable placement of feet. The investigator begins timing on the word ”go”, and stops timing when the subject completes the fifth repetition when they complete the fifth stance. Score of ≥ 10 seconds is predictive of balance dysfunction (Bean et al., 2002; R. W. Bohannon, 1995, 1998; S. R. Lord et al., 2002; Suzuki et al., 2001; Whitney et al., 2005).

*Standing Single Heel Rises.* Standing single heel rises are reflective of functional lower extremity strength. The subject is instructed to stand on one leg with the opposite leg flexed at the knee and foot off the ground. Finger tip touch for balance on a supporting surface is allowed on the opposite side as the weight bearing leg. The subject is instructed to plantar flex the supporting limb and raise the heel off the ground as completely as possible for 25 repetitions. A metronome is set at 60 beats per minute. The subject is instructed to raise the heel on one beat of the metronome and then drop down on the next beat. The test score equals the number of heel rises completed as long as the heel and plantar surface is off the floor to the metatarsal heads (Svantesson et al., 1998) .

The investigator will start the metronome; demonstrate test movements; and then observe subject’s ankle plantar flexion ROM during the first heel rise. The subject is asked to stand straight and to rise and lower on the balls of their feet in rhythm with the metronome, set at a rate of one heel rise every two seconds. Each leg is to be tested separately. The subject is to continue the activity until they have completed 25 heel rises. The test is to be stopped if the subject leans and bears weight on their hand; the plantar flexion ROM decreases with more of the plantar surface of the foot then just the toes and metatarsal heads staying on the ground; or the subject asks to stop the test. A score of < 25 heel rises is indicative of strength impairments in the lower extremity leading to impairment in gait performance (Johanson et al., 2006; Lunsford & Perry, 1995; Robinovitch et al., 2002; Svantesson et al., 1998).

## Instrumentation

A quiet physical space with a standard height chair without arm rests of approximately 18 inches, a table, wall, and 20 foot walking area was required for test administration. Equipment necessary to administer the HSQ (Appendix B) and MFRS included a stopwatch, tape measure, yardstick, goniometer, metronome, visual acuity eye chart, and a 5.07 monofilament. Test packets consisting of IRB, HIPPA forms, and the self-report HSQ were given to each participant to complete prior to screening with the assistance of the investigator. The SBT was to be utilized if the subject was not orientated to person, place, time, and date. A MFRS recording form was used to document the physical screening test component results. Each subject received a MFRS Summary form with physical therapy recommendations as indicated by the presence of impairments upon completion of the testing (Appendix D). The completed screening form served as a record of their fall risk stratification. All testing was administered by the primary investigator with the assistance of a physical therapy student. The student was required to undergo IRB and HIPPA training approval prior to participating in the study. Both investigators tested the first twenty subjects together, checking the timing and verbal instructions for consistency between investigators. The investigators used standby guarding to provide a safe test perimeter and minimize the risk of injury during the testing.

## Statistical Analysis

Statistical analyses were conducted using SPSS 16.0 (SPSS Inc.2005) and statistical textbook *Applied Multivariate Statistics for the Social Sciences*, 4th ed. by Stevens J.P., 2002. Descriptive statistics were used to identify subject self reported fall risk characteristics that included age, fall history, mobility and ADL limitations, physical inactivity, medications, medical conditions, dizziness, muscle weakness, pain, fear of falling, and self efficacy. A primary objective of the study was to provide a sample set of reference values for the MFRS physical performance component test scores by decade age groups from 20 to 79 years of age. Descriptive analysis of group means and standard deviations were calculated to provide the age decade reference values for each of the sixteen tests.

Impairment frequencies from each of the MFRS component scores across age decades were tabulated to determine nature of the deficits picked up during screening.

The statistical hypotheses are:

$Ho_1$: There will be no significant difference in the MFRS component scores across the six age decade groups tested.

$Ho_1$: $A1_{1\text{-}16} = A2_{1\text{-}16} = A3_{1\text{-}16} = A4_{1\text{-}16} = A5_{1\text{-}16} = A6_{1\text{-}16}$, where A represents the mean MFRS component score for each of the six adult age groups tested. The subscripts denote the individual component test scores.

$Ho_2$: There will be no significant difference among the mean MFRS total scores across the six age groups (20-29, 30-39, 40-49, 50-59, 60-69, 70-79) tested.

$Ho_2$: A1 = A2 =A2 = A4 = A5 =A6, where A represents the MFRS total score for each of the six adult age decade groups tested.

$Ho_{3:}$ There will be no significant association of the mean MFRS total scores across the six age decade groups due to sex and physical activity.

$Ho_3$: $A_{1\text{-}2} = B_{1\text{-}6}$, where A with subscripts represents sex and physical activity, and B with subscripts represents the six age decade groups

To test the statistical hypotheses, age, served as a categorical independent variable made up of six age decade subgroups from 20 to 79 years of age in the study. The sixteen MFRS component tests of physiological and functional performance constituted the dependent variables. Sex and physical activity were treated as independent factors along with age group when the third null hypothesis was tested.

A multivariate analysis of variance (MANOVA) was utilized to test the equality of the six decade age group means for each of the component test scores while maintaining the Type I error at the predetermined .01 alpha level of significance. Assumptions for the MANOVA were assessed. If the omnibus F level test showed a significant multivariate effect, univariate ANOVAs were to be conducted for each of the component test scores to determine which component test scores show a significant difference among the age groups. These analyses were followed up by a multiple comparison procedure to search for specific differences among the age groups for individual component test scores. Choice of post hoc test depended on meeting the homogeneity of variances assumption. The Games-Howell multiple comparison test was utilized as the model demonstrated a lack of adherence by some of the dependent variables to the homogeneity assumption.

A multiple regression analysis was performed to examine the relationship between the MFRS total scores to age group, sex, and physical activity. Verification that the data met the linear regression assumptions was carried out. The regression analysis determined if age group, sex, and physical activity were significant predictors of the total MFRS score. Multicollinearity was closely monitored for the three fixed factors. Significant aging changes across the six age groups will support the need to screen adults earlier in life for impairments that can lead to functional limitations, thus decreasing fall risk.

## Summary

This chapter describes the methods that were carried out in this study. The MFRS components test procedures are described. Study population, variables, and instrumentation are outlined. The MFRS components allowed multidimensional physiological and functional screening of modifiable risk factors through out the adult lifespan. Statistical analysis provided expanded performance reference values for the six age decades studied. Efficacy of screening for modifiable impairments and preclinical disability in the younger adult age groups versus current guidelines to provide routine screening in adults 65 and older was shown by comparing score differences across the six adult age decades. Significant impairments in the younger age group as well as in the older age group will provide the rationale for routine screening in the younger adult.

The statistical hypotheses are outlined along with the associated statistical analyses. Institutional Review Board (IRB) application was submitted to the University of Missouri-Columbia Health Sciences Center once the research proposal was approved by the doctoral committee. The consent form to participate in a research study and the HIPAA authorization form were signed by the IRB and implemented into the consent procedure for each subject. Results of the testing and statistical analysis follow in Chapter IV.

# CHAPTER IV

# Results

## Introduction

The focus of this study was to research and compile individual modifiable fall risk tests into a multidimensional fall risk instrument to assess independent community dwelling adults 20-79 years of age. The Multidimensional Fall Risk Screen (MFRS) was developed into an instrument that was to be administered as a screen in community settings, requiring minimal equipment, space, and time. The study sought to develop a preliminary set of reference values to bench mark physical performance across six adult decade age groups. Fall risk stratification of the independent community dwelling adult could then occur from these reference values. Data analysis of the MFRS component test scores sought to describe a trend of decreasing physical performance across domains of functioning that have been found to precipitate falls and result in fall related injury. These age related changes signal preclinical disability in the areas of strength, vestibular function, postural stability, and functional mobility prior to age 65. Targeted intervention prior to fall incidence may be warranted and strongly supported by the literature to ameliorate modifiable impairments identified through the screening process.

This investigation presented three research hypotheses, that if supported by the study, sought to facilitate fall prevention efforts in our country by fall risk stratification of adults prior to the age of 65. The following hypotheses will be discussed in detail with their statistical analyses:

$H_1$ The component tests scores on the MFRS will show age related differences across six adult decade age groups.

$H_2$ The mean MFRS total score will have a negative correlation with aging across the six adult decade age groups.

$H_3$ Sex and physical activity will have effects on the MFRS total scores.

## Data Analysis of the First Hypothesis

*Descriptive Statistics*

A cross sectional study of 190 independent community living adults was completed. The volunteers that met the inclusion criteria were placed into age decade groups consisting of six subgroups (20-29, 30-39, 40-49, 50-59, 60-69, and 70-79) as they were recruited. Recruitment for each age category was terminated as the predetermined sample sizes of age and sex were met. All subgroups were filled with approximately equal numbers of male and female participants (Table 1).

Table 1
*Subject Characteristics*

| | Age Decades | | | | | |
|---|---|---|---|---|---|---|
| | 20-29 | 30-39 | 40-49 | 50-59 | 60-69 | 70-79 |
| Male | 15 | 15 | 16 | 15 | 15 | 15 |
| Female | 15 | 16 | 16 | 16 | 17 | 19 |
| Total | 30 | 31 | 32 | 31 | 32 | 34 |

Self reported fall risk characteristics across age decade groups were identified and their frequencies tabulated (Table 2). An upward trend in the presence of five of the ten reported fall risk factors is evident as the participants aged. The age decade of 50-59 appeared to be a pivotal age period in which fall risk factors took an upward climb in occurrence. Mobility and ADL limitations were reported with increased frequency at age 50-79. Physical Inactivity showed a gradual increase in incidence from 40-79 years of age. Fall history of two or more falls was present at the youngest age group (20-29) and then from ages 50-79. Greatest incidence of <4 medications was at age group 30-39, with polypharmacy occurring at 40-49 and gradually increasing with age with a peak at 60-69.

Medical conditions known to be fall risk factors were reported beginning at the 40-49 age decade and more than doubling by the 60-69 age group. Pain showed a gradual increase incidence throughout five of the age groups with a drop in incidence at the 50-59 and 70-79 age groups. Onset of fear of falling was demonstrated by more than doubling at age 60-69. Dizziness was reported at a similar incidence in the first five age groups and a drop off at the 70-79 age decade. Fear of falling and self efficacy were the least reported fall risk factors across all the age groups.

Table 2
*Frequency of Participant Self Reported Fall Risk Characteristics Across Age Decades in the Independent Community Dwelling Adult*

| | Age Decades | | | | | |
|---|---|---|---|---|---|---|
| HSQ Fall Risk Factors[a] | 20-29 *N*=30 | 30-39 *N*=31 | 40-49 *N*=32 | 50-59 *N*=31 | 60-69 *N*=32 | 70-79 *N*=34 |
| Fall History[b] | 3 | 0 | 0 | 3 | 4 | 3 |
| Mobility and ADL Limitations | 2 | 2 | 1 | 7 | 10 | 9 |
| Physical Inactivity[c] | 5 | 5 | 7 | 7 | 8 | 8 |
| Medications[d] | | | | | | |
| <4 | 3 | 16 | 13 | 10 | 11 | 5 |
| >4 | 0 | 0 | 3 | 3 | 9 | 5 |
| Medical Conditions[e] | 0 | 0 | 9 | 8 | 19 | 10 |
| Dizziness | 6 | 5 | 5 | 6 | 6 | 2 |
| Muscle Weakness | 0 | 0 | 0 | 4 | 7 | 0 |
| Pain | 1 | 4 | 8 | 5 | 10 | 2 |
| Fear of Falling | 0 | 2 | 1 | 2 | 5 | 0 |
| Self Efficacy | 1 | 1 | 1 | 1 | 2 | 1 |

[a]Fall Risk Factors as tabulated from the Health Status Questionnaire
[b]Fall History = ≥ 2 falls within past year
[c]Physical Inactivity = < 5 days/week of moderate activity, accumulated 30 minutes daily or < 3 days/week vigorous activity, 30 minute duration
[d]Medications = cardiovascular, psychoactive, musculoskeletal, hypoglycemic, allergy
[e]Medical Conditions = musculoskeletal, neurological, diabetes, heart disease

A preliminary set of reference values from analysis of the sixteen MFRS component tests was developed. Means and standard deviations are displayed for each of the component tests by decade age group (Appendix E). Performance on all the components tests shows a gradual decrease throughout the six decade age groups. Increased variability is evident in the 70-70 age group standard deviations for fourteen of the component tests when compared to each of their younger age groups. The Multidireactional Reach Tests Right and Left show greatest the variability at ages 20-29. Ankle Dorsiflexion Right and Left have the largest variance in standard deviation in the 30-39 age group.

Impairment frequencies across age decades for each of the component tests are presented in Table 3. Aging changes are evident in the physical performance tests, with different age decades heralding an obvious increase in significant deficits. The analysis shows deficits in all the component test scores prior to the 60-69 age decade. Single Leg Stance tests, Eyes Closed more than Eyes Open tests, followed by Ankle Dorsiflexion ROM, Five Times Sit To Stand Test, Dynamic Visual Acuity, and Single Heel Rises showed the greatest decline in performance at the significant impairment level. Impairments were defined by fall risk threshold values identified in the literature for each of the component tests. The self reported fall risk characteristics, component test scores reference values and impairment frequencies all demonstrated an age related trend.

Table 3
*Impairment Frequencies across Age Decades in the Independent Community Dwelling Adult*[a]

| MFRS Component Tests | Age Decades 20-29 N=30 | 30-39 N=31 | 40-49 N=32 | 50-59 N=31 | 60-69 N=32 | 70-79 N=34 |
|---|---|---|---|---|---|---|
| Habitual Gait Speed | 0 | 1 | 0 | 0 | 2 | 9 |
| Multidirectional Reach Test | | | | | | |
| Forward | 0 | 0 | 0 | 0 | 0 | 3 |
| Backward | 0 | 0 | 0 | 0 | 1 | 5 |
| Right | 0 | 1 | 2 | 0 | 1 | 5 |
| Left | 0 | 1 | 0 | 0 | 3 | 4 |
| Dynamic Visual Acuity | 0 | 1 | 1 | 2 | 7 | 5 |
| Single Leg Stance | | | | | | |
| Eyes Open Right | 1 | 2 | 3 | 2 | 11 | 14 |
| Eyes Open Left | 2 | 3 | 2 | 5 | 8 | 18 |
| Eyes Closed Right | 16 | 22 | 29 | 27 | 31 | 25 |
| Eyes Closed Left | 16 | 26 | 29 | 28 | 32 | 27 |
| Ankle Dorsiflexion ROM | | | | | | |
| Right | 9 | 8 | 3 | 8 | 15 | 24 |
| Left | 13 | 9 | 5 | 7 | 12 | 22 |
| Timed Up and Go Test | 0 | 0 | 0 | 0 | 0 | 1 |
| Five Times Sit to Stand Test | 0 | 0 | 1 | 4 | 9 | 16 |
| Single Heel Rises | | | | | | |
| Right Leg | 1 | 0 | 1 | 0 | 1 | 7 |
| Left Leg | 1 | 0 | 1 | 1 | 3 | 8 |

[a] Impairment scores derived from fall risk thresholds found in the literature

### *Multivariate Analysis of Variance*

A primary purpose of this study was to examine the effect of age on the performance of sixteen balance and mobility component tests. A one-way multivariate analysis of variance (MANOVA) was conducted on one independent variable with six subcategories (age decades of 20-29, 30-39, 40-49, 50-59, 60-69, and 70-79). The multiple dependent variables consisted of sixteen component tests compiled into the MFRS ( Habitual Gait Speed; Multidirectional Reach Test-Forward, Backwards, Right, Left; Horizontal Dynamic Visual Acuity; Single Left Stance Eyes Open-Right, Left;

Single Leg Stance Eyes Closed-Right, Left; Ankle Dorsiflexion Right and Left; Timed Up and Go Test; Five Times Sit to Stand Test; and Single Heel Rises Right and Left).

The MANOVA assumptions were examined. Assignment of the 190 participants into the six age decades as they volunteered and individual presentation of consent and orientation to testing took place to preserve independence of observations. The independent variable, age group, is categorical. The scale of measurement for the sixteen dependent variables is interval as they are test scores. The group sizes are very close to being equal (20-29- *N*= 30; 30-39- *N*=31; 40-49- *N*=32; 50-59- *N*=31; 60-69- *N*=32; 70-79 – *N*=34). Appropriate sum of squares was used to run the F-test. The Type III sum of squares was the default type as the model was slightly unbalanced but had no empty cells in the design. Adequate sample size was present as every cell had more cases (average size of 32) than there were dependent variables (16 dependent variables).

The normality assumption calls for the slope of the groups' distributions to be symmetric and follow a normal population distribution. Tests of normality, Kolmogorov-Smirnov, Shapiro-Wilk, kurtosis and skewness were acceptable for Habitual Gait Speed, all four Multidirectional Reach Tests, Time Up and Go Test, Five Times Sit to Stance Test, and Ankle Dorsiflexion Right and Left (Appendix G and H). Single Leg Stance Eyes Closed Right and Left demonstrated kurtosis greater than +3 and -3 in the 60-69 age group, Single Leg Stance Eyes Closed Right had problems with skew and kurtosis in the younger age groups 20-59. The scores clustered towards the right. This skew was reflective of perfect scores in those age groups. Heel Rises Right and Left demonstrated similar findings with skew and kurtosis towards perfect scores except for age groups 40-79. Histograms of ninety six component test scores revealed an approximate normal distribution across all the age groups with exception of approximate platykurtosis in two of the histograms, Single Leg Stance Eyes Open Right and Left (Appendix H). Despite the presence of nonnormality  of some of the component tests, the planned F test should be robust enough with these violations of normality to allow accepting the preceeding findings in this study. MANOVA is robust if fluctuations of this assumption occur as long as the sample sizes are greater than twenty. Absence of platykurtosis in 94 of the 96 histograms and similar group sizes also support the use of the F test.

Homoscedasticity or equality of covariance of the dependent variables across age groups was not supported by Box's M Test for the multivariate tests (Table 4). Equality of error variance was tested by Levene's Test of the univariate ANOVA tests (Table 5). Six of the dependent variables had significant Levene statistics greater than .05 (Habitual Gait Speed, four Multidirectional Reach Tests, and Right Ankle Dorisiflexion). Ten of the dependent variables failed to meet the assumption of homogeneity of variances (Dynamic Visual Acuity, four Single Leg Stance Tests, Left Ankle Dorsiflexion, Timed Up and Go, Five Times Sit to Stance, and both Heel Rise Tests). Failure to meet the assumption of homoscedasticity by some of the variables is not fatal to analysis of variance as long as the group sizes are similar. MANOVA and ANOVA are robust to departures from this assumption. In order to minimize Type I errors in the F tests due to problems with homogeneity of variance, a specific significance test, Pillai's Trace, was uitilized to determine if each age group had a significant effect on the dependent variables. Post Hoc testing also needed to be adjusted to accommodate violations of homoscedasticity by using the Games-Howell multiple comparison test for unequal variances and unequal sample size.

Table 4

*Box's Test of Equality of Covariance Matrices*

| | |
|---|---|
| Box's M | 897.687 |
| F | 2.500 |
| df1 | 272.000 |
| df2 | 23533.365 |
| Sig. | .000 |

Table 5

*Levene's Test of Equality of Error Variances*

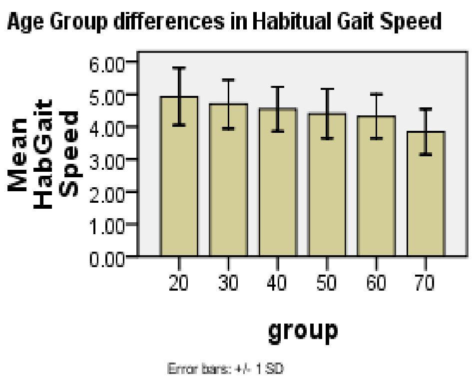
| | F | df1 | df2 | Sig. |
|---|---|---|---|---|
| HabGait Speed | .990 | 5 | 184 | .425 |
| MDRTF | .054 | 5 | 184 | .998 |
| MDRTB | .469 | 5 | 184 | .799 |
| MDRTR | 1.850 | 5 | 184 | .105 |
| MDRTL | .880 | 5 | 184 | .495 |
| DVA | 8.445 | 5 | 184 | .000 |
| SLSEOR | 32.288 | 5 | 184 | .000 |
| SLSEOL | 24.055 | 5 | 184 | .000 |
| SLSECR | 12.581 | 5 | 184 | .000 |
| SLSECL | 12.177 | 5 | 184 | .000 |
| AnkleDFR | 1.417 | 5 | 184 | .220 |
| AnkleDFL | 2.421 | 5 | 184 | .037 |
| TUG | 4.179 | 5 | 184 | .001 |
| FTSS | 3.411 | 5 | 184 | .006 |
| HeelRisesR | 16.576 | 5 | 184 | .000 |
| HeelRisesL | 21.061 | 5 | 184 | .000 |

Graphs with error boxes (Figure 1) and subsequent boxplots (Figure 2) were used to check if there was significant variability between age groups for each of the component tests. Visual inspection of boxplots and bar graphs show a gradual increase in preclinical impairment scores with increasing age (Y axis = MFRS score; X axis = age group). Differences between the means suggested that an analysis of variance would be supported to test the hypothesis.

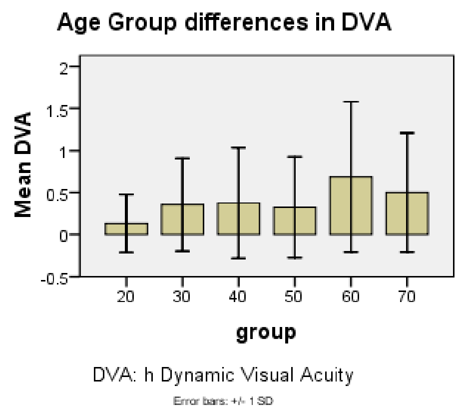
Figure 1

*Bar Graph Comparison of Mean Component Test Scores Across Six Age Groups*

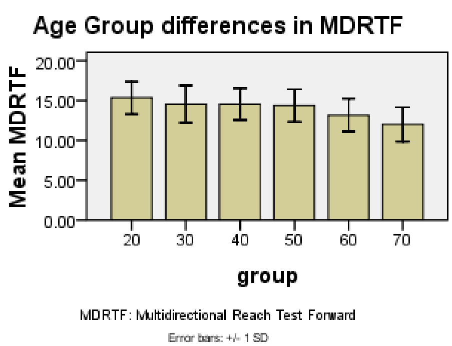
A.



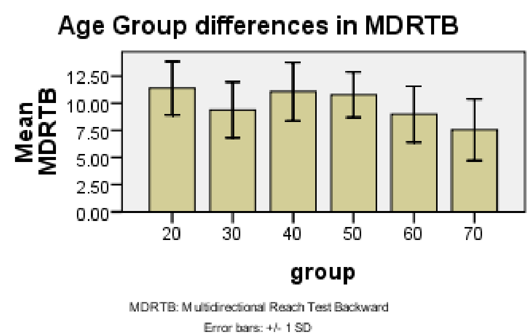

B.



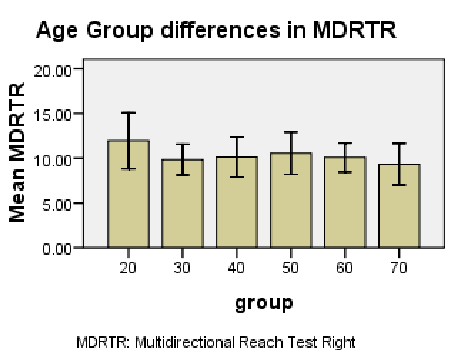

C.



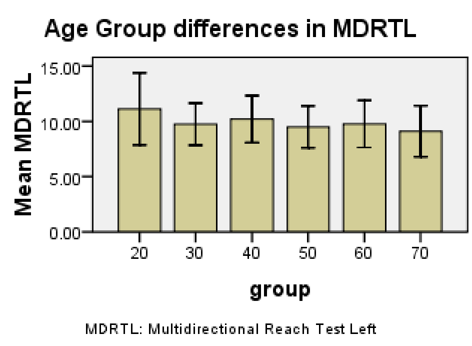

D.



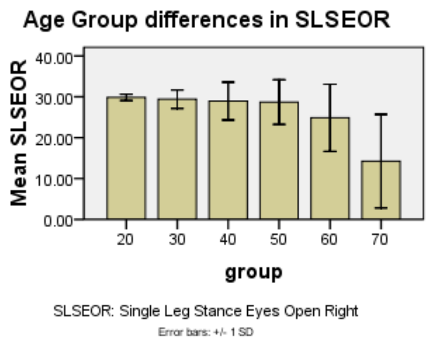

E.




F.

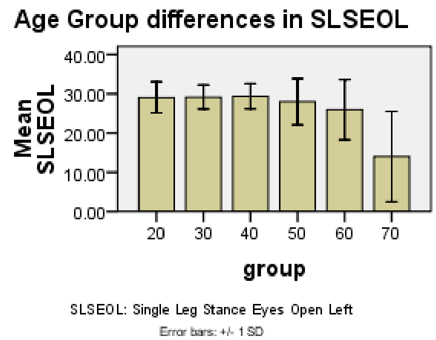


G.



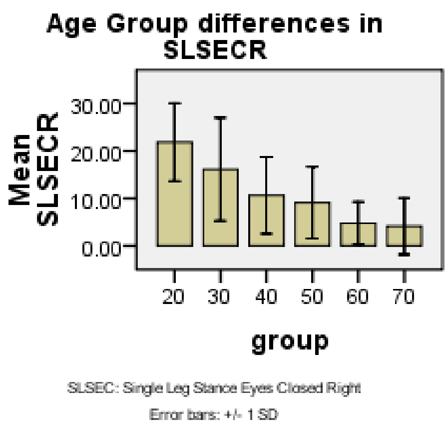
Age Group differences in SLSEOR
Mean SLSEOR
40.00
30.00
20.00
10.00
0.00
20
30
40
50
60
70
group
SLSEOR: Single Leg Stance Eyes Open Right
Error bars: +/- 1 SD


H.



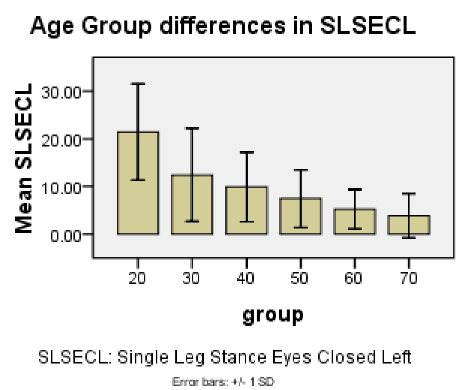
Age Group differences in SLSEOL
Mean SLSEOL
40.00
30.00
20.00
10.00
0.00
20
30
40
50
60
70
group
SLSEOL: Single Leg Stance Eyes Open Left
Error bars: +/- 1 SD


I.



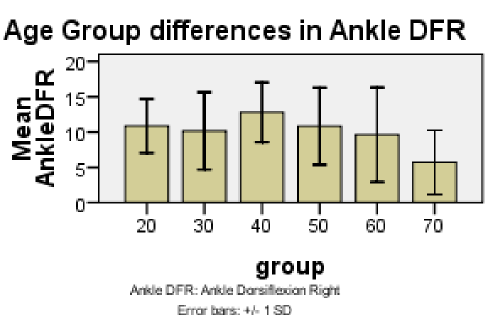
Age Group differences in SLSECR
Mean SLSECR
30.00
20.00
10.00
0.00
20
30
40
50
60
70
group
SLSEC: Single Leg Stance Eyes Closed Right
Error bars: +/- 1 SD


J.



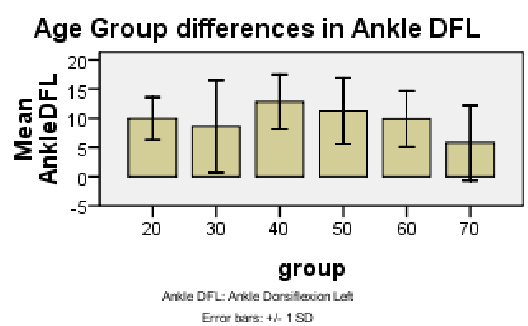
Age Group differences in SLSECL
Mean SLSECL
30.00
20.00
10.00
0.00
20
30
40
50
60
70
group
SLSECL: Single Leg Stance Eyes Closed Left
Error bars: +/- 1 SD


K.



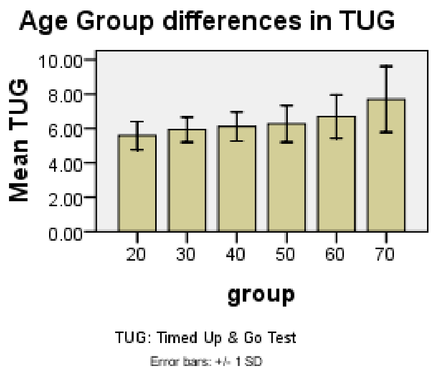
Age Group differences in Ankle DFR
Mean AnkleDFR
20
15
10
5
0
20
30
40
50
60
70
group
Ankle DFR: Ankle Dorsiflexion Right
Error bars: +/- 1 SD


L.

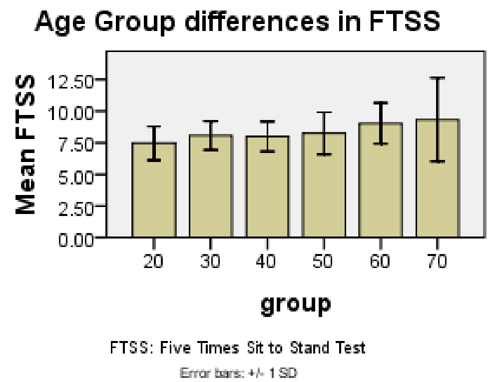


Age Group differences in Ankle DFL
Mean AnkleDFL
20
15
10
5
0
-5
20
30
40
50
60
70
group
Ankle DFL: Ankle Dorsiflexion Left
Error bars: +/- 1 SD

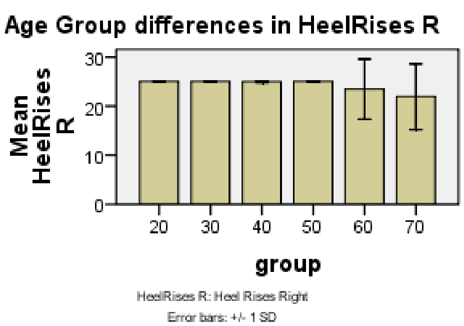
M.




N.




O.

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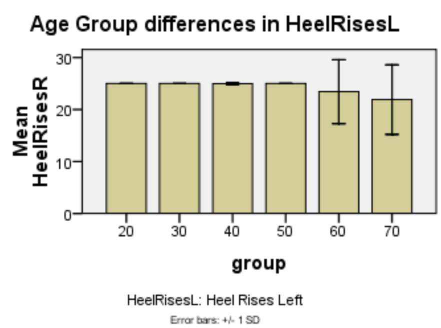
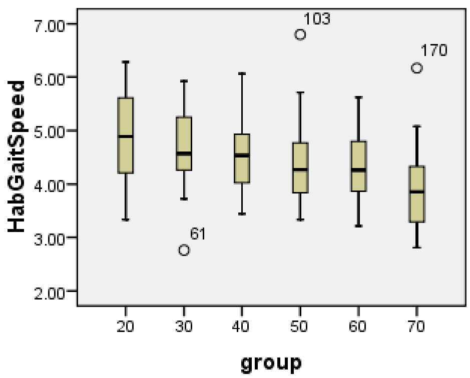



The presence of significant variability between age groups for each of the component tests was checked by boxplots A-P (Figure 2). Visual comparisons of the variances and central tendency across the age groups are possible with the boxplots. Differences in means and medians are easily visualized. Outliers or nonnormality of some of the points can be identified from these plots.

Figure 2

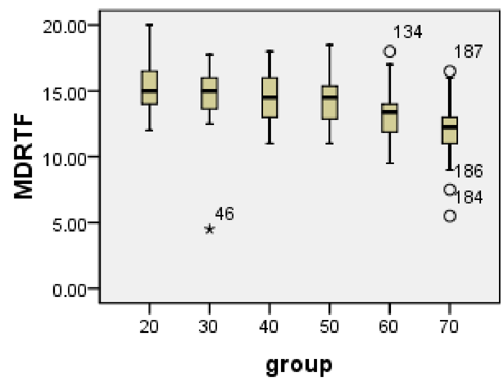
*Boxplot Comparison of Component Test Mean Scores Across Six Age Groups*

A.



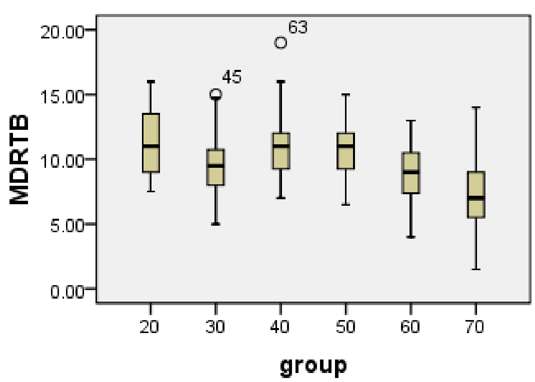

Impairment threshold: >3.3 ft/sec

B.

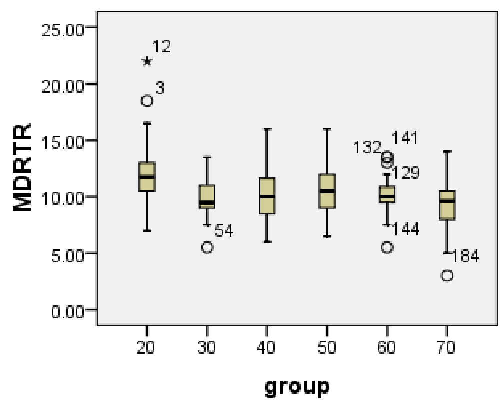



Impairment threshold: <10 inches

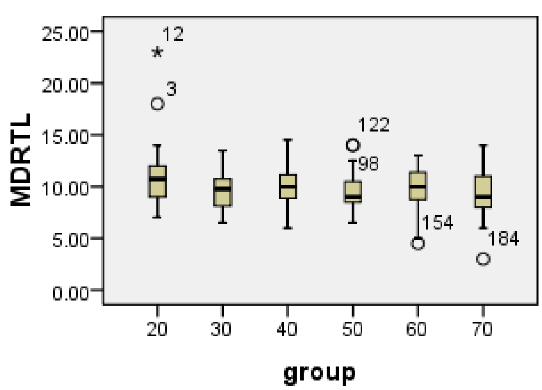
C.



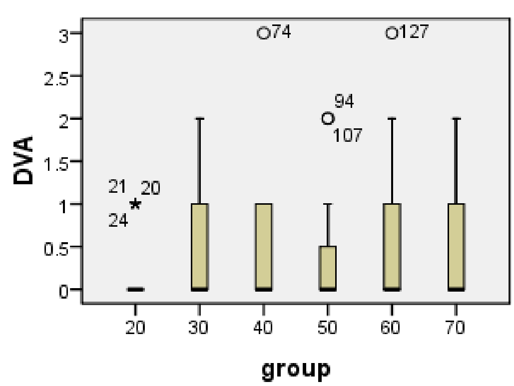

D.




E.

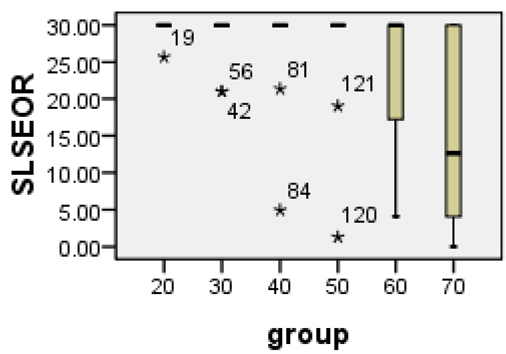



F.

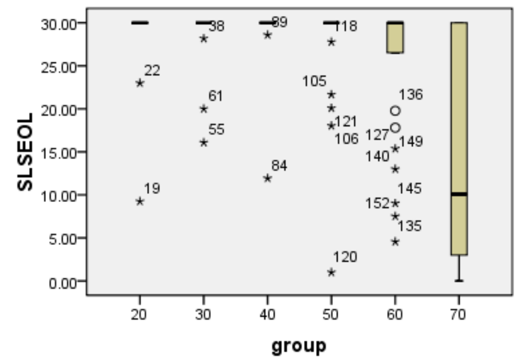



Impairment threshold: ≥2 lines lost

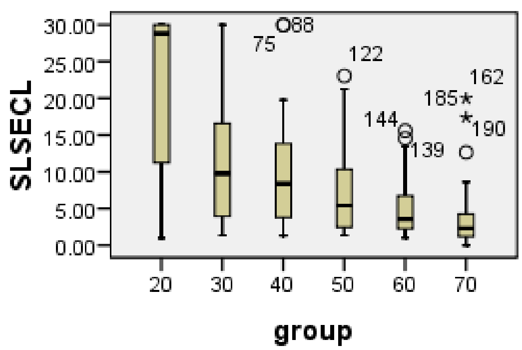
G.




H.

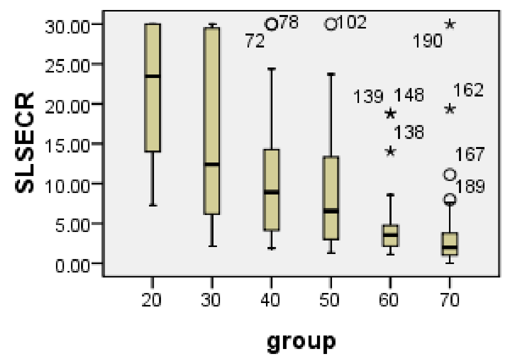



I.



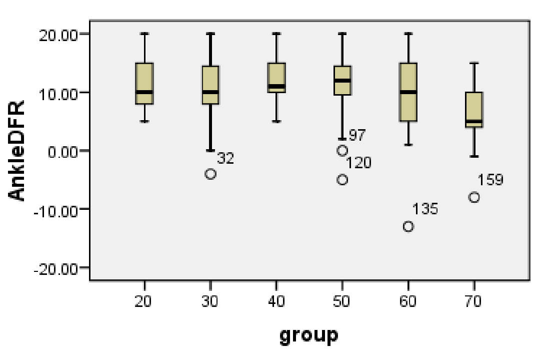

Impairment threshold: <5 sec

J.



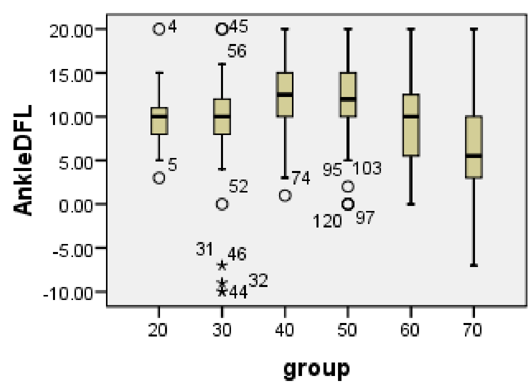

Impairment threshold: <5 sec

K.



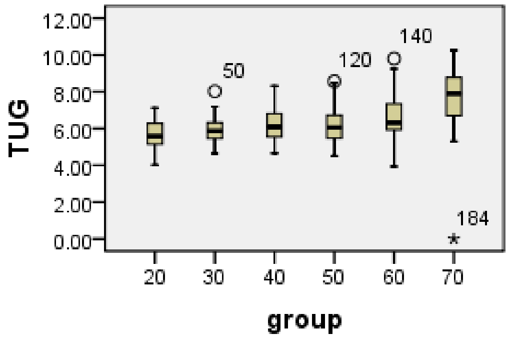

Impairment threshold: <10 degrees

L.



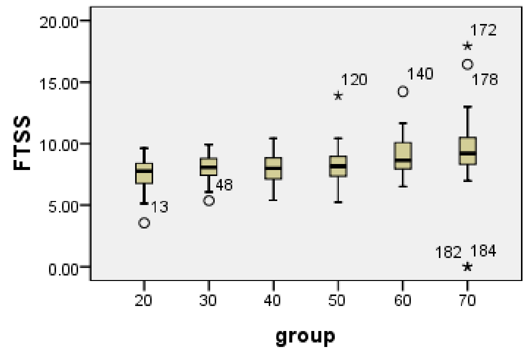

Impairment threshold: <10 degrees

M.



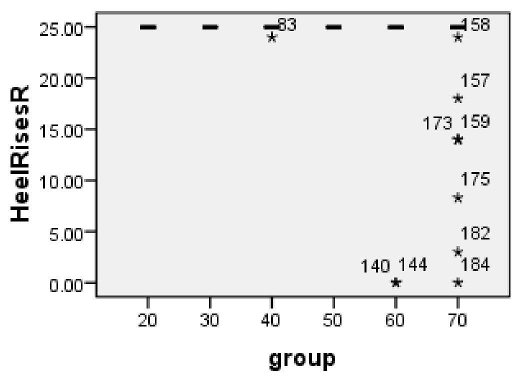

Impairment threshold: >10 sec

N.



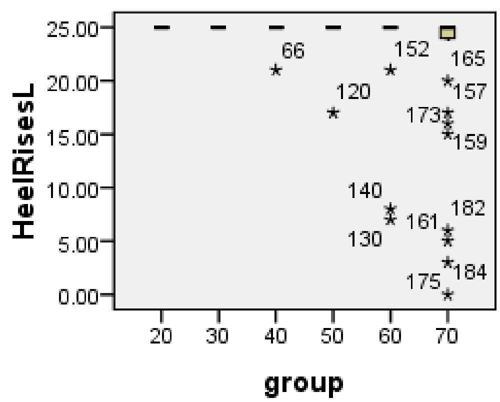

Impairment threshold: >10 sec

O.




Impairment threshold: <25 heel rises

P.




Impairment threshold: <25 heel rises

Visual inspection of boxplots and bar graphs show a gradual increase in preclinical impairment scores with increasing age (Y axis = component test score; X axis = age group). Differences between the means suggested that an analysis of variance would be appropriate to use to test the first hypothesis.

Multivariate analysis of variance (MANOVA) was used to test the first hypothesis regarding the effect of one independent variable with six subcategories on sixteen dependent variables. The effect of age group as the independent variable on the 16 component tests as dependent variables was analyzed in this study. A probability value (p-value) of .01 was used to determine if the results were statistically significant and if the null hypothesis could be rejected. This analysis was used to detect differences in the average value of the dependent variables between the different levels of the independent variables.

MANOVA multivariate test results are displayed in Table 6. The participant's decade age group significantly affected performance of the MFRS components scores, Pillai's Trace $F(80, 865) = 3.516$, $p < .0005$. The significance of the F test shows a significant multivariate effect ($p < .0005$). Pillai's trace is > 1 at 1.227, indicating a higher group effect contributing to the model or variance in the component test dependent variables. Partial eta squared equaled .245, meaning the model explains 24.5 percent of the variance in the dependent variables. Power at 1.000, denotes a strong probability of correctly rejecting the null hypothesis when it is false.

The F test is robust to violations in homogeneity of variance if groups are equal or if the number of participants in the largest group divided by the number of participants in the smallest group is <1.5. In this study this ratio is 1.13 allowing for acceptable interpretation of F test significance. Multivariate testing points towards a null hypothesis that is less likely to be true.

Table 6

*Multivariate Tests*

| Effect | Value | F | Hypothesis df | Error df | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power |
|---|---|---|---|---|---|---|---|---|
| Pillai's Trace | 1.227 | 3.516 | 80.000 | 865.000 | .000 | .245 | 281.319 | 1.000 |
| Wilks' Lambda | .190 | 4.213 | 80.000 | 817.879 | .000 | .283 | 322.315 | 1.000 |
| Hotelling's Trace | 2.404 | 5.030 | 80.000 | 837.000 | .000 | .325 | 402.436 | 1.000 |
| Roy's Largest Root | 1.489 | 16.104 | 16.000 | 173.000 | .000 | .598 | 257.660 | 1.000 |

As the multivariate test showed a significant F test, univariate testing was performed to see if the model was significant for each dependent variable. To control for Type I error inflation due to the presence of sixteen dependent variables, an alpha value of .01 was used. In the Tests of Between-Subjects Effect Table 7, there is a significant F significance level <.0005 for each of the sixteen component tests. Strength of the relationship between age group and the component test scores was indicated by the partial eta-squared values. The partial eta-squared, measure of effect size, for thirteen of the component tests were well over 10 percent indicative of a strong relationship. MDRTL, DVA, and Heel Rises Left were at 6-9 percent, a moderate strength relationship. These values explain percent of variance across the component test scores by the variation in decade age group. Power levels match the previous relationships of eta-square values. There is significant ability to detect effect with power levels greater than .80 for thirteen of the groups and acceptable power at .6 for only two groups, MDRTL and DVA. A high power level reduces the chance of making a type II error for a finding of non-significance by the F test. Univariate testing significant p-values of <.005 lead to the conclusion that the effect of the independent variable on each of the dependent variables is real and not due to chance.

Table 7

*Tests of Between-Subjects Effects*

| Dependent Variable | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power |
|---|---|---|---|---|---|---|---|---|
| HabGaitSpeed | 21.855 | 5 | 4.371 | 7.949 | .000 | .178 | 39.745 | .997 |
| MDRTF | 235.104 | 5 | 47.021 | 10.638 | .000 | .224 | 53.192 | 1.000 |
| MDRTB | 353.982 | 5 | 70.796 | 10.873 | .000 | .228 | 54.367 | 1.000 |
| MDRTR | 126.156 | 5 | 25.231 | 4.861 | .000 | .117 | 24.306 | .921 |
| MDRTL | 74.911 | 5 | 14.982 | 2.834 | .017 | .071 | 14.169 | .632 |
| DVA | 5.387 | 5 | 1.077 | 2.535 | .030 | .064 | 12.674 | .561 |
| SLSEOR | 6043.535 | 5 | 1208.707 | 27.338 | .000 | .426 | 136.688 | 1.000 |
| SLSEOL | 5971.657 | 5 | 1194.331 | 26.576 | .000 | .419 | 132.880 | 1.000 |
| SLSECR | 7302.337 | 5 | 1460.467 | 24.240 | .000 | .397 | 121.201 | 1.000 |
| SLSECL | 6343.001 | 5 | 1268.600 | 23.837 | .000 | .393 | 119.185 | 1.000 |
| AnkleDFR | 929.076 | 5 | 185.815 | 7.030 | .000 | .160 | 35.151 | .991 |
| AnkleDFL | 944.926 | 5 | 188.985 | 5.815 | .000 | .136 | 29.076 | .967 |
| TUG | 88.890 | 5 | 17.778 | 12.455 | .000 | .253 | 62.276 | 1.000 |
| FTSS | 78.449 | 5 | 15.690 | 4.374 | .001 | .106 | 21.868 | .880 |
| HeelRisesR | 272.979 | 5 | 54.596 | 3.789 | .003 | .093 | 18.945 | .810 |
| HeelRisesL | 314.491 | 5 | 62.898 | 4.856 | .000 | .117 | 24.279 | .921 |

Parameter estimates allowed additional assessment of significance of each parameter coefficient (Appendix J). B coefficients allow inference to be made about predictive power and direction of relationship of the DV with each category of the IlV. For example in Habitual Gait Speed scores, the B coefficient is larger in the younger age groups with a gradual, almost linear trend towards smaller coefficients in each of the older age groups. This relationship is consistent for all sixteen dependent variables. The effect significance levels were well under .05 for thirteen of the dependent variables. MDRT Right and Left and DVA coefficients were not all significant for the age groups 30-60.

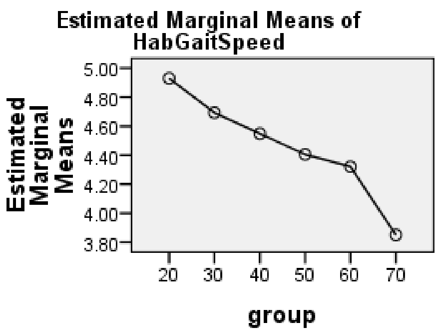
Profile plots A- P (Figure 3) compare the predicted marginal means of each MFRS component test across the six age groups. These plots aid in visualization of the relationship of the subcategories of the independent variable with a dependent variable. The plots lend support to the linear trends captured in the graphs and parameter estimates.

Further discussion of these profile plots are found under the discussion section following this section.

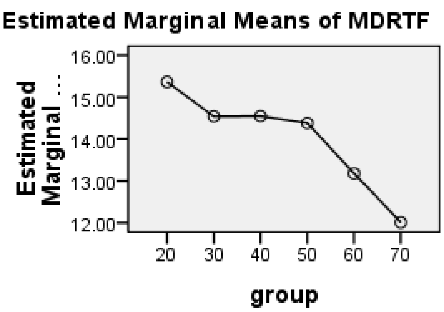
Figure 3

*Comparison of Component Test Marginal Means Across Age Groups*

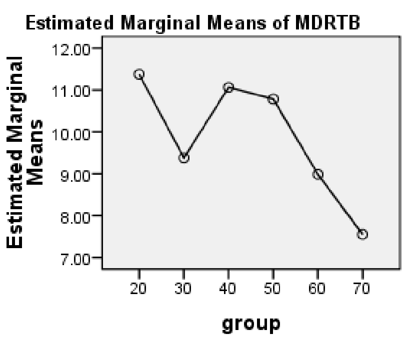
A.



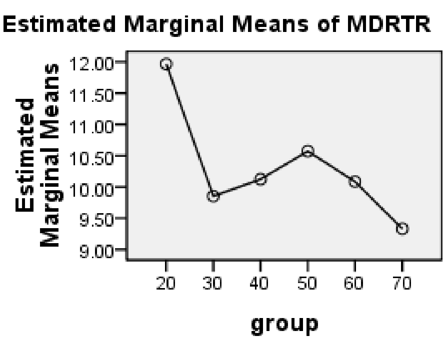

B.



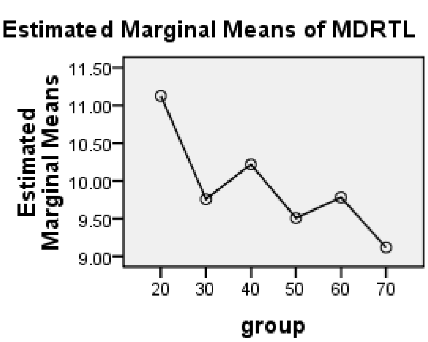

C.



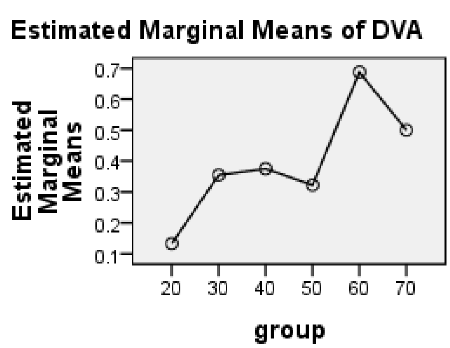

D.



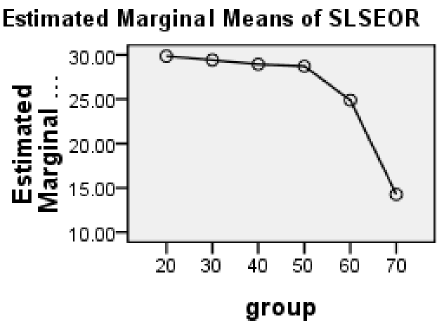

E.



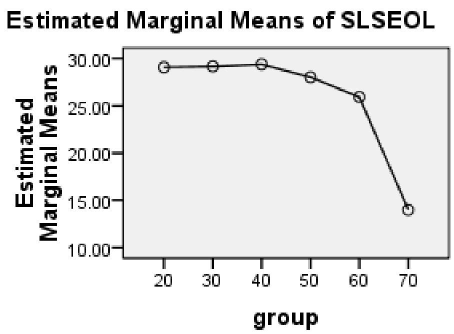

F.



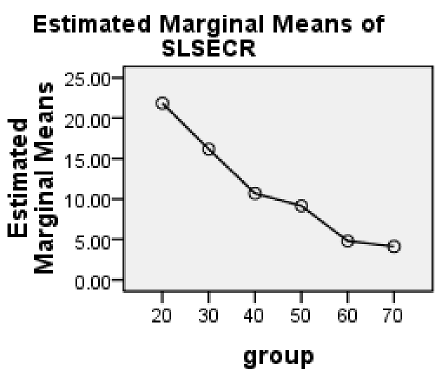
G.


Estimated Marginal Means of SLSEOR
Estimated Marginal ...
30.00
25.00
20.00
15.00
10.00
20 30 40 50 60 70
group

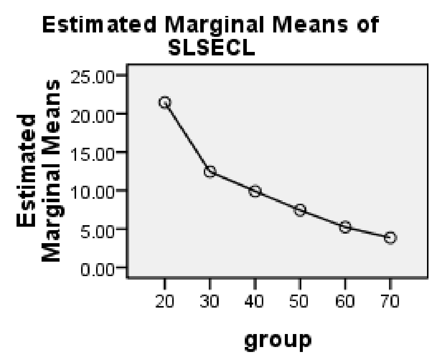
H.


Estimated Marginal Means of SLSEOL
Estimated Marginal Means
30.00
25.00
20.00
15.00
10.00
20 30 40 50 60 70
group

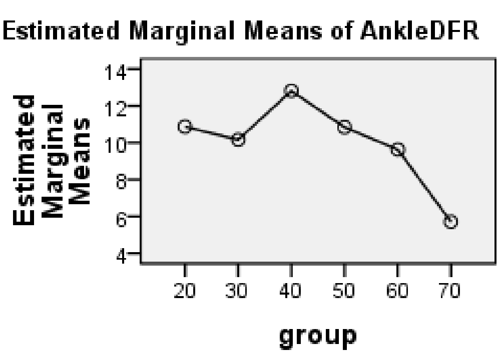
I.


Estimated Marginal Means of SLSECR
Estimated Marginal Means
25.00
20.00
15.00
10.00
5.00
0.00
20 30 40 50 60 70
group

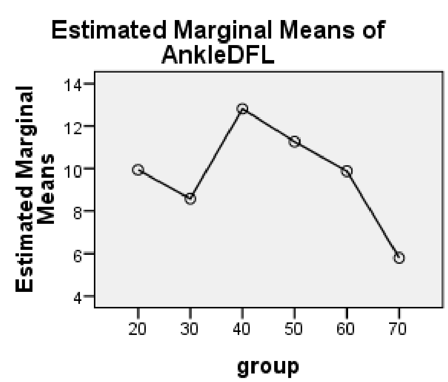
J.


Estimated Marginal Means of SLSECL
Estimated Marginal Means
25.00
20.00
15.00
10.00
5.00
0.00
20 30 40 50 60 70
group

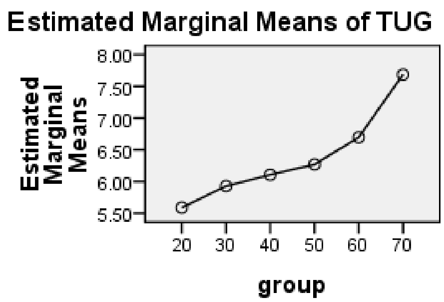
K.


Estimated Marginal Means of AnkleDFR
Estimated Marginal Means
14
12
10
8
6
4
20 30 40 50 60 70
group

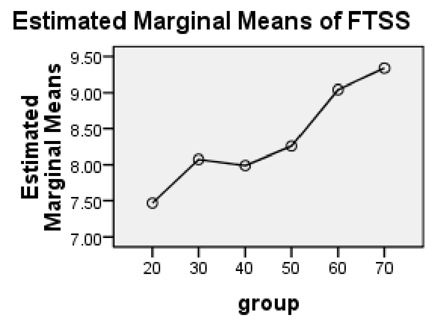
L.


Estimated Marginal Means of AnkleDFL
Estimated Marginal Means
14
12
10
8
6
4
20 30 40 50 60 70
group

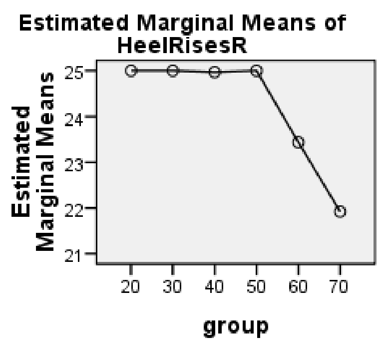
M.



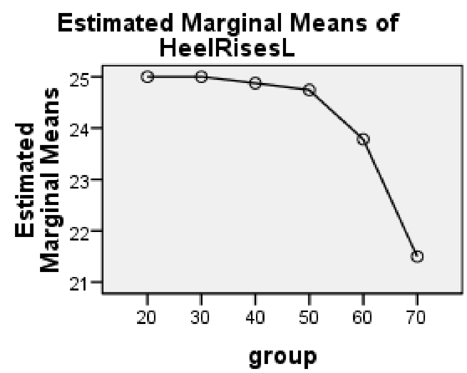

N.




O.




P.




Multivariate and univariate F tests established that there is an effect on each dependent variable by the independent variable. Post Hoc testing is used to determine which age group means differ significantly from others for each of the MFRS component score means. Pairwise multiple comparison tests analyze each pair of groups to identify the nature of the F test overall effect. The Games-Howell test, a modification of the Tukey's HSD test, was used in this study because equal variances could not be assumed and group sizes were unequal. It was an alternate procedure to use even though the F test is robust when there is a departure from homogeneity of variance (Appendix K). An alpha level of .01 was used to help control for Type I error inflation in the comparisons of the dependent variables.

Ten of the component tests had significant mean differences at <.01 of the younger age groups (20-60) when compared to the oldest 70-79 age group. Dynamic Visual Acuity, Five Times Sit to Stand Test had mean differences at the .05 level between the younger and older ages. Least significant differences were recorded with the Heel Rises Left and Right, but a consistent trend in decreasing mean scores was seen through out the six age groups, from younger to oldest group. Multidirectional Reach Test Left had the least significant difference and least consistent trend in comparison between the younger age groups, but the trend in age related scores picked back up again in four of the six age groups with the older group means at a greater difference than the younger age groups. This analysis backs up the F test main effect of age group on the MFRS component scores The research hypothesis is accepted at the .01 p-value, concluding the effect is real and not due to chance of sampling. The component scores on the MFRS show age related differences across six adult decade age groups.

*Discussion of Findings*

Descriptive statistics and multivariate analysis of variance were used successfully in this study to describe aging changes related to modifiable fall risk factors across six decade age groups. The domains of static and dynamic balance; functional vision and vestibular function; lower extremity strength, power, and range of motion; and functional performance in gait and transitional movements were compiled into the MFRS. The resultant sixteen component tests were used to assess a sample of independent community living adults for aging changing associated with preclinical disability.

*Habitual Gait Speed.* Gait speed can be used to assess mobility, dynamic balance and lower extremity power. The profile plot A, figure 3 presents a linear downward trend in habitual gait speed across each decade age group. The drop in speed begins in the twenty year old age group with a loss of linearity at age decade 60 when a sharp drop in speed occurs. Major large studies by Cesari et al., 2005 and Guralnik et al., 2000 noted aging changes in the younger adult and follow up determined that gait speed was an important predictor of incident disability. When performance of Single Leg Stance eyes closed, Timed Up and go, and Five Times Sit to Stand were compared with gait speed, there were concomitant aging changes in those abilities as well. Single Leg Stance eyes open, Ankle ROM, and Heel Rises show sharp drops in performance from 50-79 years of age. Similar drops in performance with gait speed would be expected to occur in the previously mentioned tests as well due to their assessment of abilities necessary to accomplish a normal gait speed.

*Multidirectional Reach Test.* Multidirectional reach tests examine limits of stability and the movement strategies used to maintain balance in stance. All four tests illustrated in the profile plots B - E, figure 3 have a trend of declining reach with age across the decade age groups. Forward reach has the most linear drop in performance which begins in the 20-29 age group. A sharp drop occurs at 50-59 through 70-79 age decades. The four reach tests improve or plateau at age decade 30-39 with the drop in reach common to all the tests by ages 50-59. Reference values are not available in the literature prior to age 50. The findings in this study reflect the available findings in the middle to older age groups by Brauer et al., 1999, De Waard, 2002, and Steffen et al.,

2002. The mean scores in this study are higher for all four tests by a standard deviation from the findings in a large community based study of older adults by Newton, 2001.

It is interesting to note similar drops in performance for the Ankle Dorsiflexion ROM test by age decade 50-59. Flexibility in the ankle is a prerequisite for normal movement strategies during reaching activities especially in the sagittal plane. Large variances in reaching throughout the four tests are illustrated in the boxplots B-E, figure 2. Greatest control of reach is seen on lateral displacement when compared to anterior-posterior displacements. Backwards reach had the most variance of the four directions. Newton et al., 1997 associated fear of falling with the backwards reach score. This observation may begin to explain the amount of variability in this test of an unaccustomed self-initiated movement.

*Horizontal Dynamic Visual Acuity.* Dynamic Visual Acuity (DVA) reflects functional vision and vestibular status. Deficits in these areas are predictive of future balance and mobility limitations. Herdman et al., 2003 and Di Fabio et al., 2002 report on these deficits and heightened fall risk. Review of the profile plot for dynamic visual acuity shows mean response scores increase with aging, peaking at the 60-69 age decade. Studies by Herdman et al., 2001 and Rine & Braswell, 2003 support this study's finding of a general trend of larger DVA scores with increasing age. When the DVA boxplot F, figure 2, is examined it is interesting to note the difference between the youngest age decade and the two older age decades. Perfect DVA scores are the mean at age group 20-29 while decreased functional vision close to the impairment threshold is apparent at the 30-39, 60-69, and 70-79 decades.

*Single Leg Stance.* Single leg Stance (SLS) measures static balance and lower extremity strength within a narrow base of support. SLS with eyes open shows a drop in performance at the 50-59 decade for the right side and 40-49 decade for the left side. Sharp declines in performance occur from these age groups respectively to one half of thirty seconds by the 70-79 age decade. Eyes closed means are not as high throughout the six age decades. This finding supports the work by Newton, 1997, who concluded that young children and older adults show a reliance on the visual system for static balance, single or bilateral stance. This study goes a bit further and presents performance in the younger and middle aged adult with eyes closed, adding to the information that Fregley in 1966 and Giorgetti et al, 1998 collected in large research efforts that concluded drop in performance started at 40 years of age. Right and left mean scores show a steady decline in performance from the youngest age group to the oldest age group. The drop in mean score is significant, from about 22 seconds to five seconds (Profile Plots I - J, Figure 3). Variability in performance is well illustrated in the older age groups for eyes open. The situation is reversed in the testing with eyes closed in that the variance makes up almost the entire range of scores, from 30 to one second. These large variances in performance are seen primarily in the 20-29 through 50-59 age decades. The oldest age groups demonstrated small variances within their low mean scores (Boxplots G - H, Figure 2). Single stance reflects the ability to maintain static balance and integration of visual, vestibular, and kinesthetic input. Deficits in this area are associated with functional limitations in stair climbing and dependence in performing instrumental activities of daily living.

*Ankle Dorsiflexion Range of Motion.* Range of motion at the ankle is necessary for safe ambulation, postural stability, and performance of movement strategies to maintain the center of mass over the base of support during perturbation. Estimated marginal means of ankle dorsiflexion show a loss of almost ten degrees in most adults at age decades 20-29 and 30-39; an increase to near normal values during 40-49 age decade; and a fairly sharp drop in the 50-59, 60-69 and 70-79 age decades (Profile Plots K - L, Figure 3). Choy et al. (2003) in a study of 372 women found similar aging results, although the ages only included 40-80 year olds. The average mean scores in the oldest age group are at the impairment level of >10 degree loss in dorsiflexion. Left ankle dorsiflexion shows very large variances when compared to right dorsiflexion means (Boxplots K - L, Figure 2). Loss of range of motion across the six adult age groups is troubling and can be postulated to be a contributing factor to poor Single Leg Stance Eyes Closed performance as well as with the decreases in functional reach, especially in the older age groups. Mecagni et al., (2000) arrived at the same conclusion. Studies by Bohannon (1995); Gehlesen & Whaley (1990) and Gross et al. (1998) concluded that healthy older adults maintain ankle range of motion compared to a significant difference in range of motion of fallers.

*Timed Up and Go Test.* The Timed Up and Go Test (TUG) measures basic functional mobility, balance, lower extremity strength, and gait. A trend is seen of increasing mean scores with aging starting at the youngest age group and peaking at the oldest age group. A gradual rise in marginal means with a sharper increase occurring from the 60-69 age decade is obvious from examining the profile plot M, figure 3. Bohannon, 2006 developed a set of reference values by age groups from 60 through 89 for the TUG. These findings as well as the original findings by Podsiadlo & Richardson (1991) demonstrated age related decreases in performance. This study has contributed to knowledge about younger and middle aged adults. Variance in TUG scores can be examined from the boxplot M. Performance variance and mean scores increase significantly from the 60-69 age decade. The TUG has been shown to correlate with gait speed and multidirectional reach, both tests that show similar aging changes in this study (Newton, 1997; Podsiadlo & Richardson, 1991).

*Five Times Sit to Stand Test.* Five Times Sit to Stand Test (FTSST) is a functional movement test that incorporates lower extremity strength, power, coordination and postural stability during a transitional activity. A gradual increase in the time needed to complete the test was seen across the six age decades (Profile Plots N, Figure 3). An approximate two second average increase in score is seen from the youngest to the oldest age group. The largest variance in performance by the 70-79 age decade is evident in the boxplot N, figure 2. These findings concur with several researchers who have demonstrated that age is a strong predictor of FTSST performance in individuals without balance dysfunction (S.R. Lord et al., 2002; Whitney et al., 2005). Review of the scores show the identification of impairments in the 40-49 and 50-59 age groups as defined by Whitney et al., 2005.

*Single Heel Rises.* Standing Single Heel Rises Test is a measure of functional lower extremity strength and power. Impairments in plantar flexor strength and power are associated with mobility limitations and gait performance. Heel Rise means were normal and stable across the age groups 20-29, 30-39, 40-49. A subtle drop in means is noted in the older age decades, left heel rises worse than right (Boxplots O- P, Figure 2; Profile

Plots O - P, Figure 3). These findings are congruent with findings of Kerrigan et al., 2000, Svantesson et al., and Whipple et al., 1987. The gradual loss of normal functional strength in the oldest age groups would be indicative of preclinical disability.

## Data Analysis of the Second and Third Hypotheses

*Descriptive Statistics*

The second half of the data analysis investigated the relationships of age group, sex, and physical activity to the MFRS total score. The research hypotheses that were tested stated that the mean MFRS total score will have a negative correlation with aging across the six adult decade age groups; and that the factors of sex and physical activity will have effects on the MFRS total scores. Descriptives included mean, standard deviation, standard error, skewness, and kurtosis for the MFRS total score for each age group (Appendix K). Correlation coefficients match correlation procedures performed individually for MFRS, Group, Sex, and Physical Activity (Table 8). The total MFRS score has a strong Pearson Correlation of .532 with Age Group and a moderate correlation of .173 with Sex. Both of these relationships are significant at <.01. Physical Activity shows a weak Pearson Correlation of .117 with a lower significance level of .053.

Table 8

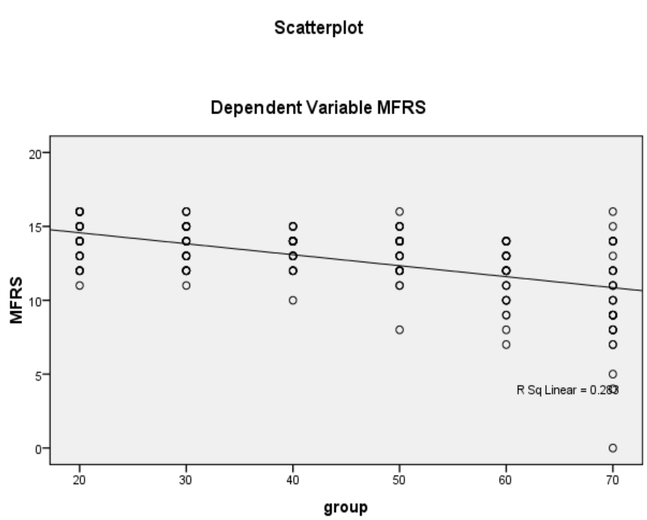
*Correlations*

| | | MFRS | Group | Sex | PhyAct |
|---|---|---|---|---|---|
| Pearson Correlation | MFRS | 1.000 | -.532 | .173 | .117 |
| | Group | -.532 | 1.000 | -.035 | -.073 |
| | Sex | .173 | -.035 | 1.000 | .004 |
| | PhyAct | .117 | -.073 | .004 | 1.000 |
| Sig. (1-tailed) | MFRS | | .000 | .009 | .053 |
| | Group | .000 | | .313 | .158 |
| | Sex | .009 | .313 | | .478 |
| | PhyAct | .053 | .158 | .478 | |

*Multiple Regression*

The General Linear Model was chosen to access multiple regression. The nature of the relationship of age decade, sex, and physical activity as independent variables with MFRS total scores the dependent variable was analyzed. The data were checked to verify that the assumptions of linear regression were met. A linear relationship should exist between the independent variables and the dependent variable. Scatterplot (Figure 4) of MFRS total scores by age group shows a good fit and thus a linear relationship of the dependent variable by the predictor.

Figure 4



The normality assumption states that the residuals are normally distributed to validate the p-values for the *t*-tests. The Explore function was used to run descriptives of skewness and kurtosis, tests of normality, histograms, and Q-Q plots. Skewness and kurtosis statistics were well with in the normal range for all age groups (Appendix K). Shapiro-Wilk statistics, specifically designed to test normality, were very close to meeting a statistic of 1 indicative of perfectly normal data. Table 9 lists the Shapiro-Wilk statistic and level of significance.

Table 9

*Tests of Normality*

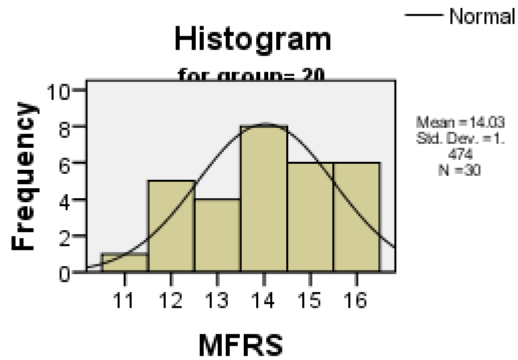
| group | | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|---|
| | | Statistic | df | Sig. | Statistic | df | Sig. |
| MFRS | 20 | .158 | 30 | .055 | .918 | 30 | .024 |
| | 30 | .161 | 31 | .040 | .918 | 31 | .021 |
| | 40 | .320 | 32 | .000 | .824 | 32 | .000 |
| | 50 | .255 | 31 | .000 | .874 | 31 | .002 |
| | 60 | .210 | 32 | .001 | .913 | 32 | .014 |
| | 70 | .120 | 34 | .200* | .950 | 34 | .126 |

a. Lilliefors Significance Correction
*. This is a lower bound of the true significance.

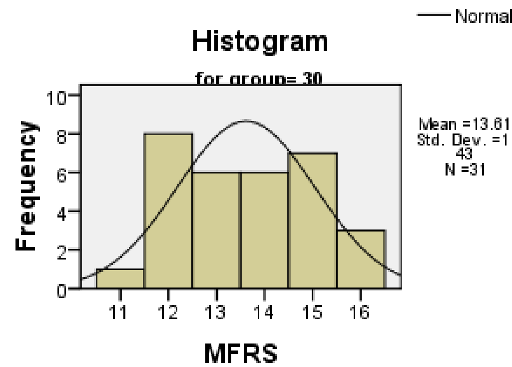
Histograms A-F (Figure 5) demonstrate fairly normal curves with no platykurtosis. Mild skew and kurtosis can be identified on observation of the histograms but all values are insignificant at < -3 and < +3.

Figure 5

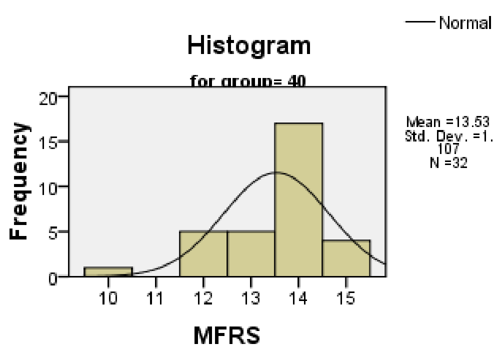
A.



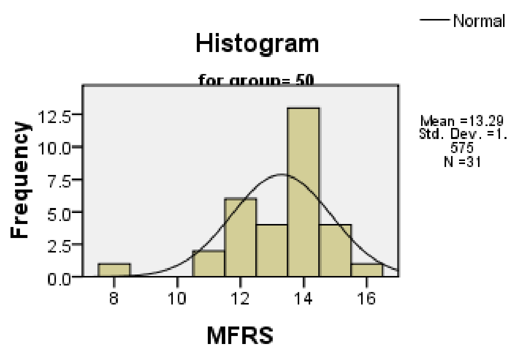

B.



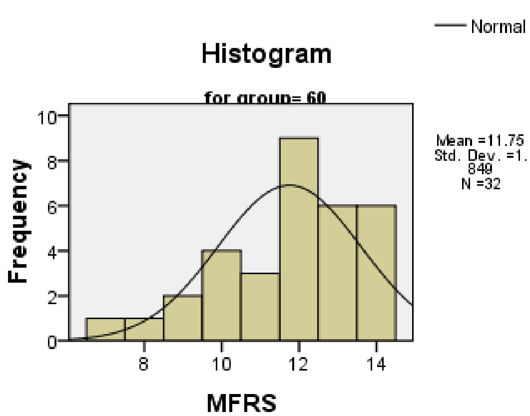

C.



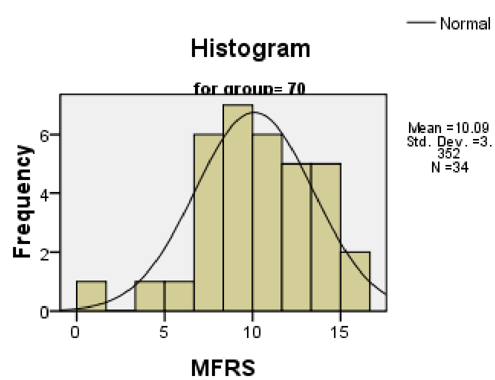

D.




E.



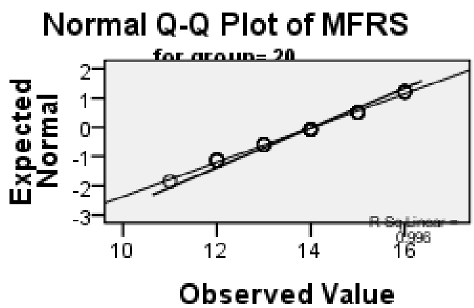

F.



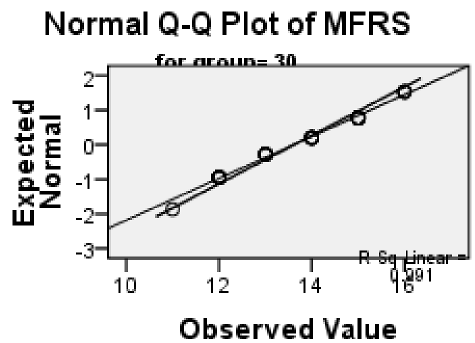
Normal Q-Q plots A-F (Figure 6) were created to further check linearity and centrality. Observed values for MFRS scores for each age group are plotted individually. All observed values follow an approximate straight path with points close to the reference line in each plot.

Figure 6

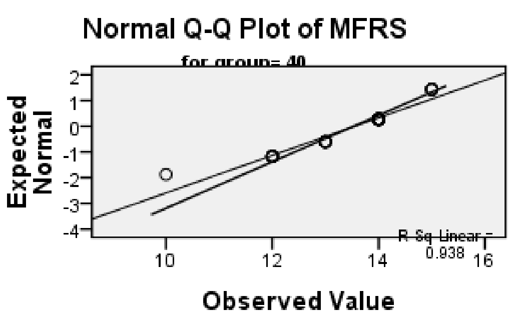
A.



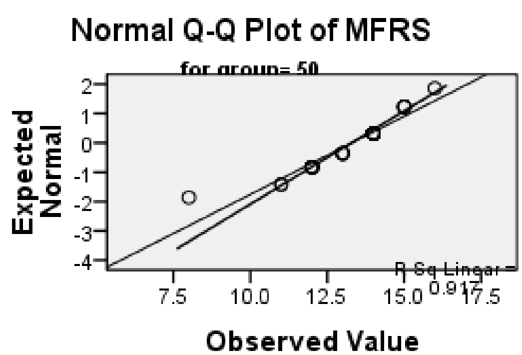

B.



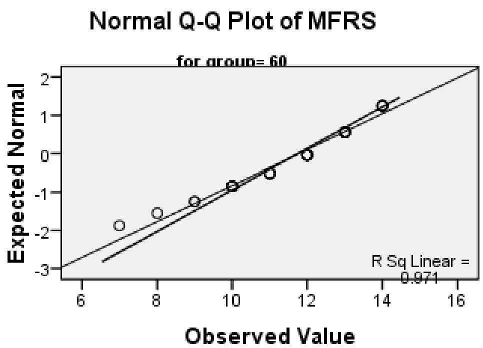

C.



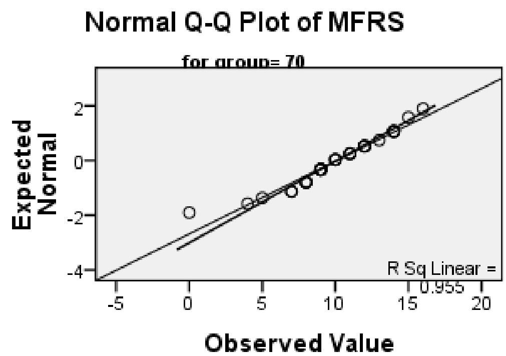

D.



E.

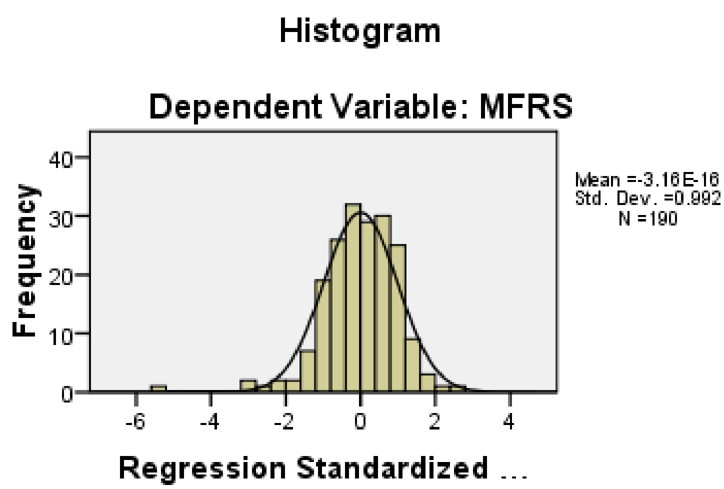



F.



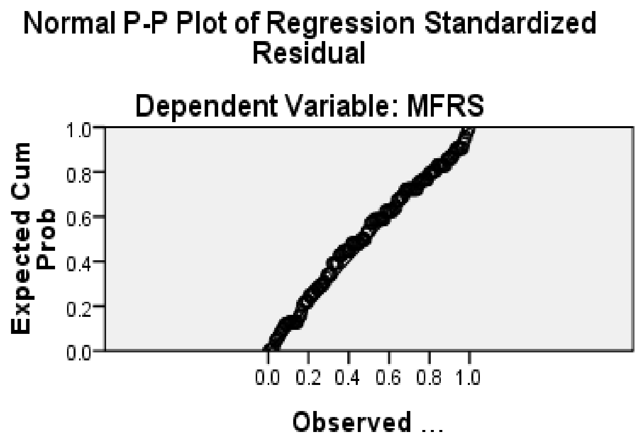

The regression standardized residual histogram is also a method used to visualize normality (Figure 7). The distribution of the standardized MFRS residuals looks symmetrical with only one value > 3 standard deviations

Figure 7




The probability plot (Figure 8), a test of normally distributed residual error, shows the observed values line up very well along a 45- degree line describing a nearly perfect normal distribution.

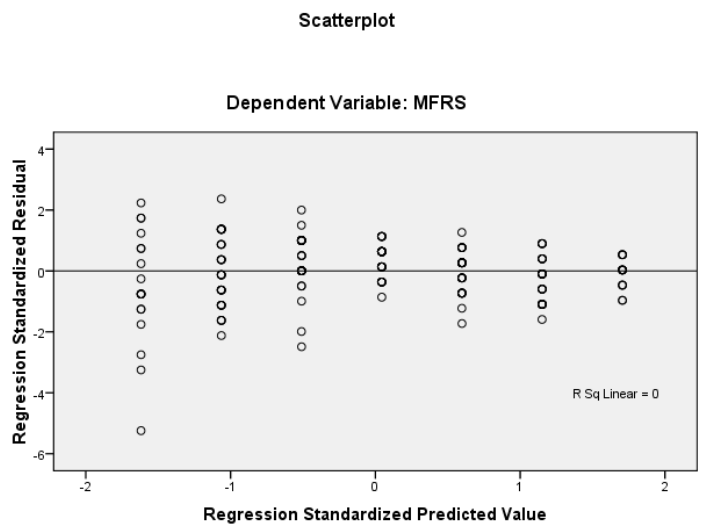
Figure 8




As most of these tests were normal, it can be said that the residuals from this regression appear to adhere to the assumption of being normally distributed. Regression is robust when there is some violation of this assumption. This will help minimize the interpretation of the Shapiro-Wilk test.

Homoscedasticity or the assumption that the variance of the residuals is homogeneous across levels of the predicted values is illustrated in the scatterplot below (Figure 9). The plot of residuals (difference between obtained and predicted dependent variable scores) shows the majority of the residuals around the zero horizontal line in a symmetrical pattern. The presence of one outlier greater than three standard deviations from the mean line can also be seen. Homoscedasticity can be seen as the plots follow a symmetrical pattern and width for most values of the predicted dependent variable, with concentration of plots along the horizontal line. The variance that is seen is linear as the points form a straight line.

Figure 9




The independence assumption implies the errors associated with one observation are not correlated with the errors of any other observation. In this study this assumption was easily met since the subjects were only tested once and one at a time. Adherence to this assumption will decrease the likelihood of a Type I Error.

Two methods were utilized in this study to specify a model. The first and strongest method is substantial knowledge of the area under study. Evidence based research clearly has pointed towards validity of the predictors used in the analyses. Only three predictors were chosen in order to adhere to the principle of scientific parsimony. Model specification errors can be controlled by choosing the appropriate sequential model. This analysis used Stepwise regression. SPSS first tested age group, the independent variable with the highest correlation to the dependent variable. Secondly, group and sex were tested together since these variables had the next highest correlation. This given ordering of predictors helped to determine the contribution each independent variable made on the dependent variable. This method also helped to eliminate physical activity as a strong predictor in the model due to its poor partial correlation to the MFRS score. These two methods helped meet the assumption of model specification.

Regression analysis was utilized to determine how much the MFRS score is affected by the independent variables, age group, sex, and physical activity. This analysis sought to determine the predictive capability of the independent variables as a group and individually at a better than chance probability. A strong correlation coefficient of age group with the MFRS score points towards a linear relationship between these two variables. Variance ($R^2$) is used the proportion of variance of the dependent variable accounted for by the independent variables. The Beta coefficients and their p-values give an individual measure of how much each independent variable is associated with the dependent variable. Coefficients that have p-values less than alpha (.01) are statistically significant. These findings helped determine the importance of each predictor.

Individual and joint predictive power of the multiple coefficient R are strong at .532 and .554 for age group and age group combined with sex. R needs to be $\geq .5$ to be considered an important predictor. $R^2$ are strong at .283 and .307 respectively (.25 considered strong $R^2$). Variance from the adjusted $R^2$ values present 27.9 percent variance effect on the dependent variable due to regression from the age group independent variable. When age group and sex are combined as predictors, the variance effect on the DV is increased to 29.9 percent. Approximately 70 percent variability due to factors other than the independent variables is present in the MFRS scores. The Change Statistics show the significance levels associated with adding sex and physical activity as predictors in the model. The first two steps were significant. The third step, adding physical activity was not, as it is not modeled in the Change Statistics. The Model

Summary in Table 10 presents this information as well as the Durbin-Watson statistic of 1.892, supportive of the independence assumption for residuals. The statistic is < 2 from a range of 0 – 4.

Table 10

*Multiple Correlation Model Summary*

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .532[a] | .283 | .279 | 2.035 |
| 2 | .554[b] | .307 | .299 | 2.006 |

| | | Change | Statistics | | | |
|---|---|---|---|---|---|---|
| Model | R Square Change | F Change | df1 | df2 | Sig. F Change | Durbin-Watson |
| 1 | .283 | 74.271 | 1 | 188 | .000 | |
| 2 | .024 | 6.384 | 1 | 187 | .012 | 1.892 |

a. Predictors: (Constant), age group
b. Predictors: (Constant), age group, sex

When the F test is reviewed, variability about the mean is divided into variability due to regression and variability about the regression. The analysis of variance table for regression is seen in Table 11. Significance of the F value, 74.271 (1, 188) at p-value <.0005 explains a statistically significant portion of variability in the dependent variable, MFRS score, is due to the variability in the independent variable, Age Group. Sex and Physical Activity, as predictors were excluded due the alpha value set at .01.

Table 11

*Regression ANOVA*[b]

| Model | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| 1 Regression | 307.569 | 1 | 307.569 | 74.271 | .000[a] |

a. Predictors: (Constant), age group
b. Dependent Variable: MFRS

Predictive power and the direction of relationship of the independent variables can be studied by looking at the regression coefficients in Table 12. Beta coefficient, the standardized regression coefficient, a -.532 and *t* value at -8.618 for Age Group are high enough to be important in the model at p-value <.0005. Every change in beta (Age Group) effects a change in the MFRS score. Age Group is 3.5 times a better predictor than sex in the model. The B value in the table represents the confidence interval, denoting the number of units the dependent variable changes when the independent variable changes one unit. The associated 95% confidence interval for B is also included. Partial correlation with only one important predictor left is not essential to interpretation of the regression equation. Collinearity is not a problem as the independent variables have low correlations with each other. Collinearity statistics in Table 13 for Age Group show high Tolerance (>.1) at 1.000 and Eigenvalue value (well above zero) at 1.936, both indicative of a lack of linear relationship of the predictors. All these factors attest to the stability of B and the beta coefficient in this analysis. Age group has significant predictive power on the MFRS score.

Table 12

*Coefficients*[a]

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | 95% Confidence Interval for B | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound |
| 1 | (Constant) | 16.056 | .420 | | 38.240 | .000 | 15.228 | 16.884 |
| | group | -.074 | .009 | -.532 | -8.618 | .000 | -.091 | -.057 |

a. Dependent Variable: MFRS

*Coefficients*[a]

| Model | | Correlations | | | Collinearity Statistics | |
|---|---|---|---|---|---|---|
| | | Zero-order | Partial | Part | Tolerance | VIF |
| 1 | (Constant) group | -.532 | -.532 | -.532 | 1.000 | 1.000 |

a.Dependent Variable: MFRS

Collinearity statistics in Table 13 for Age Group show high Tolerance (> .1) at 1.000 and Eigenvalue value (well above zero) at 1.936, both indicative of a lack of linear relationship of the predictors. All these factors attest to the stability of B and the beta coefficient in this analysis. Age group has significant predictive power on the MFRS score.

Table 13

*Collinearity Diagnostics[a]*

| Mode | Dimension | Eligenvalue | Condition Index | Variance Proportions | |
|---|---|---|---|---|---|
| | | | | (Constant) | group |
| 1 | 1 | 1.936 | 1.000 | .03 | .03 |
| | 2 | .064 | 5.506 | .97 | .97 |

Excluded Variables Table 14 presents the predictors sex and physical activity that were excluded from the regression model due to poor correlations and significance values in the model. This table is used to determine what would result if one or two of the variables were placed back into the model. Sex has the larger partial correlation variable and making it the better candidate to consider adding back into the model. Physical Activity's Beta In coefficient of .079 has minimal relative importance in the model with an unacceptable p-value at .203. Sex has a Beta coefficient of .154 resulting in a possible variance of 15% in the dependent variable. Neither predictor, Sex nor Physical Activity has the predictive power needed for the model at p-value ≤ .01.

Table 14

*Excluded Variables[b]*

| Model | | Beta In | t | Sig. | Partial Correlation | Collinearity Statistics | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Tolerance | VIF | Minimum Tolerance |
| 1 | sex | .154[a] | 2.527 | .012 | .182 | .999 | 1.001 | .999 |
| | PhyAct | .079[a] | 1.277 | .203 | .093 | .995 | 1.005 | .995 |

a. Predictors in the Model: (Constant),age group
b. Dependent Variable: MFRS

Casewise diagnostics in Table 15 presents a listing of two outliers where observed data are three standard deviations or more from the mean value of the dependent variable. The outliers represent sample peculiarity as data entry was checked twice. The standardized residuals histogram illustrated these outliers. It was expected that casewise diagnostics would also list these values as outliers.

Table 15

*Casewise Diagnostics*[a]

| Case Number | Std. Residual | MFRS | Predicted Variable | Residual |
|---|---|---|---|---|
| 182 | -3.368 | 10.85 | 10.85 | -6.853 |
| 184 | -5.333 | 10.85 | 10.85 | -10.853 |

The Residual Statistics Table 16 assesses the fit of the model providing summary data regarding residuals. The bottom three rows are measures of the influence of the minimum, maximum, and case on the model. Cook's Distance (threshold value of > .021), and maximum Centered Leverage Value (.063) are above the values reported for the case in the model. These outliers do not appear to exert undue influence on the regression coefficients. The assumption of normally distributed residual error is met despite the presence of two outliers.

Table 16

*Residuals Statistics*[a]

| | Minimum | Maximum | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| Predicted Value | 10.85 | 14.57 | 12.67 | 1.276 | 190 |
| Std. Predicted Value | -1.423 | 1.490 | .000 | 1.000 | 190 |
| Standard Error of Predicted Value | .152 | .265 | .204 | .044 | 190 |
| Adjusted Predicted Value | 10.77 | 14.63 | 12.67 | 1.276 | 190 |
| Residual | -10.853 | 5.147 | .000 | 2.030 | 190 |
| Std. Residual | -5.333 | 2.529 | .000 | .997 | 190 |
| Stud. Residual | -5.377 | 2.549 | .000 | 1.004 | 190 |
| Deleted Residual | -11.030 | 5.230 | -.002 | 2.056 | 190 |
| Stud. Deleted Residual | -5.829 | 2.588 | -.004 | 1.022 | 190 |
| Mahal. Distance | .066 | 2.221 | .995 | .850 | 190 |
| Cook's Distance | .000 | .235 | .006 | .020 | 190 |
| Centered Leverage Value | .000 | .012 | .005 | .040 | 190 |

a. Dependent Variable: MFRS

### *Discussion of Findings*

Correlation and regression analyses demonstrated that the mean MFRS total score is negatively correlated with aging across the six adult decade age groups. Sex and physical activity were found to have relationships to the MFRS total score although not at significant levels.

*Decade Age Groups.* Total physical performance scores of the MFRS decrease across the six age decades as seen in the histogram and boxplot below (Figures 10 & 11). Modifiable fall risk impairments show a slow decline in mean scores from the younger decade age groups 20-29, 30-39, 40-49, and 50-59. Studies by Choy et al. (2003) and

Isles et al. (2004) found similar findings in physiological aging changes and balance tests. In the histogram a sharp drop in performance is evident in each of the older age groups, 60-69 and 70-79. Standard deviations are consistent in the younger age groups 20-29, 30-39 and 40-49. Variability in performance increased at 40-49 and becomes greater in the older decade ages groups, 50-59. 60-69. The greatest variability in performance is seen in the 70-79 decade age group illustrated in the boxplots below.

Figure 10

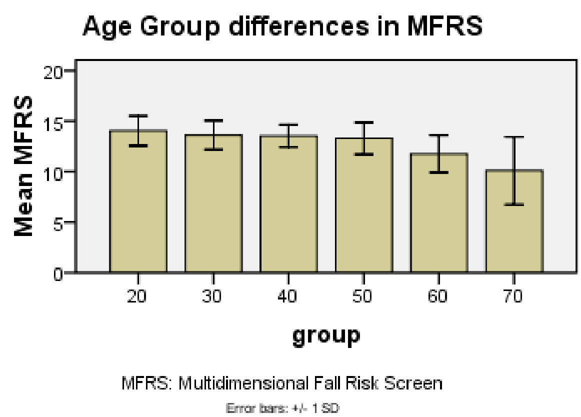
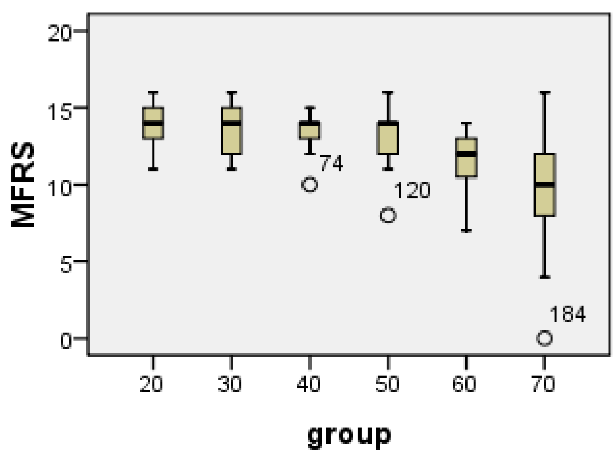
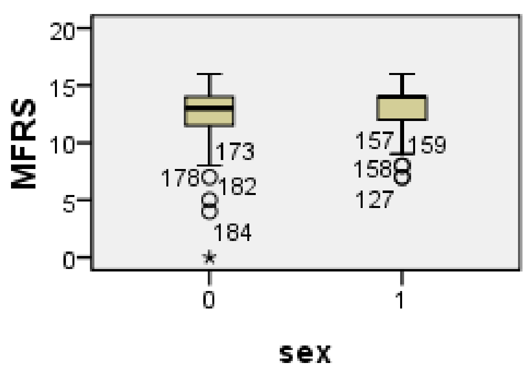



Figure 11



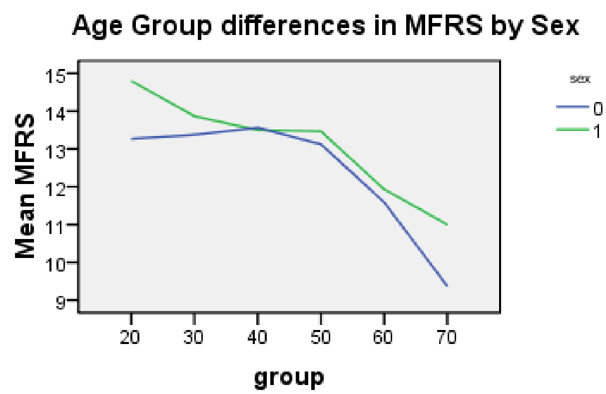

*Sex.* Differences between male and females performances on the MFRS had a significant moderate correlation. When sex was entered into the regression analysis its 15 percent variance significance was not significant at p-value <.01. It was subsequently excluded as a predictor variable in the model. Sex, as a predictor of fall risk, is one of many that have been identified in the literature by Grisso et al. (1991) and Stevens and Sogolow (2005). Stevens et al. (2006) reported that fatal fall rates have increased significantly from 2001-2005 among both genders but there continued to be a higher incidence in males. Nonfatal fall related injuries disproportionately were sustained by females. The boxplot illustrates the trend identified in this study (Figure 12). Males (coded 1) had slightly higher scores on the mean MFRS scores indicative of fewer balance and mobility impairments. The line graph illustrates gender differences greatest in the 20-29 age group with a gradual decline and leveling off in physical performance from 30-39 and 40-49 (Figure 13). Mean MFRS scores drop significantly in both genders at 50-59 age decade and continue to decline into the 70-79 age decade with the males showing fewer impairments during this period.

Figure 12




male =1; female = 0

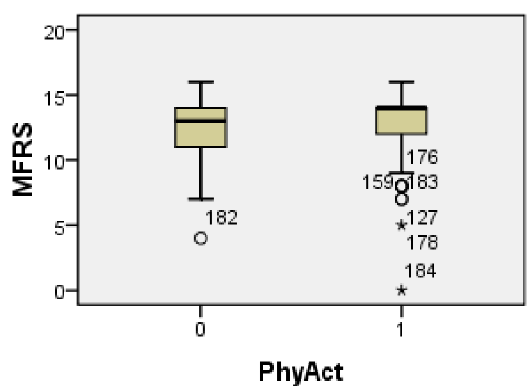
Figure 13




MFRS: Multidimensional Fall Risk Screen Score
Male: 1; Female: 0

*Physical Activity.* A low statistical relationship of physical activity to the MFRS total score (see Table 8) was found in this study. Examination of the boxplot (Figure 14) of MFRS scores by physical activity level show a decrease in physical performance in the physically inactive adult.

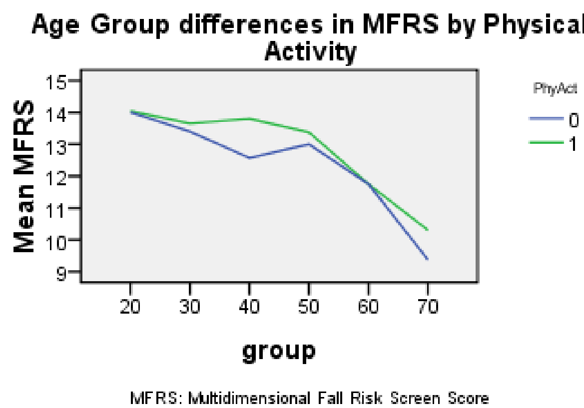
Figure 14




1 = active; 0 = inactive

Physical activity level was also assessed in relationship to the MFRS score and age decade. The line graph below clearly illustrates the relationships of these three variables (Figure 15). Activity levels, whether active or inactive, parallel each other through out the age decades with the exception of a difference in these levels from ages 30-50. Despite this difference in activity level associated with these ages, there is a negative linear trend in activity level with aging, and increased impairment levels of the participants in this study. Study results showed 73.3 percent of the participants across the six age decades considered themselves to be active. This is a higher rate when compared to work by Haskell et al. (2007) and Nelson et al. (2007). These studies reported physically active lifestyles at 59.6 percent among younger adults and 39.0 percent among older adults.

Figure 15




General downward trend in activity level associated with age and increased physical impairments is well supported in the literature (Legters, 2002). Lack of statistical significance in physical activity being an important predictor of the impairment score may be partially explained by two considerations evidenced in the literature. Fall risk is a complex, multidimensional concept (Covinsky et al., 2001; Tinettie et al., 1988). Fall risk factors are many, with physical activity being just one predisposing factor. The regression analysis estimated that physical activity accounted for only 7.9 percent of the variance in the MFRS score of impairment. A second consideration that needs to be addressed when understanding the relevance of physical activity in the ability to perform tests of balance and mobility is that of exercise specificity. Herdman, in 2000, discussed research in the area of vestibular adaptation and the requirement that the nervous system adapts well to specific stimuli.

# Chapter V

## Summary and Conclusions

Epidemiological reports indicate high prevalence of falls in individuals age 65 and older. Currently in the United States, prevention standards are available primarily for the older adult population. Research has identified and prioritized physiologic factors (eg., visual, vestibular, neural, and muscular changes) predictive of future falls that may be present earlier than 65 years of age. Multidimensional fall risk screening can enable identification of impairments from each of the physiological systems that contribute to balance and functional mobility. Current practice focuses on secondary or tertiary fall prevention after a serious fall related injury has been sustained. Primary prevention has not evolved to the point of recommending nor providing a mechanism to systematically examine the precipitating factors, functional consequences, and potential for future prevention of falls and fall related injuries in adults.

Identification of impairments in an adult prior to falling and or sustaining a fall related injury can serve as a significant primary prevention strategy in our country. This study has undertaken these issues by providing a primary prevention tool in order to provide multidimensional physical performance screening to independent community dwelling adults throughout the lifespan. Community screening would be able to identify fall risk and preclinical disability that lead to decreasing physical functioning and increasing fall risk as they age. Fall risk stratification, an important primary prevention strategy, can provide the high functioning adult with information and direction on how to age healthy. This chapter will present summary of procedures used in the study; summary of findings from the statistical analyses related to the research hypotheses; conclusions that have been reached in reference to the problems that the study was based on; discussion of findings and resultant contribution of the study; and lastly, recommendations for further study.

## Summary of Procedures

One hundred ninety independent community dwelling adults participated in this cross sectional study. Participants were placed into one of six decade age groups (20-29, 30-39, 40-49, 50-59, 60-69, and 70-79). Recruitment was completed as each age decade cell consisted of approximately 30 subjects with at least 15 male and 15 females in each age group. Testing took place in various community settings: churches, school gymnasiums, public library, homes, workplace settings. Two investigators, a physical therapist and physical therapy student, completed testing of the 190 participants. The first 20 participants were tested by both investigators. Reliability of each investigator was insured by dual timing and practice of using the same explanations and set of test instructions.

Each participant underwent IRB informed consent and HIPPA authorization. Exclusion criteria consisted of significant cognitive, neurological and orthopedic disabilities that would disallow functional independence. Acute illness, unstable medical condition, or significant visual impairment excluded participation in the study. Participants underwent an interview to complete a health status questionnaire at which time sensory testing with a 5.07 monofilament and measurement of ankle dorsiflexion took place.

The MFRS was administered individually within a 10-15 minute time frame. Eight categories with sixteen components of physical performance were tested. The order of the tests were arranged to minimize fatigue and overuse of one body segment. The investigators monitored for signs of fatigue, distress, or impending loss of balance. The subjects were instructed to stop the testing at any point in time they felt unable to follow the test instructions or if they began to have pain of any kind. The following components tests were administered.

*Habitual Gait Speed*. Gait speed is associated with functions of mobility, dynamic balance, and lower extremity power. Subjects were timed during a 20 foot walk, walking at their normal walking speed. Velocity was calculated. Gait speed of
< 3.3 ft/sec was used as the threshold value for fall risk. This value was also used to determine presence of impairment.

*Multidirectional Reach Test.* Multidirectional reaching measures self-imposed movement that challenges limits of stability. Subject was asked to stand with an arm raised to shoulder level with an outstretched hand. Investigator held a yardstick parallel to the raised arm. Subject was instructed to reach forward as far as possible without lifting either feet off the ground. Measurements were taken at the end of the middle finger before and after reaching. One practice trial was allowed. Reach was recorded in inches. Backwards, right and left reaches are then measured. Threshold value for fall risk is available for forward reach at < 10 inches.

*Horizontal Dynamic Visual Acuity*. Passive dynamic visual acuity assessed functional vision and vestibular function. Subject was seated 10 feet from a Visual Acuity Eye chart. Static acuity was recorded as the last line that could be read clearly.

Subject's head was held from behind in 30 degrees of neck flexion. A metronome set at 120 beats per minute assisted investigator in passive oscillation of the subject's head to the right and left. Subject was instructed to read out loud the lowest line possible while his is being moved. Dynamic visual acuity is recorded as the number of lines lost during the maneuver. Threshold value for vestibular hypofunction is a loss of ≥ 2 lines.

*Single Leg Stance*. Single Leg Stance measures lower extremity strength and static balance within a narrowed base of support. Subject was asked to assume single leg stance with arms crossed at the chest, hands touching shoulders. The nonweightbearing leg was held bent at the knee with the foot held off the floor. Subject was instructed to focus on a target a few feet away. Right and left legs are timed up to 30 seconds with eyes open and eyes closed. The test is terminated if the subject can not hold the test position. A threshold value of < 5 seconds is indicative of significant impairment in balance and at risk for an injurious fall.

*Ankle Dorsiflexion ROM*. Passive ankle dorsiflextion is a component of a normal gait pattern and required for movement strategies used in maintaining balance. Subject was seated with the lower extremity to be tests extended at the knee and foot placed on a standard stool. A goniometer was placed along the lateral side of the ankle, lined up with the fibular head, calcaneous, and fifth metatarsal head. Subject was asked to dorsiflex at the ankle and then the investigator made sure the ankle was at maximum dorsiflexion prior to taking the measurement. Normal locomotion requires 10 degrees of dorsiflexion with the knee extended. This value was used as the impairment threshold.

*Timed Up and Go Test*. The TUG measures basic functional mobility. Balance, lower extremity strength, transitional movement, and gait pattern are assessed during this activity. The investigator first demonstrated the movement pattern. The subject was seated 10 feet away from a wall or mark on the floor. When the investigator said ”Go”, the subject stood, walked at their habitual gait speed to the wall or mark, turned around, walked back to the chair and sat down. Time was recorded from the point they lean forwards in the chair to stand and until they are seated and their back is against the back of the chair. A chair height of 18 inches without arm rests was used. A score of > 10 seconds was used as an indicator of impairment.

*Five Times Sit to Stand Test*. The Five Times Sit to Stand Test is a measure of lower extremity power and ability to transition from one position to another. The subject was seated in a chair (18 inches in height without armrests) with their back against the chair. The investigator demonstrated the test movements. One practice sit to stance was practiced by the subject. Subject was then timed during sit to stance, five times, performed as quickly as possible. Timing started when the subject assumed the stance position and stopped when the subject sat down on the seat on the fifth repetition. Arms were held crossed across the chest during the test. A score of $\geq$ 10 seconds was recorded as an impairment.

*Single Heel Rises*. Standing Heel Rises are indicative of lower extremity functional strength. The investigator started a metronome set at 60 beats per minute and demonstrated the test movement. The subject then stood next to a counter, bent the knee of the leg closest to the counter so the foot was completely off the floor. The subject was instructed to maintain finger tip touch pressure on the counter during heel rises with the leg still on the ground. The subject was to perform 25 heel rises with the beat of the metronome. The test was terminated if the subject began to lean or bear excessive pressure on the counter; the plantar flexion range of motion decreased with more of the foot touching the ground; or the person chose to stop the test. Threshold value for the test was < 25 repetitions.

On completion of the MFRS test each participant received a written summary of their fall risk screening. The number of modifiable fall risk factors present was tabulated. Impairments were based on scores that reached specific threshold values derived from fall risk evidence based literature. A few minutes were taken to provide recommendations and instructions to minimize what impairments were identified during testing.

SPSS 16.0 was used to provide statistical analysis of the data collected. The statistical hypotheses were:

$Ho_1$: There will be no significant difference in the MFRS component scores across the six age decade groups tested.

$Ho_2$: There will be no significant difference among the mean MFRS total scores across the six age groups tested.

$Ho_3$: There will be no significant association of the mean MFRS total score across the six age decade groups due to sex and physical activity.

Descriptive statistics were used to identify self reported fall risk characteristics. Component test score means and standard deviations were used to develop a table of reference values by age decade for each of the MFRS component tests. Impairment frequencies were tabulated for each of the MFRS component tests by age group to determine fall risk stratification.

Age group served as the independent variable made up of six age decade subgroups from 20-79 years of age. The sixteen MFRS component tests of physiological and functional performance constituted the dependent variables in the study. Sex and physical activity were treated as independent factors along with age group when the third null hypothesis was tested.

A multivariate analysis of variance (MANOVA) was used to test the equality of the six decade age groups means for each of the component test scores. The Type I error was maintained as the predetermined .01 alpha level of significance. MANOVA assumptions were assessed. Multivariate and univariate analysis of variance were completed to determine if the component mean test scores showed a significant difference across the six age groups. The Games-Howell multiple comparison procedure was selected as homogeneity of variances assumption was violated by some of the dependent variables.

Correlation procedures and correlation coefficients were utilized to test the second null hypothesis. Multiple regression analysis was performed to examine the relationship between the MFRS total scores to age group, sex, and physical activity. The assumptions for linear regression were tested first. The regression analysis determined if age group, sex, and physical activity were significant predictors of the total MFRS mean scores. Multicollinearity was monitored for the three fixed factors. Residual statistics were also performed to analyze the influence and leverage of any outliers in the data.

## Summary of Findings

### *Analysis of the First Hypothesis*

Descriptive statistics were used to tabulate subject characteristics of sex and number of subjects in each age group (Table 1). The total number of participants was 190 with an approximately equal number of male and female subjects in each age group. Descriptive statistics also tabulated frequencies of self reported fall risk characteristics (Table 2). An upward trend in the presence of five of the ten reported fall risk factors was evident with aging. A pivotal age decade appeared to be 50-59 at which fall risk factors took an upward climb in incidence. The fall risk factors of medications, medical conditions, mobility and ADL limitations, physical inactivity, and pain were the most frequently reported factors, all peaking by age group 60-69. Fall history in the previous twelve months was reported in the 50-59, 60-69, and 70-79 age decades.

Performance reference values for the sixteen MFRS component tests were organized into a table of means and standard deviations by test and age group. A decreasing trend in performance is evident for each component test across the six age decades. Impairment frequencies were calculated for each of the component tests (Table 3). Aging changes are evident in the component test scores as well as decreased performance scores to the point of turning into impairments. Impairments are noted early in adulthood for six of the component tests, the four Single Leg Stance tests, Eyes Closed more than Eyes Open; and both Ankle Dorsiflexion Range of Motion tests. Single Leg Stance Eyes Closed impairment incidence peaked in the 60-69 age group while the other four tests peaked in the oldest age group 70-79.

Descriptive statistics picked up an age related trend of decreasing performance in the component test means and also increasing incidence of impairments in most of the component tests. A one-way multivariate analysis of variance (MANOVA) was conducted to test the null hypothesis that states the component test scores on the MFRS will not show age related differences across six adult decade age groups. MANOVA was used to detect differences in the mean component test scores between the six levels of age group, the independent variable. Age group served as the independent variable with six subgroups (20-29, 30-39, 40-49, 50-59, 60-69, and 70-79). MFRS component tests made up sixteen dependent variables in the analysis. The assumptions for MANOVA were explored for independence of variables, scale of measurement, normality, and homoscedasticity. Shapiro-Wilk statistic, kurtosis and skewness were acceptable for Habitual Gait Speed, the four Multidirectional Reach Tests, Time up and Go Test, Five Times Sit to Stance Test, and Ankle Dorsiflexion Right and Left. Skew statistics and histograms revealed clustering of scores towards the perfect side of the scores in the younger age groups during Single Leg Stance Eyes Close Right and Heel Rises Right and Left. Histograms revealed normal distribution of scores in 94 of the 96 graphs. Platykurtosis was found in two of the histograms, Single Leg Stance Eyes Open Right and Left (Appendix H). The planned F test should be robust enough with these violations of normality to support its use in testing the null hypothesis.

Both multivariate and univariate tests underwent analysis for homoscedasticity across the age groups. This assumption was not supported by Box's M test for the multivariate test. The Levene's Test of the univariate ANOVA tests demonstrated acceptable homogeneity of variance in six of the dependent variables (Habitual Gait

Speed, four Multidirectional Reach tests, Right Ankle Dorsiflexion, Timed Up and Go, Five Times Sit to Stance, and both Heel Rise Tests). MANOVA and ANOVA are robust to departures from this assumption. In order to minimize Type I errors in the F tests, a specific significance test, Pillai's Trace, would be used to determine if each age group had a significant effect on the dependent variables. Visual inspection of boxplots and bar graphs showed a gradual increase in preclinical impairment scores with increasing age. Difference between the means suggested that an analysis of variance would support the research hypothesis.

The significance of the F test showed a significant multivariate effect, Pillai's Trace $F(80, 865) = 3.516$, $p < .0005$. Age decade significantly affected mean MFRS component test scores. Partial eta squared = .245, indicating the model explains 24.5 percent of the variance in the dependent variables. Power at 1.000 denotes a strong probability of correctly rejecting the null hypothesis when it is false (Table 6).

Univariate testing was used to see if the model was significant for each of the sixteen dependent variables. Alpha value of .01 was used to control for Type I error inflation due to the presence of sixteen dependent variables. In the Tests of Between-Subjects Effect Table 7, there is a significant F at $p$ - $< .0005$ for each of the component tests. The partial eta-squared values, measures of effect size, for thirteen of the component tests were well over 10 percent indicative of a strong relationship between independent variable and each dependent variable. Multidirectional Reach Test Left, Dynamic Visual Acuity, and Heel Rises Left showed moderate strength relationship at 6-9 percent. Thirteen of the tests had significant ability to detect effect with power levels greater than .80; acceptable power at .6 was noted for two groups. Parameter estimates, provided additional assessment of significance of each parameter coefficient. A consistent relationship was found for all sixteen dependent variables and each of the six age groups. Significance levels were all under .05 for thirteen of the dependent variables.

Post Hoc testing at an alpha level of .01 followed the F significance tests. The Games-Howell test was used because equal variances could not be assumed and group sizes were unequal. Multiple comparison testing determined which age group means differed significantly from the others for each of the MFRS component score means. Least significant differences were noted with Heel Rises Left and Right. Multidirectional Reach Test Left demonstrated the least significant difference and least consistent trend when comparing differences in scores from youngest to oldest group. A consistent trend in decreasing mean scores was seen through out the six age groups, from younger to oldest group. Multivariate and univariate testing were significant at the .01 p-value. It can be concluded that the main effect is real and not due to chance of sampling. The null hypothesis is rejected. The MFRS component scores show age related differences across six adult decade age groups.

*Analysis of the Second and Third Hypotheses*

Descriptive statistics tabulated means, standard deviations, standard errors, skewness, and kurtosis for the MFRS total score for each age group (Appendix K). Correlation coefficients and individual correlation procedures performed for MFRS, Age Group, Sex, and Physical Activity. MFRS had a strong Pearson Correlation of .532 with Age Group and a moderate correlation of .173 with Sex. Both of these relationships were significant at p – value <.01. Physical Activity had a weak Pearson Correlation to MFRS at .173 at a p-value of .117.

Multiple Regression was used to assess the nature of the relationship of Age Group, Sex, and Physical Activity as independent predictors with the dependent variable MFRS. The linearity assumption was examined by scatterplot and Q-Q plots which showed linear relationships of the dependent variable with Age Group. Normality of the residuals was indicated by normal skew and kurtosis statistics for all age groups. The Shapiro-Wilk statistics and significance levels failed to indicate perfect normal data with the exception of the MFRS-age group 70 data. Further evidence of meeting the normality assumption was gathered by running a regression standardized histogram. The distribution was normal with the exception of one value greater than three standard deviations. Homoscedasticity was present upon examination of a scatterplot of standardized residuals and predicted dependent variable scores. The plots followed a symmetrical pattern with concentration along the horizontal line. The variance that is seen is linear as the point formed a straight line.

Stepwise regression identified Age Group as the strongest predictor with R of .532. Variance from the adjusted R square values presents 27.9 percent variance effect on the dependent variable due to regression from the predictor, age group. When age and sex are combined as predictors in the model, variance effect was increased to 29.9 percent, approximately 70 percent of the variability due to other factors not identified in the model. Significance of the F value, 74.271 (1, 188) at p-value < .0005 explained a statistically significant portion of variability in the dependent variable. Sex and Physical Activity were excluded from the model when the alpha level was set at .01. Beta coefficient at .532 and *t* value at – 8.618 for Age Group were high enough to be important in the model at p-value <.0005. Age Group is 3.5 times a better predictor than sex in the model. Collinearity was not a problem as correlations, tolerance and Eigenvalue statistics are indicative of a lack of linear relationship of the predictors with each other. Casewise diagnostics presented two outliers in the data. Measures of influence of the outliers did not appear to exert undue influence on the regression coefficients. The assumption of normally distributed residual error was met despite the presence of two outliers. Correlation and regression analyses rejected the second null hypotheses in this study. The mean MFRS total score was negatively correlated with aging across the six adult decade age groups. The statistical analysis of the third null hypothesis was inconclusive. Sex and physical activity were found to have small predictive relationships to the MFRS total score but not at significant levels.

## Conclusions

Based upon the findings and within the limitations of this study a multidimensional fall risk screening test (MFRS) was compiled for the independent community dwelling adult. The MFRS proved to be an efficient measure of modifiable fall risk factors in the areas of balance and functional mobility. Adults from age decades 20-29 through 70-79 demonstrated significant age related differences in physical performance on most of the sixteen component tests and on the MFRS total score of impairment. Sex and physical activity have a relationship to the age associated changes in physical performance but not as primary predictors. Reference values for sixteen physical performance tests are available for adults throughout the lifespan. Impairments in physical function are seen in the younger and middle aged adult. Risk stratification of young and middle aged adults is a valid indicator of preclinical disability. The use of modifiable fall risk factors in the screening process is a primary fall prevention strategy that captures the attention of the individual being tested. Personalizing the risk stratification to an individual's lifestyle can make the education and exercise prescription palatable to an individual that has not taken physical activity or the idea of decreased physical functioning seriously.

## Discussion and Implications

Aging is a complex process with multidimensional interacting factors. Primary prevention needs to address not only fall risk but also look more in depth into areas of preclinical disability to keep the adult healthy and vigorous as long as possible later in life.

This study has supported current concepts of physiological aging and identified specific areas of balance and functional performance that can be used to make decisions on further examination and specific interventions. This process was in keeping with CDC recommendations, gerontological research, and professional organization fall prevention guidelines. Whipple in 1997 in pursuit of appropriate balance training stimuli concluded that the postural response is dependent on systems integration. The systems mentioned in her work make up the component tests of the MFRS. Assessment of muscle strength, power, sensorimotor function, joint range of motion, endurance, and vestibulo-ocular processing. Gait and balance impairments have been found to predict future falls more often than any other domain when assessing individuals who have not fallen within the past twelve months (Ganz, Bao, Shekele, & Rubenstein, 2007). This study has presented a screening instrument that is multidimensional in nature and focuses on the independent community dwelling adult prior to serious fall history. The MFRS has the capacity to be administered to the high functioning adult within 10-15 minutes. The ceiling effect of several clinical measures, eg., Functional Gait Assessment, and Berg Balance Scale was taken into account as the MFRS was compiled. The MFRS component tests Single Leg Stance, Timed Five Times Sit to Stand Test, Habitual Gait Speed, and Multidirectional Reach Test challenged the highest functioning participant. The Single Leg Stance Test and Timed Sit to Stand Test have been found to be reliable and discriminatory between the most high functioning adult and those with just good function in a larger population based sample by Curb et al., 2006.

Fall risk stratification was easily determined as a result of the screening. The moment in time when the screening was completed became an optimal opportunity for communication of the adult's status. Strength areas and impairments were easily explained to the participants along with the opportunity to prescribe physical activity and targeted exercise. The 190 participants received the screening, exercise prescription, and education within a 20-30 minute session.

This study has contributed reference values for sixteen physical performance tests. The reference values will be immediately useful in community and clinical settings. This information is comprehensive in that normative values are provided for the adult lifespan from 20-79 years of age for sixteen different component tests. Most of the research to this point has presented reference values for small or for special populations. Most of the work that has been reported in the literature centers around values to be used by clinicians for adults well over 65 years old.

An interesting finding in this study has been what a preliminary profile of the independent community living adult looks like when aspects of the Health Status Questionnaire and MFRS total score are combined (Table 17). Overall, all participants had normal cognitive functioning. The Short Blessed Test did not have to be administered. Participants were quick to respond to health status questions. Physical activity and being active were defined according to updated 2008 CDC, ACSM and AHA health recommendations for populations aged 18-65 and for over 65 years of age. The independent adults was found to be not sedentary, active enough to meet physical activity threshold values on a regular basis; perceived themselves as having excellent to good health, with no one reporting poor health. On physical performance testing the profile describes a 94.21 percent incidence of one or more impairments in the participants. This last finding in itself provides justification for primary prevention earlier than 65 years of age.

Table 17

*Profile of the Independent Community Living Adult*[a]

| Characteristic | Incidence (%) |
|---|---|
| Physical Activity | |
| Active | 73.33 |
| Inactive | 26.67 |
| Perceived Health Status | |
| Excellent | 41.05 |
| Good | 55.67 |
| Fair | 3.68 |
| Poor | --- |
| Self Reported Fall Risk[b] | |
| Low[c] | 79.5 |
| High[d] | 20.5 |
| Physical Performance Impairments[e] | **94.21** |

[a]N=190
[b]Self reported fall risk taken from the Health Status Questionaire (HSQ)
[c]Low risk = Less than four risk factors
[d]High risk = four or more risk factors
[e]Physical performance impairments calculated from MFRS total score

## Recommendations for Future Study

Issues that need investigation in the area of fall prevention can be approached from several levels. The most basic and simple area that demands further in depth study is that of intrinsic and extrinsic fall risk factors, eg., long lies on the floor, a marker of eminent illness and mortality (Tinnetti et al., 1993, Nevitt et al., 1991); contrast sensitivity as a marker of functional vision and predictor of falls (Lord et al., 1991). It would be expedient to focus scientific investigation and health promotion efforts into fall risk factors that are modifiable. This study emphasized modifiable physical performance risk factors. Other modifiable risk factors such as the extrinsic factors of polypharmacy and environmental hazards have been identified as predictors of falls and fall related injuries (CDC, 2006; Tinnetti et al., 1988). These factors have been incorporated into fall prevention strategies but implementation of the strategies has not been comprehensive and usually occurs after a fall related injury. State and local community pilot programs need to be supported to bring these strategies into primary fall prevention.

Other areas of study that should be pursued include: psychosocial aspects of changing behavior of an adult to take fall risk seriously and, most importantly, personally; validation of fall risk stratification utilizing primary fall risk indicators; implementation of fall risk stratification by medical service providers; incorporation of fall risk stratification as fall primary prevention by individuals, medical service providers, and CDC. These are a few areas of study that are essential to the multifaceted approach of primary prevention.

The next step in continued research with the MFRS as a screening instrument would need to involve instrument validation by looking at factor analysis to make sure each component test is important. Longitudinal analysis using the MFRS pre and post intervention in a randomized controlled study would also be imperative to see what types of disability would occur in the treatment and control groups. Investigation of how the Health Status Questionnaire used in this study complements the MFRS findings would help to more fully understand the profile of an adult prior to disability. Prevention and or delay of frailty, another major health concern in our country, could be impacted by early assessment of balance and mobility with an instrument like the MFRS. The MFRS total score and the sixteen component tests have provided reference values for adults throughout the lifespan that can be immediately put into use in clinical or community screening activities. Work by Rivara et al., 1997 concluded that screening is a passive component of prevention strategies and that it can be included in individual routine medical examinations or part of a community's prevention program. The active behavioral component to prevention would entail the adult taking risk stratification gained from the screening and making changes on their person to minimize the identified fall risk factors.

Extensive study and beginning national fall prevention efforts have paved the way to begin to control the rising incidence of falls and fall related injuries. Capability of identifying fall risk with subsequent stratification is present in our society. This study has added significant evidence of preclinical disability in young and middle aged adults. Fall risk stratification was easily performed with a screening instrument. The impetus for early fall risk stratification and intervention is present, whether it is epidemiological data, physiology of aging, or significant incidence of balance and functional mobility impairments in adults younger than 65 years of age.

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# Appendix A

## Multidimensional Fall Risk Screen

# Multidimensional Fall Risk Screen

ID ____ Date ____

**Pass/Fail**
**0 / 1**

**Habitual Gait Speed**

Begin timing once subject has gone 5 feet. Timing is stopped once subject has walked for 10 feet.

Time _____ sec _____ ft/sec _____

**Multidirectional Reach Test**

Subject stands with feet together and is asked to lean in each direction as far as he is able to without moving or lifting either foot. Arm held at shoulder level.

Forward ____ inches _____
Backward ____ inches _____
Right ____ inches _____
Left ____ inches _____

**Horizontal Dynamic Visual Acuity**

Static acuity (Snellen Chart) _______

Dynamic acuity: Head undergoes 20 passive head side to side movements while subject determines which line he is able to clearly read.

Lines lost ____ _____

**Single Leg Stance**

Stand on one leg, arms crossed across chest with opposite leg bent at the knee at a 90 degree angle off the floor.

EO RLE ____sec _____
EO LLE ____sec _____
EC RLS ____sec _____
EC LLE ____sec _____

**Ankle Dorsiflexion ROM**

Subject is seated. Lateral measurement is taken with knee extended.

R Passive dorsiflexion ____ degrees _____
L Passive dorsiflexion ____ degrees _____

**Timed Up and Go Test**

On the command "go" the subject is to stand from a chair, walk forward at a comfortable pace, 10 feet, to the mark on the floor, turn around, walk back to the chair and sit down. Perform one practice trial.

Time ____ sec _____

**Five Times Sit to Stand Test**

Subject will rise from a chair five times as fast as possible with arms crossed at the chest. Perform one practice sit to stand.

Time ____ sec _____

**Single Heel Rises**

Perform 25 heel raises one leg at a time. Opposite leg is held off the floor bent at the knee at 90 degrees.

Right Leg ____ heel raises _____
Left Leg ____ heel raises _____

**Total Score ___/16**

# Appendix B

## Health Status Questionnaire

# Health Status Questionnaire

ID ______ Date _______

**Demographic Information**

Age _____
Gender M / F

**Fall Risk Factors**

| | |
|---|---|
| Fall history within previous year *(an unintentional change in position resulting in coming to rest on the ground or at a lower level)* | |
| 0 - 1 fall ____ ≥ 2 falls ____ | Y / N |
| Mechanism of fall __________________________________ | |
| Mobility and ADL Limitations | |
| ADLs / IADLs difficulties *(dressing, toileting, bathing, homemaking, yard work, other ______________)* | Y / N |
| Gait / balance difficulties | Y / N |
| Uses ambulation device | Y / N |
| Sensory loss on plantar surface of feet | Y / N |
| Physically inactive *(< 5 days/wk, mod activity, accumulated 30 min daily or < 3 days/wk, vigorous activity, 30 min duration)* | Y / N |
| Medication Use | |
| Polypharmacy *(four or more medications)* | Y / N |
| Cardiovascular system medications *(diuretics, anithypertensives)* | Y / N |
| Psychoactive medications *(sedatives, antidepressants)* | Y / N |
| Musculoskeletal system medications *(narcotics, corticosteroids)* | Y / N |
| Other *(hypoglycemics, allergy, cold medications ___________)* | Y / N |
| Medical Conditions | |
| Musculoskeletal *(arthritis…)* | Y / N |
| Neurological *(stroke, Parkinson's…)* | Y / N |
| Diabetes | Y / N |
| Heart disease *(postural hypotension, arrhythmias, unstable…)* | Y / N |
| Dizziness | Y / N |
| Muscle weakness | Y / N |
| Pain | Y / N |
| Cognitive status *(orientation to person, place, date and time)* | |
| SBT if indicated ____/28 | Y / N |
| Fear of falling *(Have you been afraid that you might fall inside or outside the home?)* | Y / N |
| Self Efficacy *(Does fear of falling limit yours activities?)* | Y / N |

**Perceived Health Status**

In general, would you say your health is:

Excellent ___ Good ___ Fair ___ Poor ___

**Fall Risk**

**Low risk _____ High risk *(≥ 4 risk factors)* _____**

# Appendix C

The Short Blessed Test

# The Short Blessed Test

ID_________ Date ________

**Instruction**

Score 1 error for each incorrect response, to maximum for each item.

| **No.** | **Question** | **Maximum Error** | **Score** | **x** | **Weight** | |
|---|---|---|---|---|---|---|
| 1. | What year is it now? | 1 | _____ | x | 4 | =_______ |
| 2. | What month is it now? | 1 | _____ | x | 3 | =_______ |
| | Repeat this phrase<br>John Brown,<br>42 Market Street<br>Chicago | | | | | |
| 3. | About what time is it? (within 1 hour) | 1 | _____ | x | 3 | =_______ |
| 4. | Count backwards 20 to 1 | 2 | _____ | x | 2 | =_______ |
| 5. | Say the months in reverse order | 2 | _____ | x | 2 | =_______ |
| 6. | Repeat the phrase just given | 5 | _____ | x | 2 | =_______ |

*Total error score =_____/28*

Reference

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# Appendix D

## MFRS Summary

# Multidimensional Fall Risk Screening
# Summary

**Your physical performance fall risk screening showed the following results:**

| | Risk Factor |
|---|---|
| **Habitual Gait Speed**<br>Measure of dynamic balance and leg power | _____ |
| **Multidirectional Reach Test**<br>Measure of functional reach | _____ |
| **Dynamic Visual Acuity**<br>Measure of functional vision and vestibular status | _____ |
| **Single Leg Stance**<br>Measure of static balance | _____ |
| **Ankle Dorsiflexion ROM**<br>Measure of joint and muscle flexibility | _____ |
| **Timed Up and Go Test**<br>Measure of functional mobility | _____ |
| **Five Times Sit to Stand Test**<br>Measure of leg power | _____ |
| **Single Heel Rises**<br>Measure of leg strength and power | _____ |
| **Modifiable Fall Risk Factors Present** | _____ |

**Recommendations based on your screening: ___________________________________**

**_____________________________________________________________________________**

**_____________________________________________________________________________**

**_____________________________________________________________________________**

**For further information on falls and fall prevention, see Centers for Disease Control and Prevention at: www.cdc.gov/injury**

# Appendix E

## MFRS Component Test Means and Standard Deviations

***Multidimensional Fall Risk Screen Component Test Means and Standard Deviations by Age Decade***

| | Age Decades | | | | | |
|---|---|---|---|---|---|---|
| Component Tests[a] | 20-29 Mean (SD)[b] | 30-39 Mean (SD) | 40-49 Mean (SD) | 50-59 Mean (SD) | 60-69 Mean (SD) | 70-79 Mean (SD) |
| HabGaitSpeed | 4.93 (0.88) | 4.69 (0.75) | 4.55 (0.68) | 4.41 (0.76) | 4.32 (0.68) | 3.85 (0.70) |
| MDRT | | | | | | |
| Forward | 15.36 (2.05) | 14.54 (2.33) | 14.55 (1.96) | 14.38 (2.02) | 13.18 (2.06) | 12.01 (2.17) |
| Backward | 11.38 (2.46) | 9.38 (2.56) | 11.06 (2.69) | 10.78 (2.09) | 8.98 (2.58) | 7.55 (2.83) |
| Right | 11.97 (3.13) | 9.85 (1.72) | 10.13 (2.24) | 10.57 (2.37) | 10.09 (1.62) | 9.33 (2.32) |
| Left | 11.13 (3.25) | 9.76 (1.89) | 10.22 (2.11) | 9.51 (1.89) | 9.78 (2.12) | 9.12 (2.30) |
| DVA | 0.13 (0.35) | 0.35 (0.55) | 0.37 (0.66) | 0.32 (0.60) | 0.69 (0.90) | 0.50 (0.71) |
| SLSEO | | | | | | |
| Right | 29.86 (0.79) | 29.42 (2.25) | 28.95 (4.64) | 28.72 (5.46) | 28.88 (8.22) | 14.25 (11.43) |
| Left | 29.08 (3.96) | 29.17 (3.03) | 29.39 (3.20) | 28.02 (5.87) | 25.92 (7.70) | 14.00 (11.48) |
| SLSEC | | | | | | |
| Right | 21.84 (8.20) | 16.16 (10.91) | 10.69 (8.11) | 9.15 (7.59) | 4.80 (4.51) | 4.12 (5.95) |
| Left | 21.46 (10.05) | 12.45 (9.79) | 9.90 (7.30) | 7.44 (6.08) | 5.23 (4.11) | 3.85 (4.61) |
| Ankle DF | | | | | | |
| Right | 10.87 (3.81) | 10.16 (5.48) | 12.81 (4.25) | 10.84 (5.48) | 9.62 (6.71) | 5.71 (4.55) |
| Left | 9.93 (3.68) | 8.58 (7.91) | 12.81 (4.67) | 11.26 (5.64) | 9.87 (4.78) | 5.80 (6.45) |
| TUG | 5.59 (0.82) | 5.93 (0.73) | 6.11 (0.85) | 6.27 (1.07) | 6.70 (1.26) | 7.69 (1.92) |
| FTSST | 7.47 (1.33) | 8.07 (1.14) | 7.99 (1.19) | 8.26 (1.67) | 9.04 (1.62) | 9.34 (3.31) |
| Heel Rises | | | | | | |
| Right | 25.00 (0.00) | 25.00 (0.00) | 24.97 (0.18) | 25.00 (0.00) | 23.44 (6.15) | 21.92 (6.69) |
| Left | 25.00 (0.00) | 25.00 (0.00) | 24.88 (0.71) | 24.74 (1.44) | 23.78 (4.33) | 21.50 (7.23) |

[a] HabGaitSpeed= Habitual Gait Speed; MDRT= Multidirectional Reach Test; DVA= Horizontal Dynamic Visual Acuity; SLSEO= Single Leg Stance Eyes Open; SLSEC= Single Leg Stance Eyes Closed; AnkleDF= Ankle Dorsiflexion; TUG= Timed Up and Go Test; FTSST= Five Times Sit to Stand Test; HeelRises= Single Heel Rises

[b] SD= Standard Deviation Note: N = 190

# Appendix F

MANOVA: Tests of Normality

Appendix F

**MANOVA: Tests of Normality[b,c,d,e,f]**

| | group | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|---|
| | | Statistic | df | Sig. | Statistic | df | Sig. |
| HabGaitSpeed | 20 | .096 | 30 | .200* | .957 | 30 | .267 |
| | 30 | .082 | 31 | .200* | .963 | 31 | .352 |
| | 40 | .069 | 32 | .200* | .970 | 32 | .513 |
| | 50 | .160 | 31 | .041 | .905 | 31 | .010 |
| | 60 | .100 | 32 | .200* | .963 | 32 | .327 |
| | 70 | .124 | 34 | .200* | .916 | 34 | .013 |
| MDRTF | 20 | .141 | 30 | .129 | .961 | 30 | .319 |
| | 30 | .168 | 31 | .026 | .755 | 31 | .000 |
| | 40 | .078 | 32 | .200* | .967 | 32 | .422 |
| | 50 | .107 | 31 | .200* | .964 | 31 | .366 |
| | 60 | .127 | 32 | .200* | .974 | 32 | .631 |
| | 70 | .120 | 34 | .200* | .949 | 34 | .118 |
| MDRTB | 20 | .133 | 30 | .187 | .942 | 30 | .103 |
| | 30 | .114 | 31 | .200* | .971 | 31 | .546 |
| | 40 | .145 | 32 | .086 | .939 | 32 | .069 |
| | 50 | .107 | 31 | .200* | .982 | 31 | .859 |
| | 60 | .097 | 32 | .200* | .954 | 32 | .190 |
| | 70 | .107 | 34 | .200* | .981 | 34 | .796 |
| MDRTR | 20 | .166 | 30 | .035 | .908 | 30 | .013 |
| | 30 | .122 | 31 | .200* | .969 | 31 | .505 |
| | 40 | .109 | 32 | .200* | .977 | 32 | .695 |
| | 50 | .125 | 31 | .200* | .957 | 31 | .245 |
| | 60 | .177 | 32 | .012 | .923 | 32 | .024 |
| | 70 | .118 | 34 | .200* | .961 | 34 | .263 |
| MDRTL | 20 | .194 | 30 | .005 | .834 | 30 | .000 |
| | 30 | .094 | 31 | .200* | .968 | 31 | .464 |
| | 40 | .106 | 32 | .200* | .971 | 32 | .535 |
| | 50 | .155 | 31 | .057 | .938 | 31 | .074 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 60 | .124 | 32 | .200* | .915 | 32 | .015 |
| | 70 | .100 | 34 | .200* | .981 | 34 | .807 |
| DVA | 20 | .517 | 30 | .000 | .404 | 30 | .000 |
| | 30 | .418 | 31 | .000 | .640 | 31 | .000 |
| | 40 | .403 | 32 | .000 | .590 | 32 | .000 |
| | 50 | .447 | 31 | .000 | .586 | 31 | .000 |
| | 60 | .341 | 32 | .000 | .747 | 32 | .000 |
| | 70 | .378 | 34 | .000 | .693 | 34 | .000 |
| SLSEOR | 20 | .539 | 30 | .000 | .180 | 30 | .000 |
| | 30 | .537 | 31 | .000 | .270 | 31 | .000 |
| | 40 | .527 | 32 | .000 | .245 | 32 | .000 |
| | 50 | .528 | 31 | .000 | .256 | 31 | .000 |
| | 60 | .390 | 32 | .000 | .662 | 32 | .000 |
| | 70 | .198 | 34 | .002 | .853 | 34 | .000 |
| SLSEOL | 20 | .526 | 30 | .000 | .255 | 30 | .000 |
| | 30 | .511 | 31 | .000 | .305 | 31 | .000 |
| | 40 | .513 | 32 | .000 | .192 | 32 | .000 |
| | 50 | .471 | 31 | .000 | .395 | 31 | .000 |
| | 60 | .389 | 32 | .000 | .597 | 32 | .000 |
| | 70 | .183 | 34 | .005 | .842 | 34 | .000 |
| SLSECR | 20 | .273 | 30 | .000 | .814 | 30 | .000 |
| | 30 | .182 | 31 | .010 | .840 | 31 | .000 |
| | 40 | .146 | 32 | .079 | .868 | 32 | .001 |
| | 50 | .188 | 31 | .007 | .854 | 31 | .001 |
| | 60 | .274 | 32 | .000 | .697 | 32 | .000 |
| | 70 | .287 | 34 | .000 | .602 | 34 | .000 |
| SLSECL | 20 | .296 | 30 | .000 | .790 | 30 | .000 |
| | 30 | .147 | 31 | .086 | .858 | 31 | .001 |
| | 40 | .142 | 32 | .099 | .874 | 32 | .001 |
| | 50 | .167 | 31 | .027 | .844 | 31 | .000 |
| | 60 | .208 | 32 | .001 | .816 | 32 | .000 |
| | 70 | .247 | 34 | .000 | .702 | 34 | .000 |
| AnkleDFR | 20 | .257 | 30 | .000 | .917 | 30 | .022 |
| | 30 | .166 | 31 | .030 | .950 | 31 | .160 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 | .196 | 32 | .003 | .893 | 32 | .004 |
| | 50 | .181 | 31 | .011 | .932 | 31 | .050 |
| | 60 | .120 | 32 | .200* | .912 | 32 | .013 |
| | 70 | .174 | 34 | .011 | .945 | 34 | .084 |
| AnkleDFL | 20 | .153 | 30 | .073 | .952 | 30 | .188 |
| | 30 | .281 | 31 | .000 | .817 | 31 | .000 |
| | 40 | .117 | 32 | .200* | .951 | 32 | .158 |
| | 50 | .186 | 31 | .008 | .925 | 31 | .032 |
| | 60 | .135 | 32 | .143 | .968 | 32 | .457 |
| | 70 | .127 | 34 | .177 | .960 | 34 | .244 |
| TUG | 20 | .067 | 30 | .200* | .981 | 30 | .859 |
| | 30 | .123 | 31 | .200* | .966 | 31 | .421 |
| | 40 | .072 | 32 | .200* | .972 | 32 | .567 |
| | 50 | .157 | 31 | .051 | .943 | 31 | .098 |
| | 60 | .156 | 32 | .047 | .952 | 32 | .160 |
| | 70 | .190 | 34 | .003 | .842 | 34 | .000 |
| FTSS | 20 | .128 | 30 | .200* | .938 | 30 | .082 |
| | 30 | .078 | 31 | .200* | .977 | 31 | .737 |
| | 40 | .086 | 32 | .200* | .987 | 32 | .962 |
| | 50 | .134 | 31 | .163 | .915 | 31 | .017 |
| | 60 | .133 | 32 | .162 | .933 | 32 | .046 |
| | 70 | .181 | 34 | .006 | .848 | 34 | .000 |
| HeelRisesR | 40 | .539 | 32 | .000 | .172 | 32 | .000 |
| | 60 | .538 | 32 | .000 | .265 | 32 | .000 |
| | 70 | .442 | 34 | .000 | .532 | 34 | .000 |
| HeelRisesL | 40 | .539 | 32 | .000 | .172 | 32 | .000 |
| | 50 | .539 | 31 | .000 | .176 | 31 | .000 |
| | 60 | .517 | 32 | .000 | .308 | 32 | .000 |
| | 70 | .421 | 34 | .000 | .552 | 34 | .000 |

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

b. HeelRisesR & L is constant when group = 20. It has been omitted.

c. HeelRisesR & L is constant when group = 30. It has been omitted.

d. HeelRisesR is constant when group = 50. It has been omitted.

# Appendix G

MANOVA: Descriptives

Appendix G

**MANOVA: Descriptives[a,b,c,d,e]**

| | group | | | Statistic | Std. Error |
|---|---|---|---|---|---|
| HabGaitSpeed | 20 | Mean | | 4.9293 | .16067 |
| | | 95% Confidence Interval for Mean | Lower Bound | 4.6007 | |
| | | | Upper Bound | 5.2579 | |
| | | Skewness | | -.017 | .427 |
| | | Kurtosis | | -.959 | .833 |
| | 30 | Mean | | 4.6932 | .13429 |
| | | 95% Confidence Interval for Mean | Lower Bound | 4.4190 | |
| | | | Upper Bound | 4.9675 | |
| | | Skewness | | -.173 | .421 |
| | | Kurtosis | | .089 | .821 |
| | 40 | Mean | | 4.5484 | .12054 |
| | | 95% Confidence Interval for Mean | Lower Bound | 4.3026 | |
| | | | Upper Bound | 4.7943 | |
| | | Skewness | | .386 | .414 |
| | | Kurtosis | | -.108 | .809 |
| | 50 | Mean | | 4.4058 | .13637 |
| | | 95% Confidence Interval for Mean | Lower Bound | 4.1273 | |
| | | | Upper Bound | 4.6843 | |
| | | Skewness | | 1.284 | .421 |
| | | Kurtosis | | 2.016 | .821 |
| | 60 | Mean | | 4.3209 | .11995 |
| | | 95% Confidence Interval for Mean | Lower Bound | 4.0763 | |
| | | | Upper Bound | 4.5656 | |
| | | Skewness | | .298 | .414 |
| | | Kurtosis | | -.723 | .809 |
| | 70 | Mean | | 3.8503 | .11930 |
| | | 95% Confidence Interval for | Lower Bound | 3.6076 | |

| | | | | | |
|---|---|---|---|---|---|
| | | | Upper Bound | 4.0930 | |
| | | Skewness | | 1.188 | .403 |
| | | Kurtosis | | 2.289 | .788 |
| MDRTF | 20 | Mean | | 15.3633 | .37390 |
| | | 95% Confidence Interval for Mean | Lower Bound | 14.5986 | |
| | | | Upper Bound | 16.1280 | |
| | | Skewness | | .487 | .427 |
| | | Kurtosis | | -.390 | .833 |
| | 30 | Mean | | 14.5403 | .41851 |
| | | 95% Confidence Interval for Mean | Lower Bound | 13.6856 | |
| | | | Upper Bound | 15.3950 | |
| | | Skewness | | -2.703 | .421 |
| | | Kurtosis | | 11.071 | .821 |
| | 40 | Mean | | 14.5469 | .34643 |
| | | 95% Confidence Interval for Mean | Lower Bound | 13.8403 | |
| | | | Upper Bound | 15.2534 | |
| | | Skewness | | -.128 | .414 |
| | | Kurtosis | | -.606 | .809 |
| | 50 | Mean | | 14.3790 | .36272 |
| | | 95% Confidence Interval for Mean | Lower Bound | 13.6383 | |
| | | | Upper Bound | 15.1198 | |
| | | Skewness | | .401 | .421 |
| | | Kurtosis | | -.453 | .821 |
| | 60 | Mean | | 13.1797 | .36499 |
| | | 95% Confidence Interval for Mean | Lower Bound | 12.4353 | |
| | | | Upper Bound | 13.9241 | |
| | | Skewness | | .348 | .414 |
| | | Kurtosis | | -.206 | .809 |
| | 70 | Mean | | 12.0074 | .37190 |
| | | 95% Confidence Interval for Mean | Lower Bound | 11.2507 | |
| | | | Upper Bound | 12.7640 | |
| | | Skewness | | .742 | |

| | | | | | |
|---|---|---|---|---|---|
| | | Kurtosis | | 1.840 | .788 |
| MDRTB | 20 | Mean | | 11.3750 | .44926 |
| | | 95% Confidence Interval for Mean | Lower Bound | 10.4562 | |
| | | | Upper Bound | 12.2938 | |
| | | Skewness | | .329 | .427 |
| | | Kurtosis | | -.913 | .833 |
| | 30 | Mean | | 9.3790 | .46037 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.4388 | |
| | | | Upper Bound | 10.3192 | |
| | | Skewness | | .335 | .421 |
| | | Kurtosis | | -.115 | .821 |
| | 40 | Mean | | 11.0625 | .47506 |
| | | 95% Confidence Interval for Mean | Lower Bound | 10.0936 | |
| | | | Upper Bound | 12.0314 | |
| | | Skewness | | .916 | .414 |
| | | Kurtosis | | 1.369 | .809 |
| | 50 | Mean | | 10.7823 | .37473 |
| | | 95% Confidence Interval for Mean | Lower Bound | 10.0170 | |
| | | | Upper Bound | 11.5476 | |
| | | Skewness | | -.017 | .421 |
| | | Kurtosis | | -.608 | .821 |
| | 60 | Mean | | 8.9844 | .45638 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.0536 | |
| | | | Upper Bound | 9.9152 | |
| | | Skewness | | -.031 | .414 |
| | | Kurtosis | | -.690 | .809 |
| | 70 | Mean | | 7.5515 | .48528 |
| | | 95% Confidence Interval for Mean | Lower Bound | 6.5642 | |
| | | | Upper Bound | 8.5388 | |
| | | Skewness | | .253 | .403 |
| | | Kurtosis | | -.248 | .788 |
| MDRTR | 20 | Mean | | 11.9667 | .57194 |

| | | | | | |
|---|---|---|---|---|---|
| | | 95% Confidence Interval for Mean | Lower Bound | 10.7969 | |
| | | | Upper Bound | 13.1364 | |
| | | Skewness | | 1.289 | .427 |
| | | Kurtosis | | 2.845 | .833 |
| | 30 | Mean | | 9.8548 | .30822 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.2254 | |
| | | | Upper Bound | 10.4843 | |
| | | Skewness | | -.022 | .421 |
| | | Kurtosis | | .233 | .821 |
| | 40 | Mean | | 10.1250 | .39560 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.3182 | |
| | | | Upper Bound | 10.9318 | |
| | | Skewness | | .494 | .414 |
| | | Kurtosis | | .347 | .809 |
| | 50 | Mean | | 10.5726 | .42505 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.7045 | |
| | | | Upper Bound | 11.4407 | |
| | | Skewness | | .565 | .421 |
| | | Kurtosis | | -.006 | .821 |
| | 60 | Mean | | 10.0859 | .28610 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.5024 | |
| | | | Upper Bound | 10.6695 | |
| | | Skewness | | -.052 | .414 |
| | | Kurtosis | | 1.738 | .809 |
| | 70 | Mean | | 9.3309 | .39784 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.5215 | |
| | | | Upper Bound | 10.1403 | |
| | | Skewness | | -.564 | .403 |
| | | Kurtosis | | .901 | .788 |
| MDRTL | 20 | Mean | | 11.1250 | .59364 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.9109 | |
| | | | Upper Bound | 12.3391 | |

| | | | | | |
|---|---|---|---|---|---|
| | | Skewness | | 1.961 | .427 |
| | | Kurtosis | | 5.472 | .833 |
| | 30 | Mean | | 9.7581 | .33969 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.0643 | |
| | | | Upper Bound | 10.4518 | |
| | | Skewness | | .243 | .421 |
| | | Kurtosis | | -.607 | .821 |
| | 40 | Mean | | 10.2188 | .37311 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.4578 | |
| | | | Upper Bound | 10.9797 | |
| | | Skewness | | .267 | .414 |
| | | Kurtosis | | -.448 | .809 |
| | 50 | Mean | | 9.5081 | .33890 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.8159 | |
| | | | Upper Bound | 10.2002 | |
| | | Skewness | | .752 | .421 |
| | | Kurtosis | | .513 | .821 |
| | 60 | Mean | | 9.7822 | .37429 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.0188 | |
| | | | Upper Bound | 10.5456 | |
| | | Skewness | | -.985 | .414 |
| | | Kurtosis | | .874 | .809 |
| | 70 | Mean | | 9.1176 | .39497 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.3141 | |
| | | | Upper Bound | 9.9212 | |
| | | Skewness | | -.180 | .403 |
| | | Kurtosis | | .533 | .788 |
| DVA | 20 | Mean | | .13 | .063 |
| | | 95% Confidence Interval for Mean | Lower Bound | .00 | |
| | | | Upper Bound | .26 | |
| | | Skewness | | 2.273 | .427 |
| | | Kurtosis | | 3.386 | .833 |

| | | | | | |
|---|---|---|---|---|---|
| | 30 | Mean | | .35 | .099 |
| | | 95% Confidence Interval for Mean | Lower Bound | .15 | |
| | | | Upper Bound | .56 | |
| | | Skewness | | 1.266 | .421 |
| | | Kurtosis | | .757 | .821 |
| | 40 | Mean | | .38 | .117 |
| | | 95% Confidence Interval for Mean | Lower Bound | .14 | |
| | | | Upper Bound | .61 | |
| | | Skewness | | 2.290 | .414 |
| | | Kurtosis | | 6.862 | .809 |
| | 50 | Mean | | .32 | .108 |
| | | 95% Confidence Interval for Mean | Lower Bound | .10 | |
| | | | Upper Bound | .54 | |
| | | Skewness | | 1.744 | .421 |
| | | Kurtosis | | 2.152 | .821 |
| | 60 | Mean | | .69 | .158 |
| | | 95% Confidence Interval for Mean | Lower Bound | .36 | |
| | | | Upper Bound | 1.01 | |
| | | Skewness | | .972 | .414 |
| | | Kurtosis | | -.243 | .809 |
| | 70 | Mean | | .50 | .121 |
| | | 95% Confidence Interval for Mean | Lower Bound | .25 | |
| | | | Upper Bound | .75 | |
| | | Skewness | | 1.093 | .403 |
| | | Kurtosis | | -.076 | .788 |
| SLSEOR | 20 | Mean | | 29.8563 | .14367 |
| | | 95% Confidence Interval for Mean | Lower Bound | 29.5625 | |
| | | | Upper Bound | 30.1502 | |
| | | Median | | 30.0000 | |
| | | Skewness | | -5.477 | .427 |
| | | Kurtosis | | 30.000 | .833 |
| | 30 | Mean | | 29.4194 | .40368 |

| | | | | | |
|---|---|---|---|---|---|
| | | 95% Confidence Interval for Mean | Lower Bound | 28.5949 | |
| | | | Upper Bound | 30.2438 | |
| | | Skewness | | -3.728 | .421 |
| | | Kurtosis | | 12.717 | .821 |
| | 40 | Mean | | 28.9478 | .82001 |
| | | 95% Confidence Interval for Mean | Lower Bound | 27.2754 | |
| | | | Upper Bound | 30.6202 | |
| | | Skewness | | -4.912 | .414 |
| | | Kurtosis | | 25.105 | .809 |
| | 50 | Mean | | 28.7194 | .98037 |
| | | 95% Confidence Interval for Mean | Lower Bound | 26.7172 | |
| | | | Upper Bound | 30.7215 | |
| | | Skewness | | -4.704 | .421 |
| | | Kurtosis | | 23.016 | .821 |
| | 60 | Mean | | 24.8791 | 1.45276 |
| | | 95% Confidence Interval for Mean | Lower Bound | 21.9161 | |
| | | | Upper Bound | 27.8420 | |
| | | Skewness | | -1.296 | .414 |
| | | Kurtosis | | .254 | .809 |
| | 70 | Mean | | 14.2503 | 1.96025 |
| | | 95% Confidence Interval for Mean | Lower Bound | 10.2621 | |
| | | | Upper Bound | 18.2385 | |
| | | Skewness | | .292 | .403 |
| | | Kurtosis | | -1.520 | .788 |
| SLSEOL | 20 | Mean | | 29.0750 | .72230 |
| | | 95% Confidence Interval for Mean | Lower Bound | 27.5977 | |
| | | | Upper Bound | 30.5523 | |
| | | Median | | 30.0000 | |
| | | Skewness | | -4.770 | .427 |
| | | Kurtosis | | 23.651 | .833 |
| | 30 | Mean | | 29.1694 | .54450 |
| | | 95% Confidence Interval for | Lower Bound | 28.0573 | |

| | | | | | |
|---|---|---|---|---|---|
| | | | Upper Bound | 30.2814 | |
| | | Skewness | | -3.835 | .421 |
| | | Kurtosis | | 14.241 | .821 |
| | 40 | Mean | | 29.3912 | .56499 |
| | | 95% Confidence Interval for Mean | Lower Bound | 28.2390 | |
| | | | Upper Bound | 30.5435 | |
| | | Skewness | | -5.605 | .414 |
| | | Kurtosis | | 31.573 | .809 |
| | 50 | Mean | | 28.0177 | 1.05513 |
| | | 95% Confidence Interval for Mean | Lower Bound | 25.8629 | |
| | | | Upper Bound | 30.1726 | |
| | | Skewness | | -3.739 | .421 |
| | | Kurtosis | | 15.438 | .821 |
| | 60 | Mean | | 25.9175 | 1.36183 |
| | | 95% Confidence Interval for Mean | Lower Bound | 23.1400 | |
| | | | Upper Bound | 28.6950 | |
| | | Skewness | | -1.757 | .414 |
| | | Kurtosis | | 1.755 | .809 |
| | 70 | Mean | | 14.0015 | 1.96847 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.9966 | |
| | | | Upper Bound | 18.0064 | |
| | | Interquartile Range | | 27.00 | |
| | | Skewness | | .388 | .403 |
| | | Kurtosis | | -1.516 | .788 |
| SLSECR | 20 | Mean | | 21.8407 | 1.49755 |
| | | 95% Confidence Interval for Mean | Lower Bound | 18.7778 | |
| | | | Upper Bound | 24.9035 | |
| | | Median | | 23.4900 | |
| | | Skewness | | -.243 | .427 |
| | | Kurtosis | | -1.688 | .833 |
| | 30 | Mean | | 16.1639 | 1.95885 |
| | | 95% Confidence Interval for | Lower Bound | 12.1634 | |

| | | | | | |
|---|---|---|---|---|---|
| | | | Upper Bound | 20.1644 | |
| | | Skewness | | .203 | .421 |
| | | Kurtosis | | -1.711 | .821 |
| | 40 | Mean | | 10.6938 | 1.43352 |
| | | 95% Confidence Interval for Mean | Lower Bound | 7.7701 | |
| | | | Upper Bound | 13.6174 | |
| | | Skewness | | 1.102 | .414 |
| | | Kurtosis | | .376 | .809 |
| | 50 | Mean | | 9.1506 | 1.36308 |
| | | 95% Confidence Interval for Mean | Lower Bound | 6.3669 | |
| | | | Upper Bound | 11.9344 | |
| | | Skewness | | 1.232 | .421 |
| | | Kurtosis | | .763 | .821 |
| | 60 | Mean | | 4.7959 | .79735 |
| | | 95% Confidence Interval for Mean | Lower Bound | 3.1697 | |
| | | | Upper Bound | 6.4221 | |
| | | Skewness | | 2.246 | .414 |
| | | Kurtosis | | 4.750 | .809 |
| | 70 | Mean | | 4.1176 | 1.02081 |
| | | 95% Confidence Interval for Mean | Lower Bound | 2.0408 | |
| | | | Upper Bound | 6.1945 | |
| | | Skewness | | 3.181 | .403 |
| | | Kurtosis | | 11.405 | .788 |
| SLSECL | 20 | Mean | | 21.4630 | 1.83435 |
| | | 95% Confidence Interval for Mean | Lower Bound | 17.7113 | |
| | | | Upper Bound | 25.2147 | |
| | | Skewness | | -.625 | .427 |
| | | Kurtosis | | -1.223 | .833 |
| | 30 | Mean | | 12.4452 | 1.75848 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.8539 | |
| | | | Upper Bound | 16.0365 | |
| | | Skewness | | .789 | .421 |

| | | | | | |
|---|---|---|---|---|---|
| | | Kurtosis | | -.703 | .821 |
| | 40 | Mean | | 9.9012 | 1.29047 |
| | | 95% Confidence Interval for Mean | Lower Bound | 7.2693 | |
| | | | Upper Bound | 12.5332 | |
| | | Skewness | | 1.316 | .414 |
| | | Kurtosis | | 1.771 | .809 |
| | 50 | Mean | | 7.4406 | 1.09278 |
| | | 95% Confidence Interval for Mean | Lower Bound | 5.2089 | |
| | | | Upper Bound | 9.6724 | |
| | | Skewness | | 1.197 | .421 |
| | | Kurtosis | | .632 | .821 |
| | 60 | Mean | | 5.2294 | .72743 |
| | | 95% Confidence Interval for Mean | Lower Bound | 3.7458 | |
| | | | Upper Bound | 6.7130 | |
| | | Skewness | | 1.355 | .414 |
| | | Kurtosis | | .808 | .809 |
| | 70 | Mean | | 3.8471 | .79087 |
| | | 95% Confidence Interval for Mean | Lower Bound | 2.2380 | |
| | | | Upper Bound | 5.4561 | |
| | | Skewness | | 2.346 | .403 |
| | | Kurtosis | | 5.522 | .788 |
| AnkleDFR | 20 | Mean | | 10.87 | .696 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.44 | |
| | | | Upper Bound | 12.29 | |
| | | Skewness | | .674 | .427 |
| | | Kurtosis | | -.182 | .833 |
| | 30 | Mean | | 10.16 | .984 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.15 | |
| | | | Upper Bound | 12.17 | |
| | | Skewness | | -.585 | .421 |
| | | Kurtosis | | .493 | .821 |
| | 40 | Mean | | 12.81 | .752 |

| | | | | | |
|---|---|---|---|---|---|
| | | 95% Confidence Interval for Mean | Lower Bound | 11.28 | |
| | | | Upper Bound | 14.35 | |
| | | Skewness | | .463 | .414 |
| | | Kurtosis | | -.700 | .809 |
| | 50 | Mean | | 10.84 | .985 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.83 | |
| | | | Upper Bound | 12.85 | |
| | | Skewness | | -.941 | .421 |
| | | Kurtosis | | 1.354 | .821 |
| | 60 | Mean | | 9.62 | 1.186 |
| | | 95% Confidence Interval for Mean | Lower Bound | 7.21 | |
| | | | Upper Bound | 12.04 | |
| | | Skewness | | -1.034 | .414 |
| | | Kurtosis | | 2.829 | .809 |
| | 70 | Mean | | 5.71 | .780 |
| | | 95% Confidence Interval for Mean | Lower Bound | 4.12 | |
| | | | Upper Bound | 7.29 | |
| | | Skewness | | -.638 | .403 |
| | | Kurtosis | | 1.330 | .788 |
| AnkleDFL | 20 | Mean | | 9.93 | .671 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.56 | |
| | | | Upper Bound | 11.31 | |
| | | Skewness | | .619 | .427 |
| | | Kurtosis | | .734 | .833 |
| | 30 | Mean | | 8.58 | 1.421 |
| | | 95% Confidence Interval for Mean | Lower Bound | 5.68 | |
| | | | Upper Bound | 11.48 | |
| | | Skewness | | -1.325 | .421 |
| | | Kurtosis | | 1.258 | .821 |
| | 40 | Mean | | 12.81 | .825 |
| | | 95% Confidence Interval for Mean | Lower Bound | 11.13 | |
| | | | Upper Bound | 14.49 | |

| | | | | | |
|---|---|---|---|---|---|
| | | Skewness | | -.377 | .414 |
| | | Kurtosis | | .345 | .809 |
| | 50 | Mean | | 11.26 | 1.013 |
| | | 95% Confidence Interval for Mean | Lower Bound | 9.19 | |
| | | | Upper Bound | 13.33 | |
| | | Skewness | | -.473 | .421 |
| | | Kurtosis | | -.005 | .821 |
| | 60 | Mean | | 9.88 | .846 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.15 | |
| | | | Upper Bound | 11.60 | |
| | | Skewness | | .128 | .414 |
| | | Kurtosis | | -.203 | .809 |
| | 70 | Mean | | 5.80 | 1.106 |
| | | 95% Confidence Interval for Mean | Lower Bound | 3.55 | |
| | | | Upper Bound | 8.04 | |
| | | Skewness | | -.249 | .403 |
| | | Kurtosis | | -.181 | .788 |
| TUG | 20 | Mean | | 5.5893 | .14942 |
| | | 95% Confidence Interval for Mean | Lower Bound | 5.2837 | |
| | | | Upper Bound | 5.8949 | |
| | | Skewness | | -.094 | .427 |
| | | Kurtosis | | -.528 | .833 |
| | 30 | Mean | | 5.9294 | .13165 |
| | | 95% Confidence Interval for Mean | Lower Bound | 5.6605 | |
| | | | Upper Bound | 6.1982 | |
| | | Skewness | | .716 | .421 |
| | | Kurtosis | | .973 | .821 |
| | 40 | Mean | | 6.1069 | .15085 |
| | | 95% Confidence Interval for Mean | Lower Bound | 5.7992 | |
| | | | Upper Bound | 6.4145 | |
| | | Skewness | | .224 | .414 |
| | | Kurtosis | | .031 | .809 |

| | | | | | |
|---|---|---|---|---|---|
| | 50 | Mean | | 6.2694 | .19251 |
| | | 95% Confidence Interval for Mean | Lower Bound | 5.8762 | |
| | | | Upper Bound | 6.6625 | |
| | | Skewness | | .659 | .421 |
| | | Kurtosis | | -.252 | .821 |
| | 60 | Mean | | 6.6966 | .22192 |
| | | 95% Confidence Interval for Mean | Lower Bound | 6.2439 | |
| | | | Upper Bound | 7.1492 | |
| | | Skewness | | .551 | .414 |
| | | Kurtosis | | .524 | .809 |
| | 70 | Mean | | 7.6859 | .32866 |
| | | 95% Confidence Interval for Mean | Lower Bound | 7.0172 | |
| | | | Upper Bound | 8.3545 | |
| | | Skewness | | -2.010 | .403 |
| | | Kurtosis | | 6.769 | .788 |
| FTSS | 20 | Mean | | 7.4667 | .24310 |
| | | 95% Confidence Interval for Mean | Lower Bound | 6.9695 | |
| | | | Upper Bound | 7.9639 | |
| | | Skewness | | -.980 | .427 |
| | | Kurtosis | | 1.261 | .833 |
| | 30 | Mean | | 8.0742 | .20429 |
| | | 95% Confidence Interval for Mean | Lower Bound | 7.6570 | |
| | | | Upper Bound | 8.4914 | |
| | | Skewness | | -.374 | .421 |
| | | Kurtosis | | -.210 | .821 |
| | 40 | Mean | | 7.9897 | .21035 |
| | | 95% Confidence Interval for Mean | Lower Bound | 7.5607 | |
| | | | Upper Bound | 8.4187 | |
| | | Skewness | | -.020 | .414 |
| | | Kurtosis | | -.549 | .809 |
| | 50 | Mean | | 8.2568 | .29974 |

| | | | | | |
|---|---|---|---|---|---|
| | | 95% Confidence Interval for Mean | Lower Bound | 7.6446 | |
| | | | Upper Bound | 8.8689 | |
| | | Skewness | | .945 | .421 |
| | | Kurtosis | | 3.516 | .821 |
| | 60 | Mean | | 9.0419 | .28664 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.4573 | |
| | | | Upper Bound | 9.6265 | |
| | | Skewness | | 1.109 | .414 |
| | | Kurtosis | | 1.915 | .809 |
| | 70 | Mean | | 9.3374 | .56715 |
| | | 95% Confidence Interval for Mean | Lower Bound | 8.1835 | |
| | | | Upper Bound | 10.4912 | |
| | | Skewness | | -.519 | .403 |
| | | Kurtosis | | 3.862 | .788 |
| HeelRisesR | 40 | Mean | | 24.97 | .031 |
| | | 95% Confidence Interval for Mean | Lower Bound | 24.91 | |
| | | | Upper Bound | 25.03 | |
| | | Skewness | | -5.657 | .414 |
| | | Kurtosis | | 32.000 | .809 |
| | 60 | Mean | | 23.44 | 1.087 |
| | | 95% Confidence Interval for Mean | Lower Bound | 21.22 | |
| | | | Upper Bound | 25.65 | |
| | | Skewness | | -3.795 | .414 |
| | | Kurtosis | | 13.227 | .809 |
| | 70 | Mean | | 21.92 | 1.148 |
| | | 95% Confidence Interval for Mean | Lower Bound | 19.59 | |
| | | | Upper Bound | 24.26 | |
| | | Skewness | | -2.213 | .403 |
| | | Kurtosis | | 4.093 | .788 |
| HeelRisesL | 40 | Mean | | 24.88 | .125 |
| | | 95% Confidence Interval for | Lower Bound | 24.62 | |

| | | | | |
|---|---|---|---|---|
| | | Upper Bound | 25.13 | |
| | Skewness | | -5.657 | .414 |
| | Kurtosis | | 32.000 | .809 |
| 50 | Mean | | 24.74 | .258 |
| | 95% Confidence Interval for Mean | Lower Bound | 24.21 | |
| | | Upper Bound | 25.27 | |
| | Skewness | | -5.568 | .421 |
| | Kurtosis | | 31.000 | .821 |
| 60 | Mean | | 23.78 | .766 |
| | 95% Confidence Interval for Mean | Lower Bound | 22.22 | |
| | | Upper Bound | 25.34 | |
| | Skewness | | -3.653 | .414 |
| | Kurtosis | | 12.428 | .809 |
| 70 | Mean | | 21.50 | 1.240 |
| | 95% Confidence Interval for Mean | Lower Bound | 18.98 | |
| | | Upper Bound | 24.02 | |
| | Skewness | | -2.040 | .403 |
| | Kurtosis | | 2.957 | .788 |

a. HeelRisesR is constant when group = 20. It has been omitted.

b. HeelRisesR is constant when group = 30. It has been omitted.

c. HeelRisesR is constant when group = 50. It has been omitted.

d. HeelRisesL is constant when group = 20. It has been omitted.

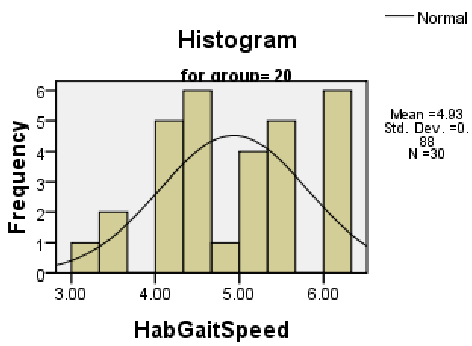
e. HeelRisesL is constant when group = 30. It has been omitted.

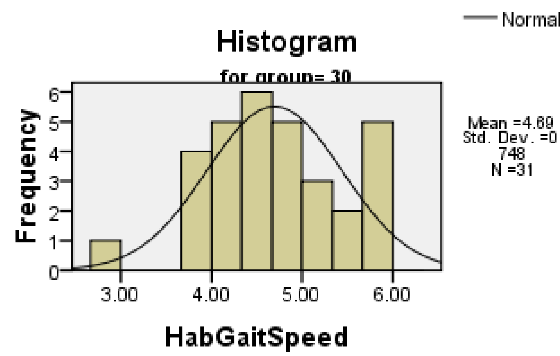
# Appendix H

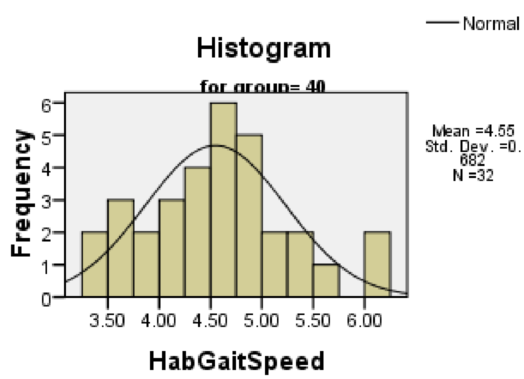
## MANOVA: Histograms

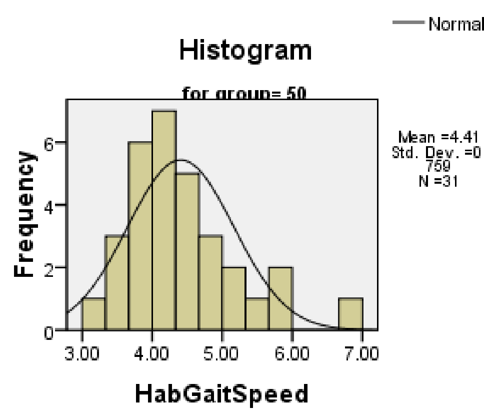
Appendix H

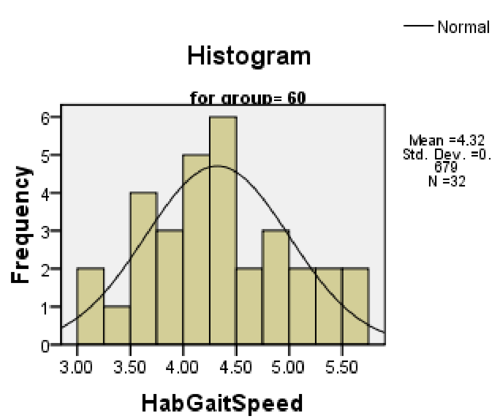
## Histograms: MANOVA

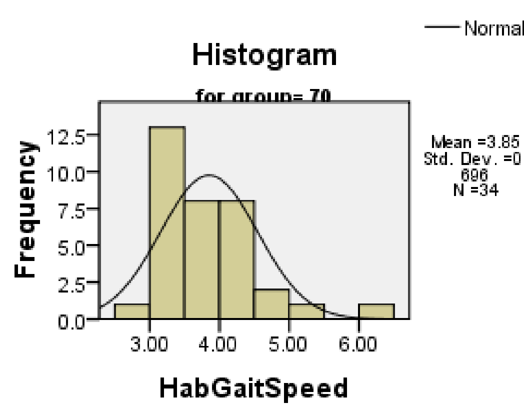


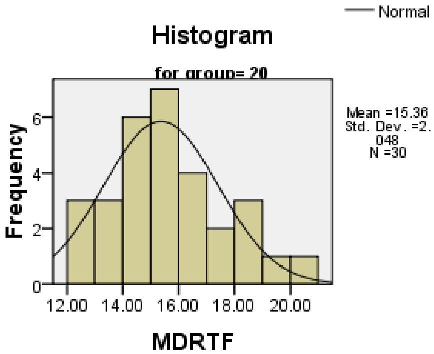



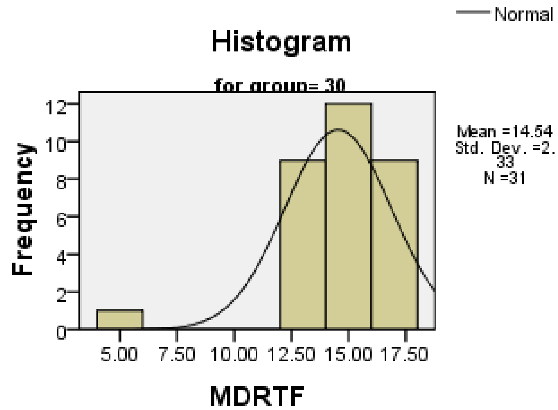



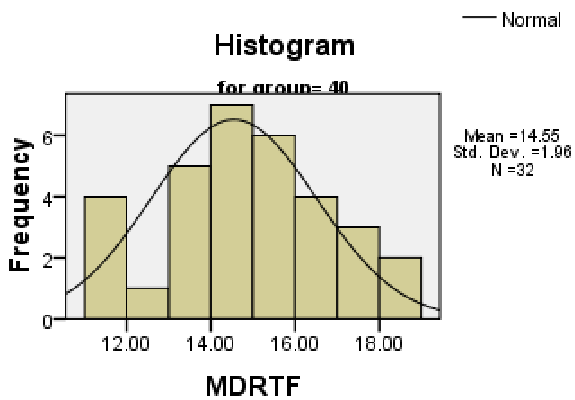



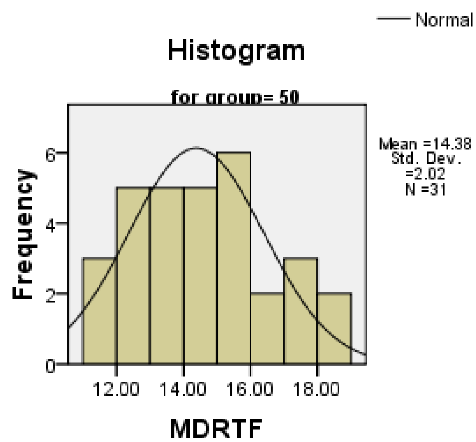



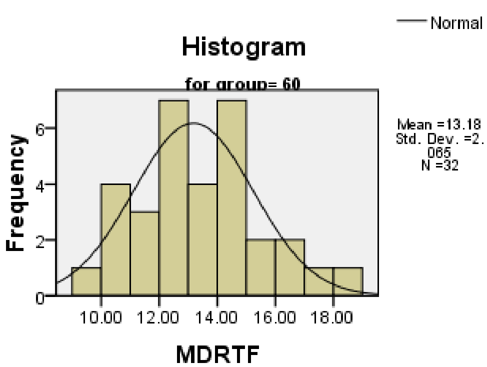



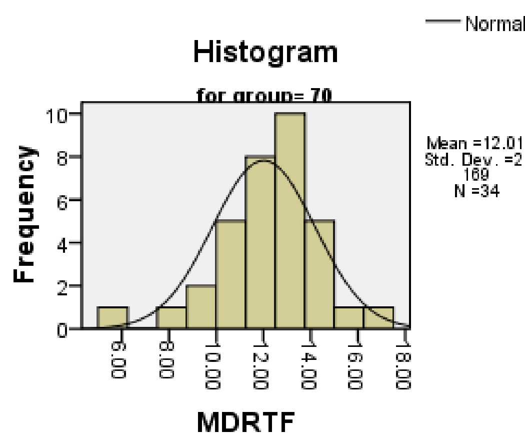

Histogram
for group= 20
Normal
Mean =15.36
Std. Dev. =2.
048
N =30
Frequency
0
2
4
6
12.00 14.00 16.00 18.00 20.00
MDRTF

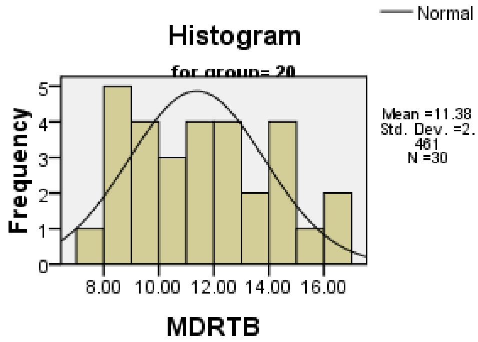

Histogram
for group= 30
Normal
Mean =14.54
Std. Dev. =2.
33
N =31
Frequency
0
2
4
6
8
10
12
5.00 7.50 10.00 12.50 15.00 17.50
MDRTF

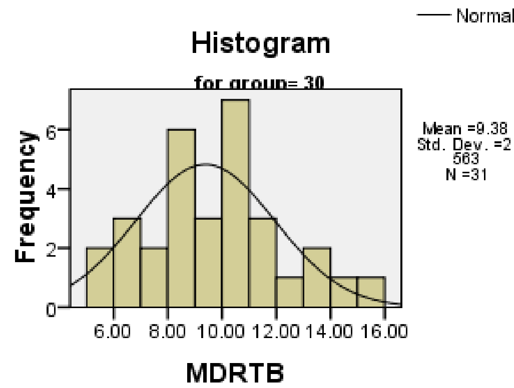

Histogram
for group= 40
Normal
Mean =14.55
Std. Dev. =1.96
N =32
Frequency
0
2
4
6
12.00 14.00 16.00 18.00
MDRTF

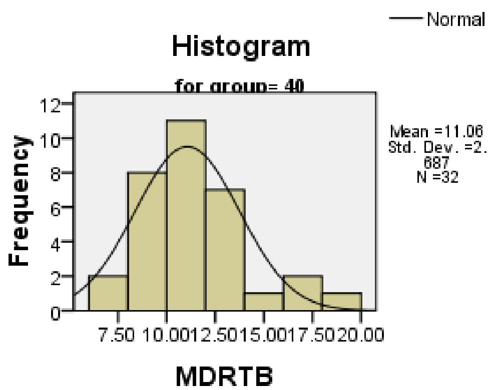

Histogram
for group= 50
Normal
Mean =14.38
Std. Dev.
=2.02
N =31
Frequency
0
2
4
6
12.00 14.00 16.00 18.00
MDRTF

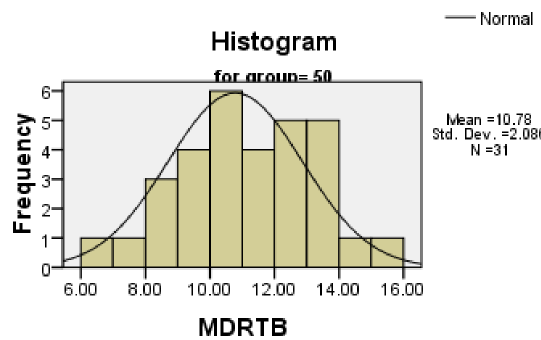

Histogram
for group= 60
Normal
Mean =13.18
Std. Dev. =2.
065
N =32
Frequency
0
2
4
6
10.00 12.00 14.00 16.00 18.00
MDRTF

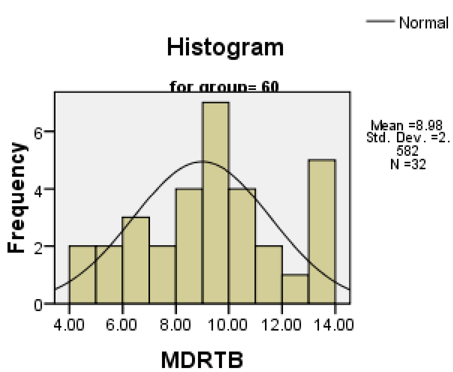

Histogram
for group= 70
Normal
Mean =12.01
Std. Dev. =2.
169
N =34
Frequency
0
2
4
6
8
10
6.00 8.00 10.00 12.00 14.00 16.00 18.00
MDRTF

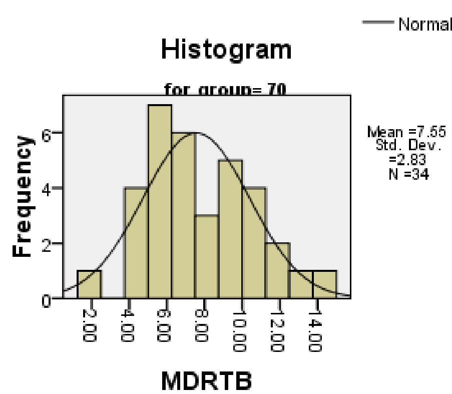

Histogram
for group= 20
Normal
Mean =11.38
Std. Dev. =2.
461
N =30
Frequency
MDRTB

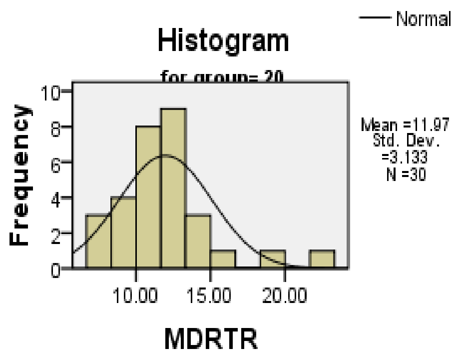

Histogram
for group= 30
Normal
Mean =9.38
Std. Dev. =2.
563
N =31
Frequency
MDRTB

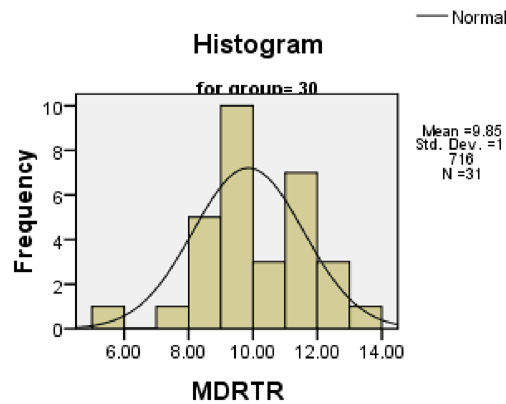

Histogram
for group= 40
Normal
Mean =11.06
Std. Dev. =2.
687
N =32
Frequency
MDRTB

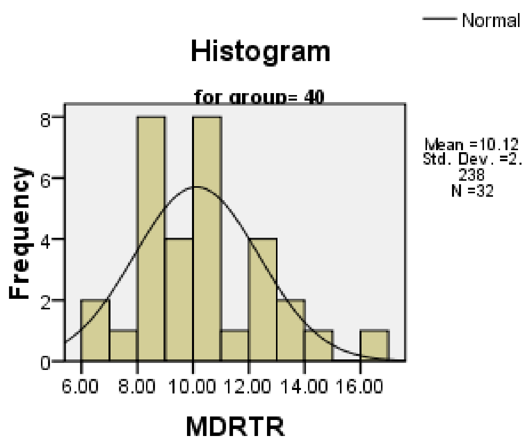

Histogram
for group= 50
Normal
Mean =10.78
Std. Dev. =2.086
N =31
Frequency
MDRTB

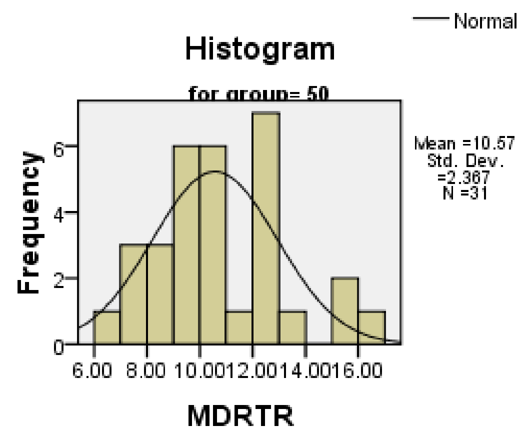

Histogram
for group= 60
Normal
Mean =8.98
Std. Dev. =2.
582
N =32
Frequency
MDRTB

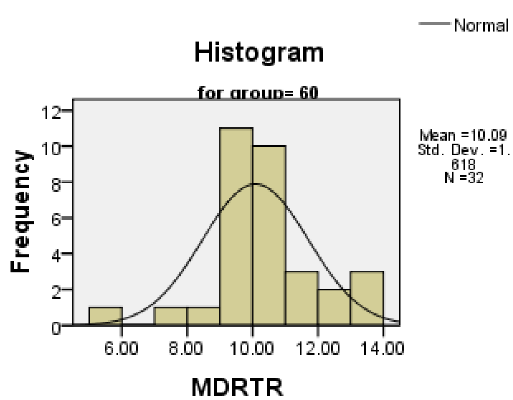

Histogram
for group= 70
Normal
Mean =7.55
Std. Dev.
=2.83
N =34
Frequency
MDRTB

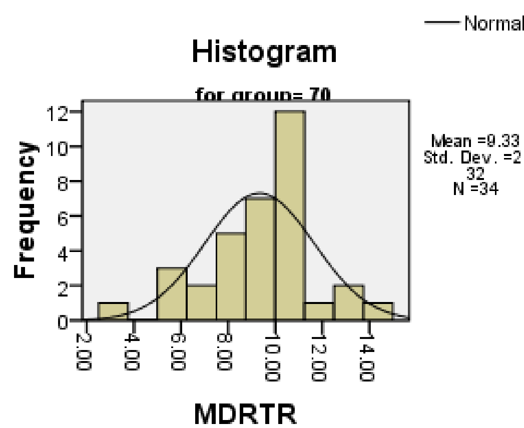

Histogram
for group= 20
Normal
Mean =11.97
Std. Dev. =3.133
N =30
Frequency
10.00
15.00
20.00
MDRTR

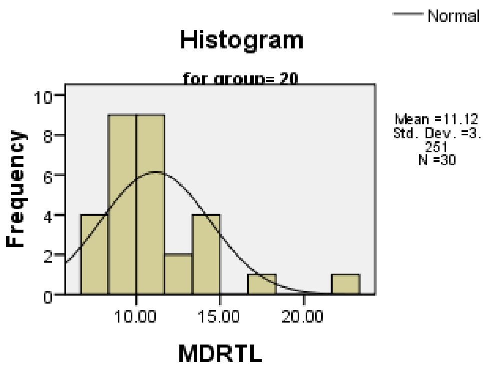

Histogram
for group= 30
Normal
Mean =9.85
Std. Dev. =1.716
N =31
Frequency
6.00
8.00
10.00
12.00
14.00
MDRTR

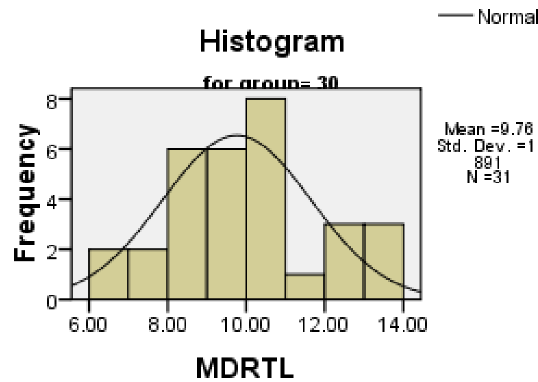

Histogram
for group= 40
Normal
Mean =10.12
Std. Dev. =2.238
N =32
Frequency
6.00
8.00
10.00
12.00
14.00
16.00
MDRTR

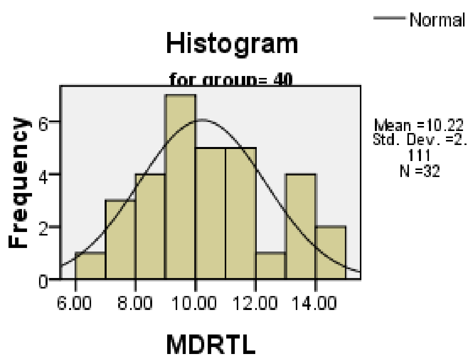

Histogram
for group= 50
Normal
Mean =10.57
Std. Dev. =2.367
N =31
Frequency
6.00
8.00
10.00
12.00
14.00
16.00
MDRTR

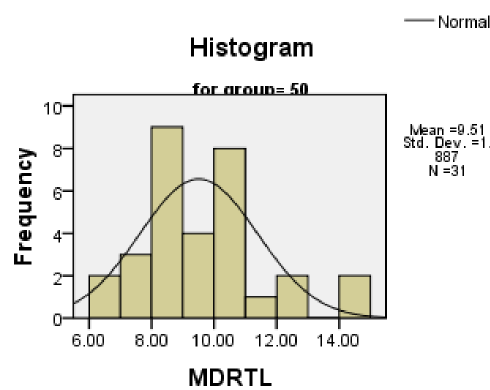

Histogram
for group= 60
Normal
Mean =10.09
Std. Dev. =1.618
N =32
Frequency
6.00
8.00
10.00
12.00
14.00
MDRTR

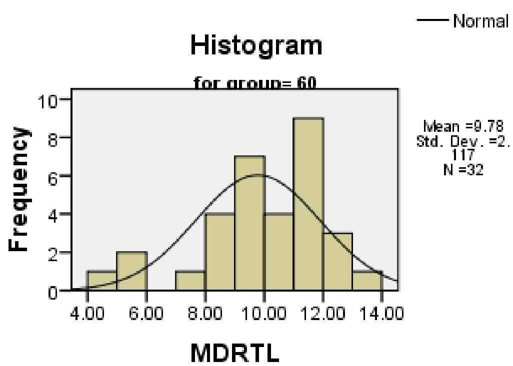

Histogram
for group= 70
Normal
Mean =9.33
Std. Dev. =2.32
N =34
Frequency
2.00
4.00
6.00
8.00
10.00
12.00
14.00
MDRTR

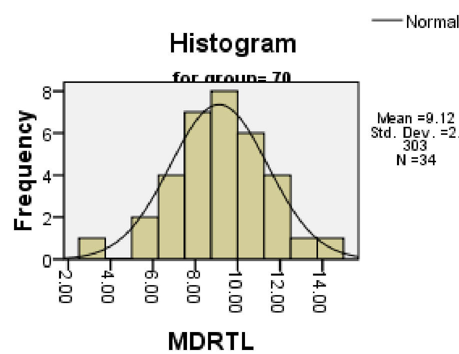

Histogram
for group= 20
Normal
Mean =11.12
Std. Dev. =3.251
N =30
Frequency
MDRTL

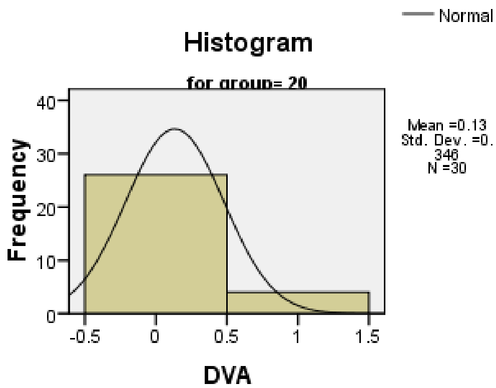

Histogram
for group= 30
Normal
Mean =9.76
Std. Dev. =1.891
N =31
Frequency
MDRTL

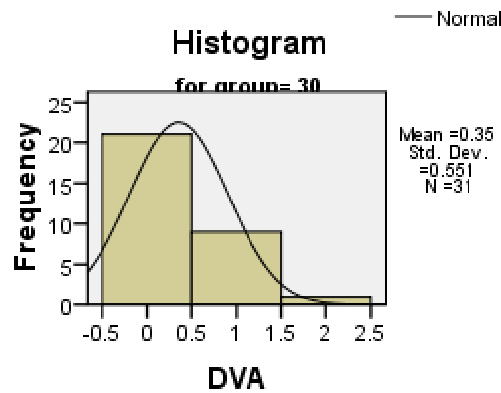

Histogram
for group= 40
Normal
Mean =10.22
Std. Dev. =2.111
N =32
Frequency
MDRTL

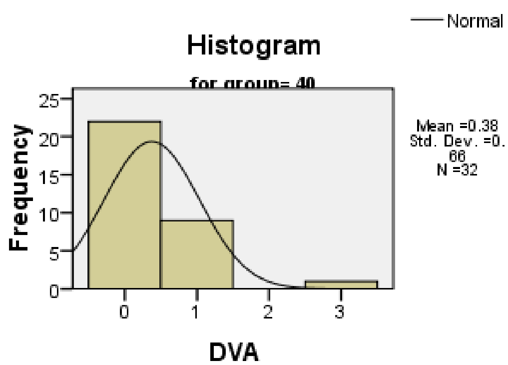

Histogram
for group= 50
Normal
Mean =9.51
Std. Dev. =1.887
N =31
Frequency
MDRTL

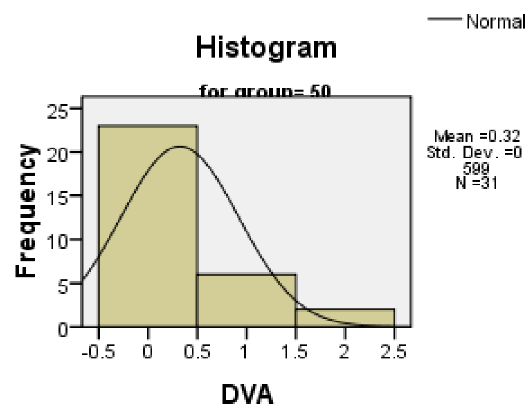

Histogram
for group= 60
Normal
Mean =9.78
Std. Dev. =2.117
N =32
Frequency
MDRTL

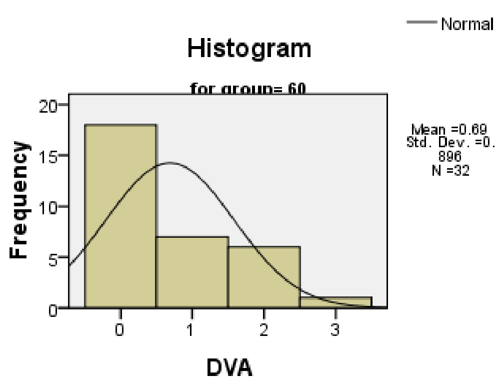

Histogram
for group= 70
Normal
Mean =9.12
Std. Dev. =2.303
N =34
Frequency
MDRTL

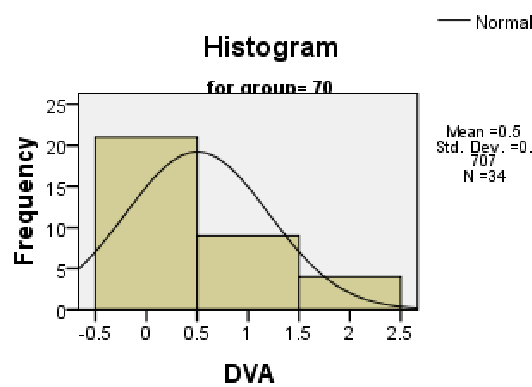

Histogram
for group= 20
Normal
Mean =0.13
Std. Dev. =0.
346
N =30
Frequency
DVA

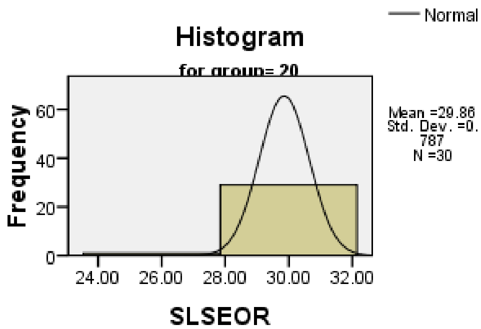

Histogram
for group= 30
Normal
Mean =0.35
Std. Dev.
=0.551
N =31
Frequency
DVA

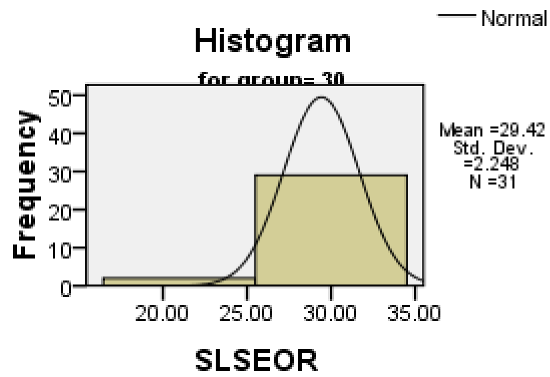

Histogram
for group= 40
Normal
Mean =0.38
Std. Dev. =0.
66
N =32
Frequency
DVA

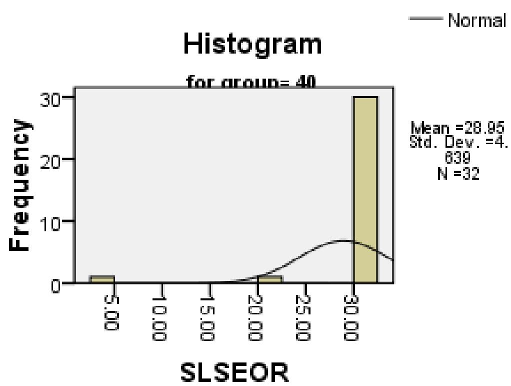

Histogram
for group= 50
Normal
Mean =0.32
Std. Dev. =0.
599
N =31
Frequency
DVA

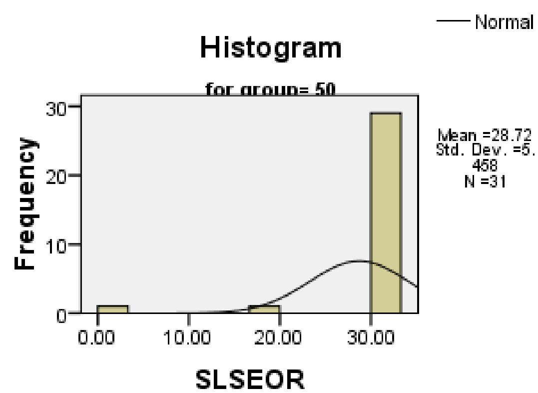

Histogram
for group= 60
Normal
Mean =0.69
Std. Dev. =0.
896
N =32
Frequency
DVA

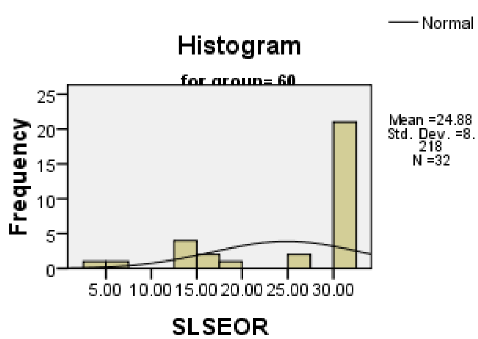

Histogram
for group= 70
Normal
Mean =0.5
Std. Dev. =0.
707
N =34
Frequency
DVA

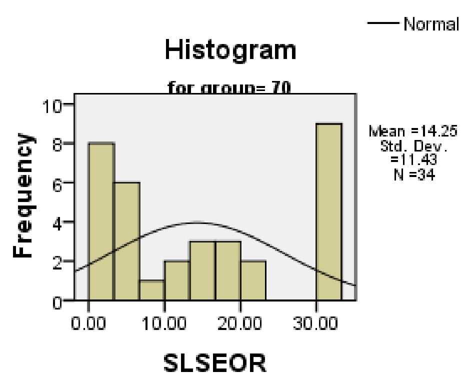

Normal
Histogram
for group= 20
Frequency
0
20
40
60
24.00 26.00 28.00 30.00 32.00
SLSEOR
Mean =29.86
Std. Dev. =0.
787
N =30

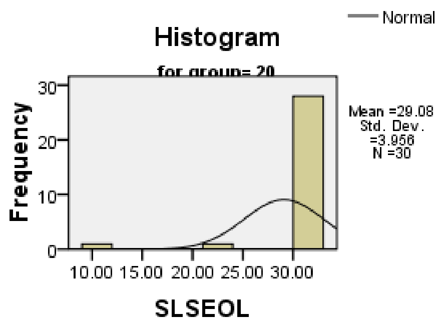

Normal
Histogram
for group= 30
Frequency
0
10
20
30
40
50
20.00 25.00 30.00 35.00
SLSEOR
Mean =29.42
Std. Dev.
=2.248
N =31

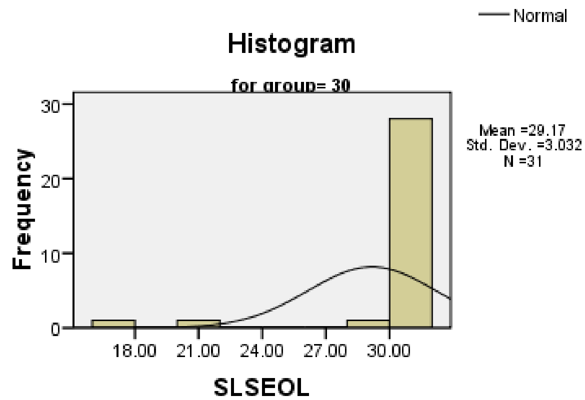

Normal
Histogram
for group= 40
Frequency
0
10
20
30
5.00 10.00 15.00 20.00 25.00 30.00
SLSEOR
Mean =28.95
Std. Dev. =4.
639
N =32

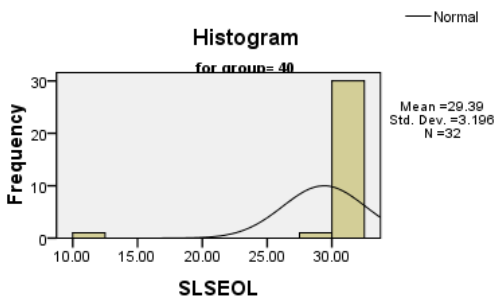

Normal
Histogram
for group= 50
Frequency
0
10
20
30
0.00 10.00 20.00 30.00
SLSEOR
Mean =28.72
Std. Dev. =5.
458
N =31

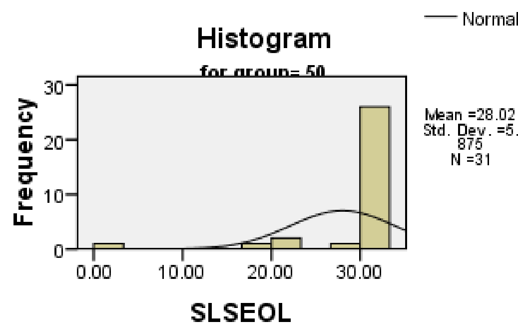

Normal
Histogram
for group= 60
Frequency
0
5
10
15
20
25
5.00 10.00 15.00 20.00 25.00 30.00
SLSEOR
Mean =24.88
Std. Dev. =8.
218
N =32

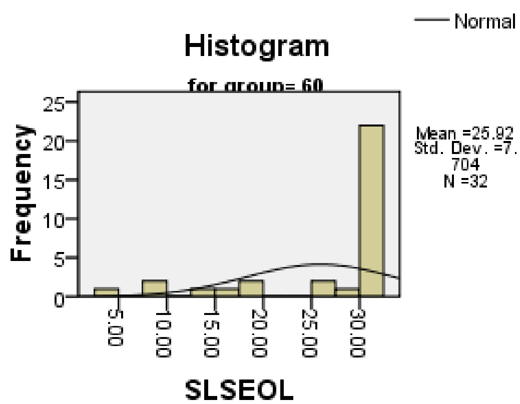

Normal
Histogram
for group= 70
Frequency
0
2
4
6
8
10
0.00 10.00 20.00 30.00
SLSEOR
Mean =14.25
Std. Dev.
=11.43
N =34

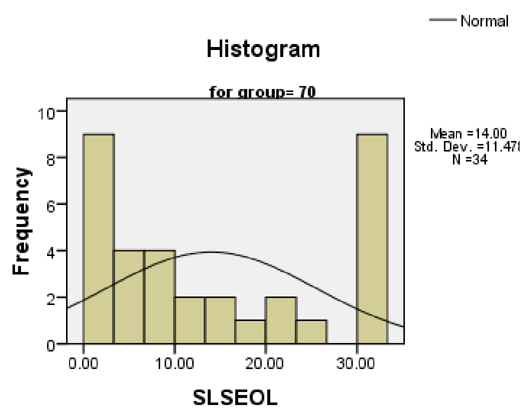

Normal
Histogram
for group= 20
Mean =29.08
Std. Dev. =3.956
N =30
Frequency
SLSEOL

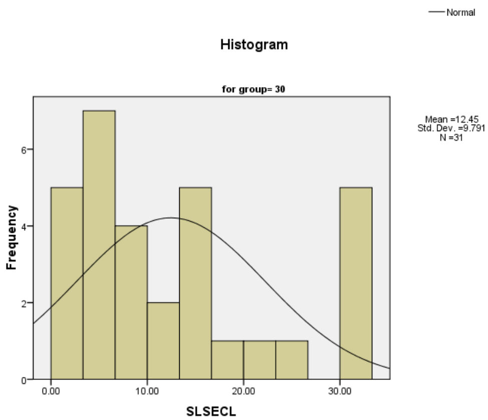

Normal
Histogram
for group= 30
Mean =29.17
Std. Dev. =3.032
N =31
Frequency
SLSEOL

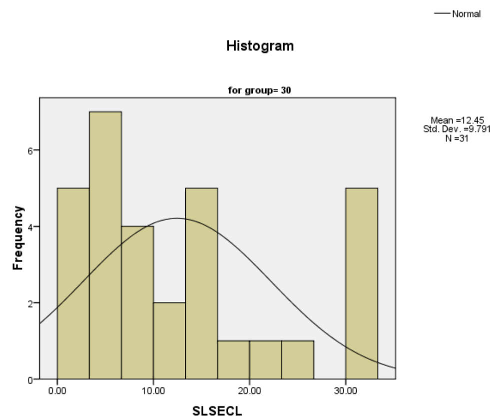

Normal
Histogram
for group= 40
Mean =29.39
Std. Dev. =3.196
N =32
Frequency
SLSEOL

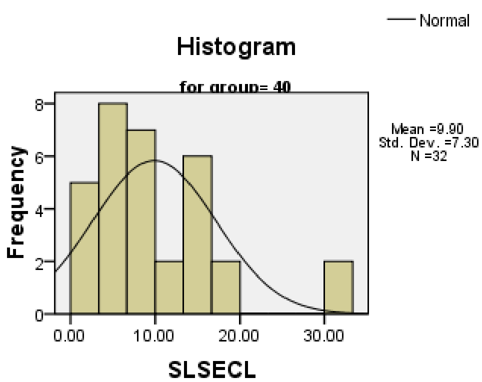

Normal
Histogram
for group= 50
Mean =28.02
Std. Dev. =5.875
N =31
Frequency
SLSEOL

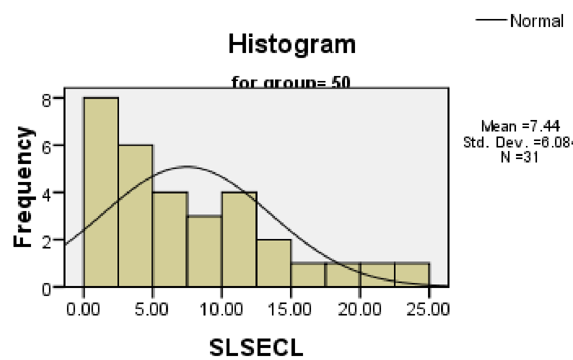

Normal
Histogram
for group= 60
Mean =25.92
Std. Dev. =7.704
N =32
Frequency
SLSEOL

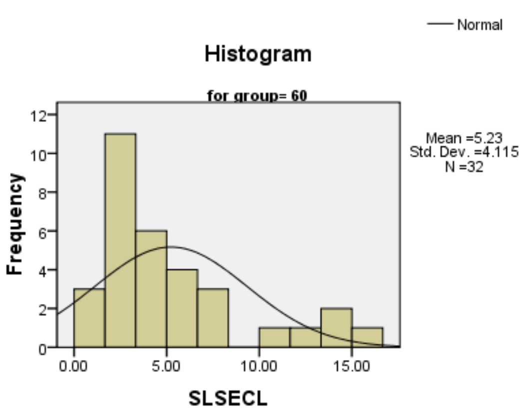

Normal
Histogram
for group= 70
Mean =14.00
Std. Dev. =11.478
N =34
Frequency
SLSEOL

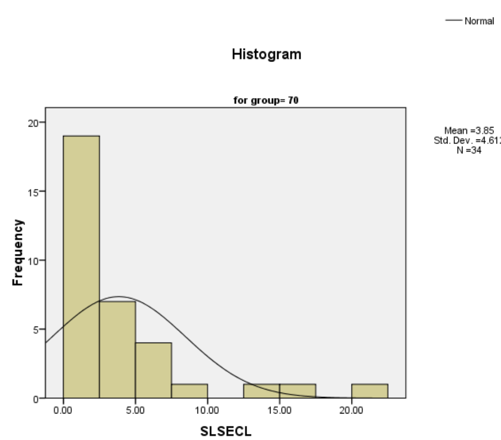

Normal
Histogram
for group= 30
Mean =12.45
Std. Dev. =9.791
N =31
Frequency
SLSECL

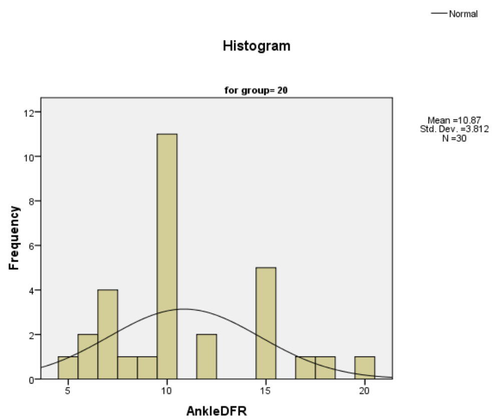

Normal
Histogram
for group= 30
Mean =12.45
Std. Dev. =9.791
N =31
Frequency
SLSECL

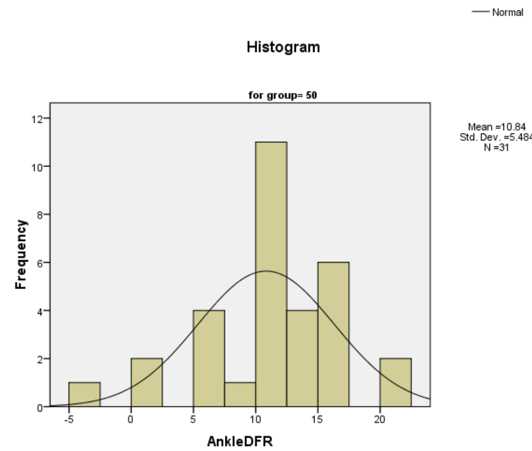

Normal
Histogram
for group= 40
Mean =9.90
Std. Dev. =7.30
N =32
Frequency
SLSECL

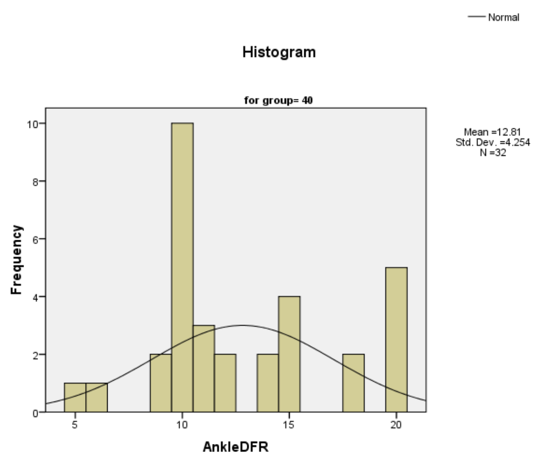

Normal
Histogram
for group= 50
Mean =7.44
Std. Dev. =6.084
N =31
Frequency
SLSECL

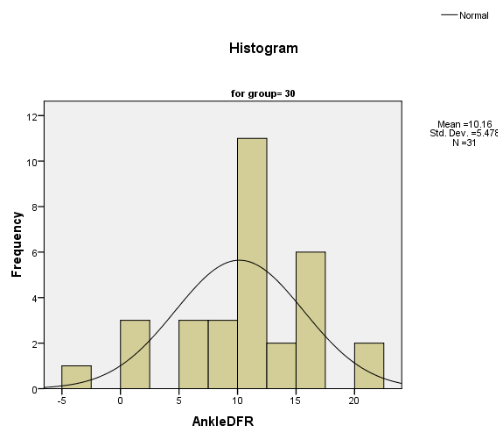

Normal
Histogram
for group= 60
Mean =5.23
Std. Dev. =4.115
N =32
Frequency
SLSECL

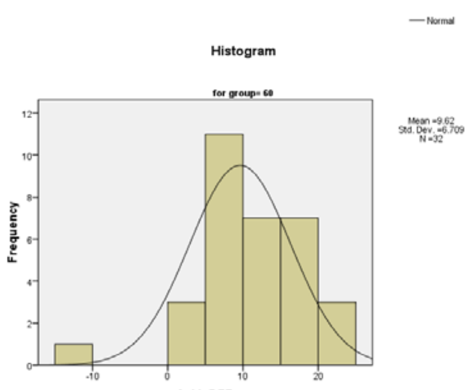

Normal
Histogram
for group= 70
Mean =3.85
Std. Dev. =4.612
N =34
Frequency
SLSECL

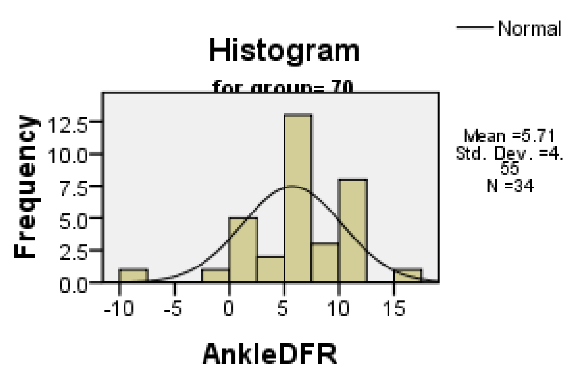

Normal
Histogram
for group= 20
Mean =10.87
Std. Dev. =3.812
N =30
Frequency
AnkleDFR

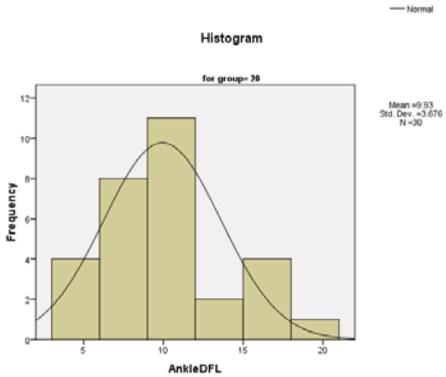

Normal
Histogram
for group= 50
Mean =10.84
Std. Dev. =5.484
N =31
Frequency
AnkleDFR

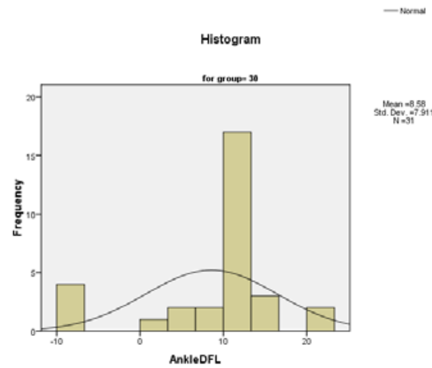

Normal
Histogram
for group= 40
Mean =12.81
Std. Dev. =4.254
N =32
Frequency
AnkleDFR

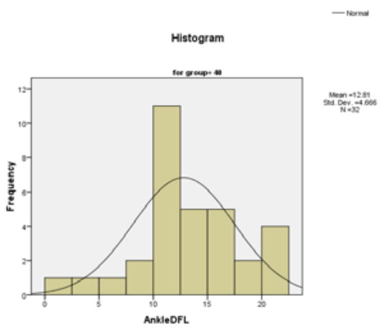

Normal
Histogram
for group= 30
Mean =10.16
Std. Dev. =5.478
N =31
Frequency
AnkleDFR

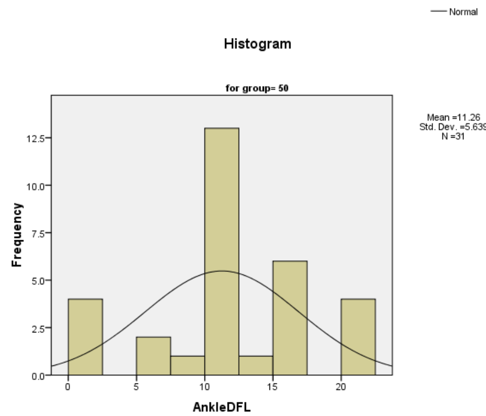

Normal
Histogram
for group= 60
Mean =9.62
Std. Dev. =6.709
N =32
Frequency
AnkleDFR

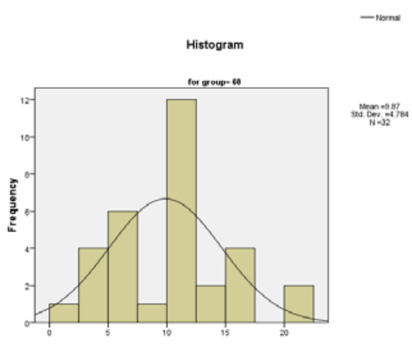

Normal
Histogram
Mean =5.71
Std. Dev. =4.
55
N =34
Frequency
AnkleDFR

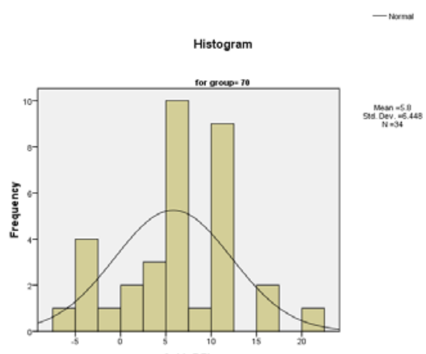

Normal
Histogram
for group= 20
Mean =9.93
Std. Dev. =3.676
N =30
Frequency
AnkleDFL

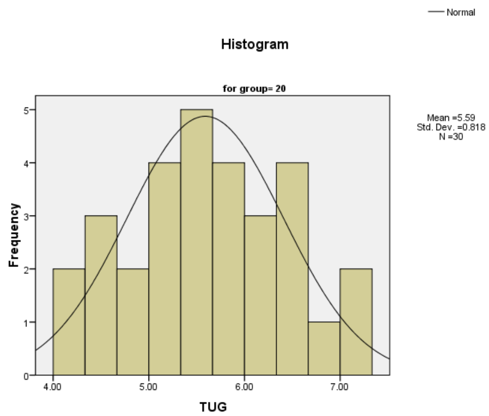

Normal
Histogram
for group= 30
Mean =8.58
Std. Dev. =7.911
N =31
Frequency
AnkleDFL

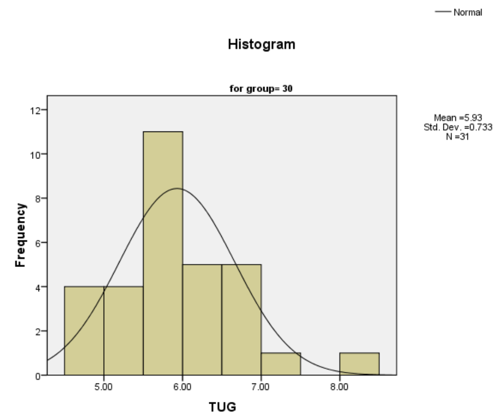

Normal
Histogram
for group= 40
Mean =12.81
Std. Dev. =4.666
N =32
Frequency
AnkleDFL

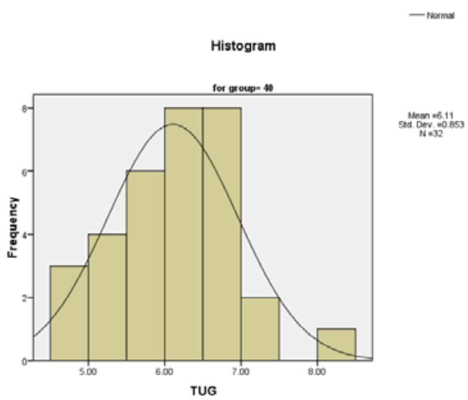

Normal
Histogram
for group= 50
Mean =11.26
Std. Dev. =5.639
N =31
Frequency
AnkleDFL

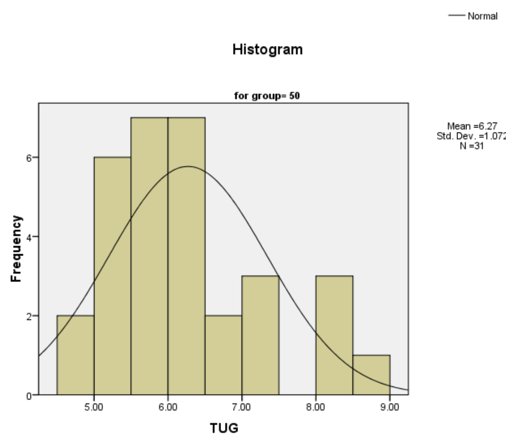

Normal
Histogram
for group= 60
Mean =9.87
Std. Dev. =4.784
N =32
Frequency
AnkleDFL

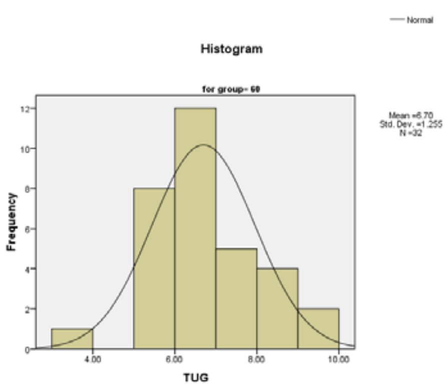

Normal
Histogram
for group= 70
Mean =5.8
Std. Dev. =6.448
N =34
Frequency
AnkleDFL

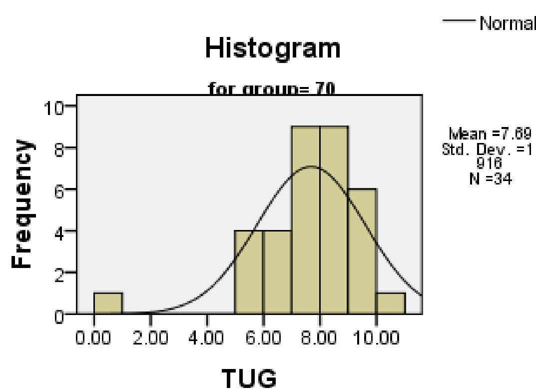

Normal
Histogram
for group= 20
Frequency
TUG
Mean =5.59
Std. Dev. =0.818
N =30

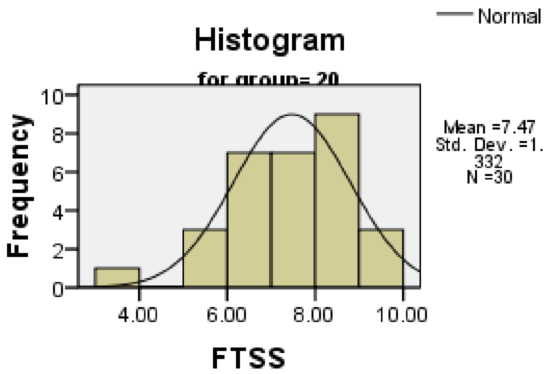

Normal
Histogram
for group= 30
Frequency
TUG
Mean =5.93
Std. Dev. =0.733
N =31


Normal
Histogram
for group= 40
Frequency
TUG
Mean =6.11
Std. Dev. =0.853
N =32

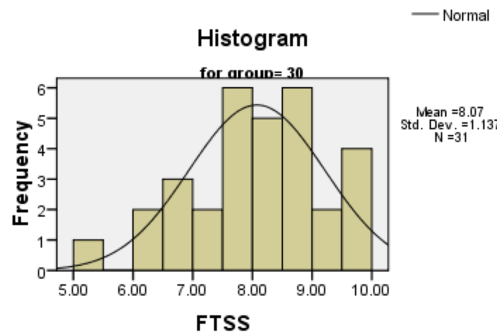

Normal
Histogram
for group= 50
Frequency
TUG
Mean =6.27
Std. Dev. =1.072
N =31


Normal
Histogram
for group= 60
Frequency
TUG
Mean =6.70
Std. Dev. =1.255
N =32

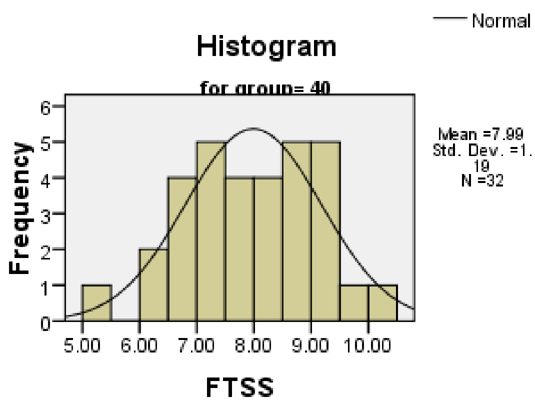

Normal
Histogram
for group= 70
Frequency
TUG
Mean =7.69
Std. Dev. =1.
916
N =34



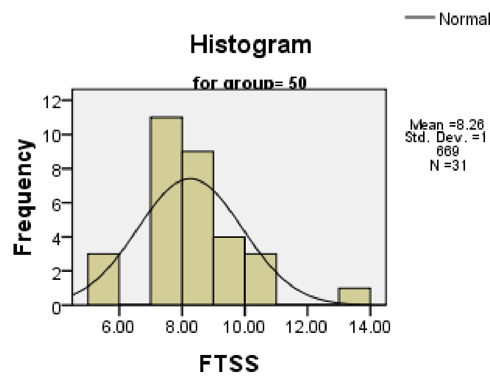
Normal
Histogram
for group= 20
Frequency
10
8
6
4
2
0
4.00
6.00
8.00
10.00
FTSS
Mean =7.47
Std. Dev. =1.
332
N =30

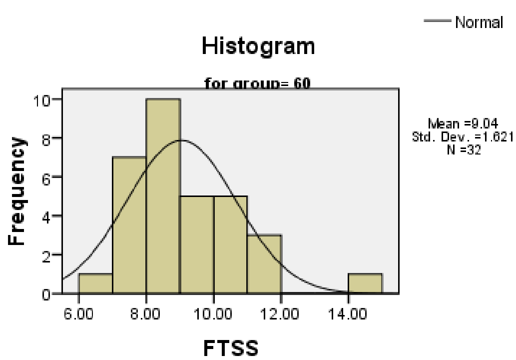
Normal
Histogram
for group= 30
Frequency
6
5
4
3
2
1
0
5.00
6.00
7.00
8.00
9.00
10.00
FTSS
Mean =8.07
Std. Dev. =1.137
N =31

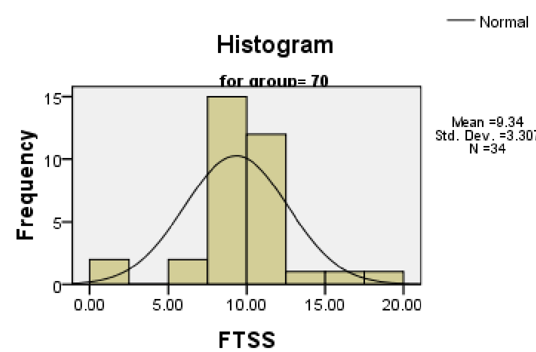
Normal
Histogram
for group= 40
Frequency
6
5
4
3
2
1
0
5.00
6.00
7.00
8.00
9.00
10.00
FTSS
Mean =7.99
Std. Dev. =1.
19
N =32

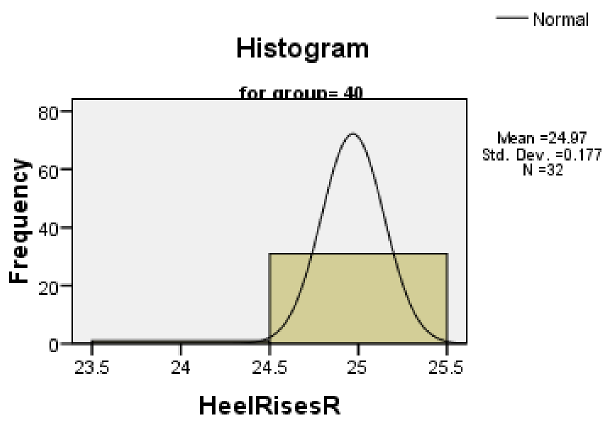
Normal
Histogram
for group= 50
Frequency
12
10
8
6
4
2
0
6.00
8.00
10.00
12.00
14.00
FTSS
Mean =8.26
Std. Dev. =1.
669
N =31

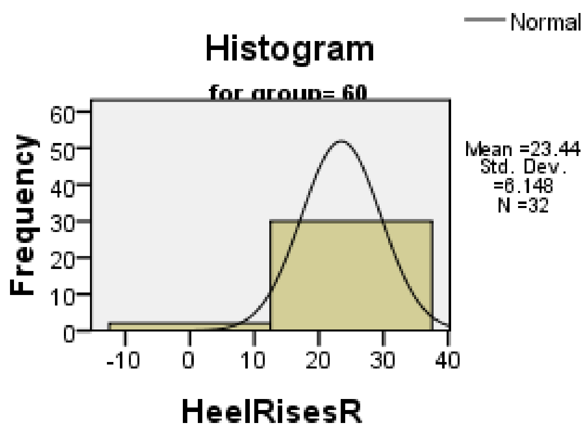



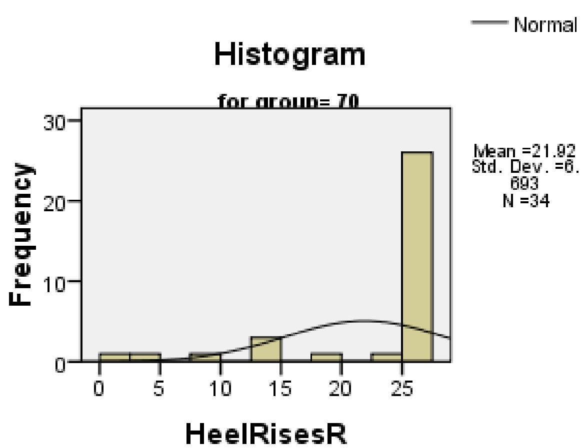
Normal
Histogram
for group= 60
Frequency
10
8
6
4
2
0
6.00
8.00
10.00
12.00
14.00
FTSS
Mean =9.04
Std. Dev. =1.621
N =32

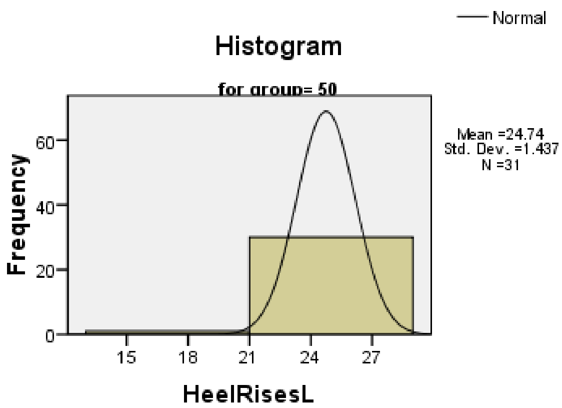
Normal
Histogram
for group= 70
Frequency
15
10
5
0
0.00
5.00
10.00
15.00
20.00
FTSS
Mean =9.34
Std. Dev. =3.307
N =34

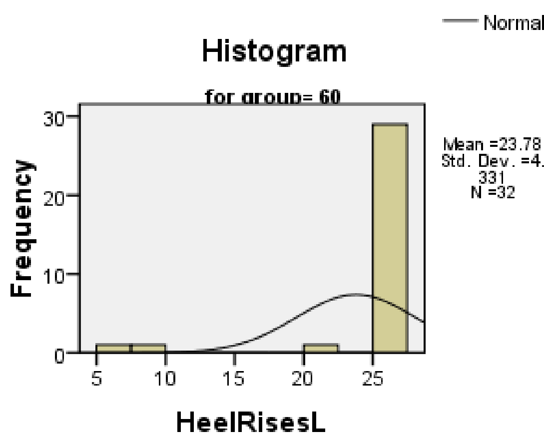


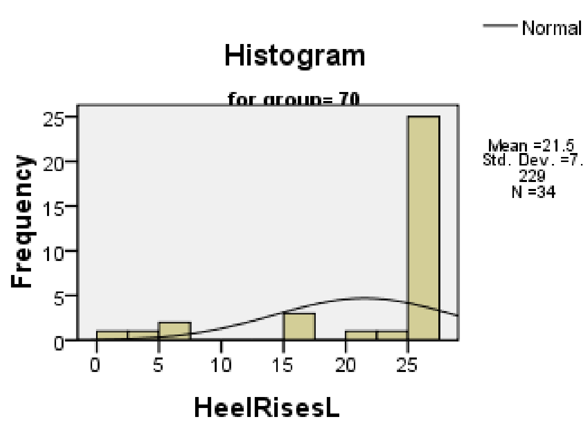




Note: HeelRisesR is constant when group = 20, 30, 50. They have been omitted




Note: HeelRisesL is constant when group = 20, 30, 40. They have been omitted.

# Appendix I

MANOVA: Parameter Estimates

Appendix I

## MANOVA: Parameter Estimates

| Dependent Variable | Parameter | B | Std. Error | t | Sig. | 99% Confidence Interval | | Partial Eta Squared | Observed Power[a] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| HabGaitSpeed | Intercept | 3.850 | .127 | 30.276 | .000 | 3.519 | 4.181 | .833 | 1.000 |
| | [group=20] | 1.079 | .186 | 5.809 | .000 | .596 | 1.563 | .155 | .999 |
| | [group=30] | .843 | .184 | 4.577 | .000 | .364 | 1.322 | .102 | .975 |
| | [group=40] | .698 | .183 | 3.823 | .000 | .223 | 1.174 | .074 | .887 |
| | [group=50] | .556 | .184 | 3.017 | .003 | .076 | 1.035 | .047 | .660 |
| | [group=60] | .471 | .183 | 2.577 | .011 | -.005 | .946 | .035 | .491 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| MDRTF | Intercept | 12.007 | .361 | 33.303 | .000 | 11.069 | 12.946 | .858 | 1.000 |
| | [group=20] | 3.356 | .527 | 6.373 | .000 | 1.985 | 4.727 | .181 | 1.000 |
| | [group=30] | 2.533 | .522 | 4.852 | .000 | 1.174 | 3.892 | .113 | .987 |
| | [group=40] | 2.540 | .518 | 4.904 | .000 | 1.192 | 3.887 | .116 | .989 |
| | [group=50] | 2.372 | .522 | 4.543 | .000 | 1.013 | 3.731 | .101 | .973 |
| | [group=60] | 1.172 | .518 | 2.264 | .025 | -.175 | 2.520 | .027 | .370 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| MDRTB | Intercept | 7.551 | .438 | 17.256 | .000 | 6.412 | 8.690 | .618 | 1.000 |
| | [group=20] | 3.824 | .639 | 5.982 | .000 | 2.160 | 5.487 | .163 | 1.000 |
| | [group=30] | 1.828 | .634 | 2.884 | .004 | .178 | 3.477 | .043 | .611 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | [group=40] | 3.511 | .628 | 5.587 | .000 | 1.875 | 5.147 | .145 | .998 |
| | [group=50] | 3.231 | .634 | 5.099 | .000 | 1.581 | 4.880 | .124 | .993 |
| | [group=60] | 1.433 | .628 | 2.280 | .024 | -.203 | 3.069 | .027 | .376 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| MDRTR | Intercept | 9.331 | .391 | 23.882 | .000 | 8.314 | 10.348 | .756 | 1.000 |
| | [group=20] | 2.636 | .571 | 4.619 | .000 | 1.150 | 4.121 | .104 | .977 |
| | [group=30] | .524 | .566 | .926 | .356 | -.949 | 1.997 | .005 | .049 |
| | [group=40] | .794 | .561 | 1.415 | .159 | -.666 | 2.255 | .011 | .120 |
| | [group=50] | 1.242 | .566 | 2.195 | .029 | -.231 | 2.714 | .026 | .344 |
| | [group=60] | .755 | .561 | 1.346 | .180 | -.705 | 2.216 | .010 | .107 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| MDRTL | Intercept | 9.118 | .394 | 23.122 | .000 | 8.091 | 10.144 | .744 | 1.000 |
| | [group=20] | 2.007 | .576 | 3.485 | .001 | .508 | 3.506 | .062 | .810 |
| | [group=30] | .640 | .571 | 1.122 | .264 | -.846 | 2.127 | .007 | .072 |
| | [group=40] | 1.101 | .566 | 1.944 | .053 | -.373 | 2.575 | .020 | .258 |
| | [group=50] | .390 | .571 | .684 | .495 | -1.096 | 1.877 | .003 | .029 |
| | [group=60] | .665 | .566 | 1.173 | .242 | -.809 | 2.139 | .007 | .079 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| DVA | Intercept | .500 | .112 | 4.472 | .000 | .209 | .791 | .098 | .968 |
| | [group=20] | -.367 | .163 | -2.245 | .026 | -.792 | .058 | .027 | .363 |
| | [group=30] | -.145 | .162 | -.897 | .371 | -.567 | .276 | .004 | .046 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | [group=40] | -.125 | .161 | -.778 | .437 | -.543 | .293 | .003 | .036 |
| | [group=50] | -.177 | .162 | -1.096 | .275 | -.599 | .244 | .006 | .068 |
| | [group=60] | .188 | .161 | 1.168 | .244 | -.230 | .605 | .007 | .078 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| SLSEOR | Intercept | 14.250 | 1.140 | 12.496 | .000 | 11.282 | 17.218 | .459 | 1.000 |
| | [group=20] | 15.606 | 1.666 | 9.370 | .000 | 11.271 | 19.941 | .323 | 1.000 |
| | [group=30] | 15.169 | 1.651 | 9.186 | .000 | 10.871 | 19.467 | .314 | 1.000 |
| | [group=40] | 14.698 | 1.638 | 8.974 | .000 | 10.435 | 18.960 | .304 | 1.000 |
| | [group=50] | 14.469 | 1.651 | 8.762 | .000 | 10.171 | 18.767 | .294 | 1.000 |
| | [group=60] | 10.629 | 1.638 | 6.490 | .000 | 6.366 | 14.891 | .186 | 1.000 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| SLSEOL | Intercept | 14.001 | 1.150 | 12.179 | .000 | 11.009 | 16.994 | .446 | 1.000 |
| | [group=20] | 15.074 | 1.679 | 8.977 | .000 | 10.703 | 19.444 | .305 | 1.000 |
| | [group=30] | 15.168 | 1.665 | 9.111 | .000 | 10.835 | 19.501 | .311 | 1.000 |
| | [group=40] | 15.390 | 1.651 | 9.321 | .000 | 11.092 | 19.687 | .321 | 1.000 |
| | [group=50] | 14.016 | 1.665 | 8.419 | .000 | 9.683 | 18.349 | .278 | 1.000 |
| | [group=60] | 11.916 | 1.651 | 7.217 | .000 | 7.619 | 16.214 | .221 | 1.000 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| SLSECR | Intercept | 4.118 | 1.331 | 3.093 | .002 | .653 | 7.582 | .049 | .688 |
| | [group=20] | 17.723 | 1.944 | 9.115 | .000 | 12.662 | 22.784 | .311 | 1.000 |
| | [group=30] | 12.046 | 1.928 | 6.249 | .000 | 7.029 | 17.063 | .175 | 1.000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | [group=40] | 6.576 | 1.912 | 3.440 | .001 | 1.600 | 11.552 | .060 | .798 |
| | [group=50] | 5.033 | 1.928 | 2.611 | .010 | .016 | 10.050 | .036 | .505 |
| | [group=60] | .678 | 1.912 | .355 | .723 | -4.298 | 5.654 | .001 | .015 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| SLSECL | Intercept | 3.847 | 1.251 | 3.075 | .002 | .591 | 7.103 | .049 | .681 |
| | [group=20] | 17.616 | 1.827 | 9.640 | .000 | 12.860 | 22.372 | .336 | 1.000 |
| | [group=30] | 8.598 | 1.812 | 4.746 | .000 | 3.883 | 13.313 | .109 | .983 |
| | [group=40] | 6.054 | 1.797 | 3.369 | .001 | 1.378 | 10.731 | .058 | .777 |
| | [group=50] | 3.594 | 1.812 | 1.984 | .049 | -1.122 | 8.309 | .021 | .271 |
| | [group=60] | 1.382 | 1.797 | .769 | .443 | -3.294 | 6.059 | .003 | .035 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| AnkleDFR | Intercept | 5.706 | .882 | 6.472 | .000 | 3.411 | 8.001 | .185 | 1.000 |
| | [group=20] | 5.161 | 1.288 | 4.007 | .000 | 1.809 | 8.513 | .080 | .919 |
| | [group=30] | 4.455 | 1.277 | 3.490 | .001 | 1.132 | 7.778 | .062 | .811 |
| | [group=40] | 7.107 | 1.266 | 5.612 | .000 | 3.811 | 10.402 | .146 | .999 |
| | [group=50] | 5.133 | 1.277 | 4.020 | .000 | 1.810 | 8.456 | .081 | .920 |
| | [group=60] | 3.919 | 1.266 | 3.095 | .002 | .623 | 7.215 | .049 | .688 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| AnkleDFL | Intercept | 5.795 | .978 | 5.927 | .000 | 3.250 | 8.340 | .160 | 1.000 |
| | [group=20] | 4.138 | 1.428 | 2.898 | .004 | .422 | 7.855 | .044 | .616 |
| | [group=30] | 2.786 | 1.416 | 1.968 | .051 | -.899 | 6.470 | .021 | .266 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | [group=40] | 7.018 | 1.404 | 4.998 | .000 | 3.363 | 10.672 | .120 | .991 |
| | [group=50] | 5.463 | 1.416 | 3.859 | .000 | 1.778 | 9.148 | .075 | .894 |
| | [group=60] | 4.080 | 1.404 | 2.906 | .004 | .425 | 7.735 | .044 | .619 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| TUG | Intercept | 7.686 | .205 | 37.512 | .000 | 7.153 | 8.219 | .884 | 1.000 |
| | [group=20] | -2.097 | .299 | -7.006 | .000 | -2.875 | -1.318 | .211 | 1.000 |
| | [group=30] | -1.757 | .297 | -5.920 | .000 | -2.529 | -.984 | .160 | 1.000 |
| | [group=40] | -1.579 | .294 | -5.366 | .000 | -2.345 | -.813 | .135 | .997 |
| | [group=50] | -1.417 | .297 | -4.774 | .000 | -2.189 | -.644 | .110 | .984 |
| | [group=60] | -.989 | .294 | -3.362 | .001 | -1.755 | -.223 | .058 | .775 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| FTSS | Intercept | 9.337 | .325 | 28.746 | .000 | 8.492 | 10.183 | .818 | 1.000 |
| | [group=20] | -1.871 | .474 | -3.943 | .000 | -3.106 | -.636 | .078 | .908 |
| | [group=30] | -1.263 | .470 | -2.686 | .008 | -2.487 | -.039 | .038 | .534 |
| | [group=40] | -1.348 | .466 | -2.889 | .004 | -2.562 | -.133 | .043 | .613 |
| | [group=50] | -1.081 | .470 | -2.297 | .023 | -2.305 | .144 | .028 | .382 |
| | [group=60] | -.295 | .466 | -.633 | .527 | -1.510 | .919 | .002 | .026 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| HeelRisesR | Intercept | 21.921 | .651 | 33.672 | .000 | 20.226 | 23.615 | .860 | 1.000 |
| | [group=20] | 3.079 | .951 | 3.239 | .001 | .605 | 5.554 | .054 | .737 |
| | [group=30] | 3.079 | .943 | 3.267 | .001 | .626 | 5.533 | .055 | .746 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | [group=40] | 3.048 | .935 | 3.260 | .001 | .615 | 5.482 | .055 | .744 |
| | [group=50] | 3.079 | .943 | 3.267 | .001 | .626 | 5.533 | .055 | .746 |
| | [group=60] | 1.517 | .935 | 1.622 | .106 | -.917 | 3.950 | .014 | .167 |
| | [group=70] | 0[b] | . | . | . | . | . | . | |
| HeelRisesL | Intercept | 21.500 | .617 | 34.833 | .000 | 19.893 | 23.107 | .868 | 1.000 |
| | [group=20] | 3.500 | .902 | 3.882 | .000 | 1.153 | 5.847 | .076 | .898 |
| | [group=30] | 3.500 | .894 | 3.916 | .000 | 1.174 | 5.826 | .077 | .904 |
| | [group=40] | 3.375 | .886 | 3.807 | .000 | 1.068 | 5.682 | .073 | .884 |
| | [group=50] | 3.242 | .894 | 3.627 | .000 | .916 | 5.568 | .067 | .846 |
| | [group=60] | 2.281 | .886 | 2.574 | .011 | -.026 | 4.588 | .035 | .490 |
| | [group=70] | 0[b] | . | . | . | . | . | . | . |

a. Computed using alpha = .01

b. This parameter is set to zero because it is redundant.

# Appendix J

Multiple Comparison Test

**MANOVA: Multiple Comparisons**

**Games-Howell**

| Dependent Variable | (I) group | (J) group | Mean Difference (I-J) | Std. Error | Sig. | 99% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| HabGaitSpeed | 20 | 30 | .2361 | .20940 | .868 | -.5049 | .9771 |
| | | 40 | .3809 | .20086 | .415 | -.3314 | 1.0932 |
| | | 50 | .5235 | .21074 | .146 | -.2220 | 1.2691 |
| | | 60 | .6084 | .20050 | .041 | -.1027 | 1.3195 |
| | | 70 | 1.0790* | .20011 | .000 | .3697 | 1.7884 |
| | 30 | 20 | -.2361 | .20940 | .868 | -.9771 | .5049 |
| | | 40 | .1448 | .18045 | .966 | -.4921 | .7816 |
| | | 50 | .2874 | .19139 | .664 | -.3881 | .9629 |
| | | 60 | .3723 | .18006 | .318 | -.2632 | 1.0078 |
| | | 70 | .8429* | .17963 | .000 | .2096 | 1.4762 |
| | 40 | 20 | -.3809 | .20086 | .415 | -1.0932 | .3314 |
| | | 30 | -.1448 | .18045 | .966 | -.7816 | .4921 |
| | | 50 | .1426 | .18200 | .969 | -.4998 | .7851 |
| | | 60 | .2275 | .17005 | .763 | -.3717 | .8267 |
| | | 70 | .6981* | .16959 | .002 | .1014 | 1.2949 |
| | 50 | 20 | -.5235 | .21074 | .146 | -1.2691 | .2220 |
| | | 30 | -.2874 | .19139 | .664 | -.9629 | .3881 |
| | | 40 | -.1426 | .18200 | .969 | -.7851 | .4998 |
| | | 60 | .0849 | .18161 | .997 | -.5562 | .7260 |
| | | 70 | .5555 | .18118 | .036 | -.0834 | 1.1945 |
| | 60 | 20 | -.6084 | .20050 | .041 | -1.3195 | .1027 |
| | | 30 | -.3723 | .18006 | .318 | -1.0078 | .2632 |
| | | 40 | -.2275 | .17005 | .763 | -.8267 | .3717 |
| | | 50 | -.0849 | .18161 | .997 | -.7260 | .5562 |
| | | 70 | .4706 | .16917 | .074 | -.1247 | 1.0660 |
| | 70 | 20 | -1.0790* | .20011 | .000 | -1.7884 | -.3697 |
| | | 30 | -.8429* | .17963 | .000 | -1.4762 | -.2096 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 40 | -.6981* | .16959 | .002 | -1.2949 | -.1014 |
| | | 50 | -.5555 | .18118 | .036 | -1.1945 | .0834 |
| | | 60 | -.4706 | .16917 | .074 | -1.0660 | .1247 |
| MDRTF | 20 | 30 | .8230 | .56120 | .686 | -1.1602 | 2.8062 |
| | | 40 | .8165 | .50972 | .601 | -.9836 | 2.6165 |
| | | 50 | .9843 | .52093 | .419 | -.8560 | 2.8246 |
| | | 60 | 2.1836* | .52251 | .001 | .3392 | 4.0281 |
| | | 70 | 3.3560* | .52736 | .000 | 1.4972 | 5.2148 |
| | 30 | 20 | -.8230 | .56120 | .686 | -2.8062 | 1.1602 |
| | | 40 | -.0066 | .54329 | 1.000 | -1.9263 | 1.9132 |
| | | 50 | .1613 | .55382 | 1.000 | -1.7953 | 2.1179 |
| | | 60 | 1.3606 | .55531 | .156 | -.5999 | 3.3212 |
| | | 70 | 2.5330* | .55987 | .000 | .5590 | 4.5069 |
| | 40 | 20 | -.8165 | .50972 | .601 | -2.6165 | .9836 |
| | | 30 | .0066 | .54329 | 1.000 | -1.9132 | 1.9263 |
| | | 50 | .1678 | .50158 | .999 | -1.6014 | 1.9370 |
| | | 60 | 1.3672 | .50322 | .086 | -.4063 | 3.1407 |
| | | 70 | 2.5395* | .50826 | .000 | .7510 | 4.3281 |
| | 50 | 20 | -.9843 | .52093 | .419 | -2.8246 | .8560 |
| | | 30 | -.1613 | .55382 | 1.000 | -2.1179 | 1.7953 |
| | | 40 | -.1678 | .50158 | .999 | -1.9370 | 1.6014 |
| | | 60 | 1.1993 | .51458 | .198 | -.6154 | 3.0141 |
| | | 70 | 2.3717* | .51950 | .000 | .5423 | 4.2010 |
| | 60 | 20 | -2.1836* | .52251 | .001 | -4.0281 | -.3392 |
| | | 30 | -1.3606 | .55531 | .156 | -3.3212 | .5999 |
| | | 40 | -1.3672 | .50322 | .086 | -3.1407 | .4063 |
| | | 50 | -1.1993 | .51458 | .198 | -3.0141 | .6154 |
| | | 70 | 1.1723 | .52109 | .230 | -.6612 | 3.0059 |
| | 70 | 20 | -3.3560* | .52736 | .000 | -5.2148 | -1.4972 |
| | | 30 | -2.5330* | .55987 | .000 | -4.5069 | -.5590 |
| | | 40 | -2.5395* | .50826 | .000 | -4.3281 | -.7510 |
| | | 50 | -2.3717* | .51950 | .000 | -4.2010 | -.5423 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 60 | -1.1723 | .52109 | .230 | -3.0059 | .6612 |
| MDRTB | 20 | 30 | 1.9960 | .64325 | .033 | -.2762 | 4.2681 |
| | | 40 | .3125 | .65384 | .997 | -1.9952 | 2.6202 |
| | | 50 | .5927 | .58502 | .912 | -1.4777 | 2.6632 |
| | | 60 | 2.3906* | .64040 | .005 | .1304 | 4.6509 |
| | | 70 | 3.8235* | .66130 | .000 | 1.4932 | 6.1539 |
| | 30 | 20 | -1.9960 | .64325 | .033 | -4.2681 | .2762 |
| | | 40 | -1.6835 | .66153 | .127 | -4.0164 | .6495 |
| | | 50 | -1.4032 | .59361 | .186 | -3.5025 | .6960 |
| | | 60 | .3947 | .64825 | .990 | -1.8915 | 2.6808 |
| | | 70 | 1.8276 | .66891 | .083 | -.5278 | 4.1830 |
| | 40 | 20 | -.3125 | .65384 | .997 | -2.6202 | 1.9952 |
| | | 30 | 1.6835 | .66153 | .127 | -.6495 | 4.0164 |
| | | 50 | .2802 | .60506 | .997 | -1.8584 | 2.4188 |
| | | 60 | 2.0781 | .65876 | .029 | -.2434 | 4.3997 |
| | | 70 | 3.5110* | .67910 | .000 | 1.1215 | 5.9006 |
| | 50 | 20 | -.5927 | .58502 | .912 | -2.6632 | 1.4777 |
| | | 30 | 1.4032 | .59361 | .186 | -.6960 | 3.5025 |
| | | 40 | -.2802 | .60506 | .997 | -2.4188 | 1.8584 |
| | | 60 | 1.7979 | .59051 | .039 | -.2878 | 3.8835 |
| | | 70 | 3.2308* | .61312 | .000 | 1.0676 | 5.3940 |
| | 60 | 20 | -2.3906* | .64040 | .005 | -4.6509 | -.1304 |
| | | 30 | -.3947 | .64825 | .990 | -2.6808 | 1.8915 |
| | | 40 | -2.0781 | .65876 | .029 | -4.3997 | .2434 |
| | | 50 | -1.7979 | .59051 | .039 | -3.8835 | .2878 |
| | | 70 | 1.4329 | .66617 | .275 | -.9112 | 3.7770 |
| | 70 | 20 | -3.8235* | .66130 | .000 | -6.1539 | -1.4932 |
| | | 30 | -1.8276 | .66891 | .083 | -4.1830 | .5278 |
| | | 40 | -3.5110* | .67910 | .000 | -5.9006 | -1.1215 |
| | | 50 | -3.2308* | .61312 | .000 | -5.3940 | -1.0676 |
| | | 60 | -1.4329 | .66617 | .275 | -3.7770 | .9112 |
| MDRTR | 20 | 30 | 2.1118 | .64970 | .025 | -.2199 | 4.4436 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 40 | 1.8417 | .69543 | .104 | -.6306 | 4.3140 |
| | | 50 | 1.3941 | .71259 | .380 | -1.1346 | 3.9228 |
| | | 60 | 1.8807 | .63951 | .055 | -.4209 | 4.1824 |
| | | 70 | 2.6358* | .69670 | .005 | .1609 | 5.1107 |
| | 30 | 20 | -2.1118 | .64970 | .025 | -4.4436 | .2199 |
| | | 40 | -.2702 | .50150 | .994 | -2.0431 | 1.5028 |
| | | 50 | -.7177 | .52504 | .746 | -2.5795 | 1.1441 |
| | | 60 | -.2311 | .42054 | .994 | -1.7147 | 1.2526 |
| | | 70 | .5240 | .50327 | .902 | -1.2515 | 2.2994 |
| | 40 | 20 | -1.8417 | .69543 | .104 | -4.3140 | .6306 |
| | | 30 | .2702 | .50150 | .994 | -1.5028 | 2.0431 |
| | | 50 | -.4476 | .58067 | .971 | -2.4961 | 1.6010 |
| | | 60 | .0391 | .48822 | 1.000 | -1.6893 | 1.7674 |
| | | 70 | .7941 | .56105 | .718 | -1.1801 | 2.7684 |
| | 50 | 20 | -1.3941 | .71259 | .380 | -3.9228 | 1.1346 |
| | | 30 | .7177 | .52504 | .746 | -1.1441 | 2.5795 |
| | | 40 | .4476 | .58067 | .971 | -1.6010 | 2.4961 |
| | | 60 | .4866 | .51237 | .931 | -1.3337 | 2.3070 |
| | | 70 | 1.2417 | .58220 | .284 | -.8096 | 3.2930 |
| | 60 | 20 | -1.8807 | .63951 | .055 | -4.1824 | .4209 |
| | | 30 | .2311 | .42054 | .994 | -1.2526 | 1.7147 |
| | | 40 | -.0391 | .48822 | 1.000 | -1.7674 | 1.6893 |
| | | 50 | -.4866 | .51237 | .931 | -2.3070 | 1.3337 |
| | | 70 | .7551 | .49004 | .640 | -.9757 | 2.4858 |
| | 70 | 20 | -2.6358* | .69670 | .005 | -5.1107 | -.1609 |
| | | 30 | -.5240 | .50327 | .902 | -2.2994 | 1.2515 |
| | | 40 | -.7941 | .56105 | .718 | -2.7684 | 1.1801 |
| | | 50 | -1.2417 | .58220 | .284 | -3.2930 | .8096 |
| | | 60 | -.7551 | .49004 | .640 | -2.4858 | .9757 |
| MDRTL | 20 | 30 | 1.3669 | .68395 | .359 | -1.0820 | 3.8159 |
| | | 40 | .9063 | .70115 | .788 | -1.5948 | 3.4073 |
| | | 50 | 1.6169 | .68356 | .190 | -.8308 | 4.0647 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 60 | 1.3428 | .70178 | .406 | -1.1602 | 3.8458 |
| | | 70 | 2.0074 | .71302 | .071 | -.5295 | 4.5442 |
| | 30 | 20 | -1.3669 | .68395 | .359 | -3.8159 | 1.0820 |
| | | 40 | -.4607 | .50457 | .942 | -2.2406 | 1.3192 |
| | | 50 | .2500 | .47983 | .995 | -1.4435 | 1.9435 |
| | | 60 | -.0241 | .50545 | 1.000 | -1.8072 | 1.7589 |
| | | 70 | .6404 | .52095 | .821 | -1.1949 | 2.4757 |
| | 40 | 20 | -.9063 | .70115 | .788 | -3.4073 | 1.5948 |
| | | 30 | .4607 | .50457 | .942 | -1.3192 | 2.2406 |
| | | 50 | .7107 | .50404 | .721 | -1.0674 | 2.4888 |
| | | 60 | .4366 | .52849 | .962 | -1.4258 | 2.2989 |
| | | 70 | 1.1011 | .54333 | .339 | -.8108 | 3.0130 |
| | 50 | 20 | -1.6169 | .68356 | .190 | -4.0647 | .8308 |
| | | 30 | -.2500 | .47983 | .995 | -1.9435 | 1.4435 |
| | | 40 | -.7107 | .50404 | .721 | -2.4888 | 1.0674 |
| | | 60 | -.2741 | .50492 | .994 | -2.0553 | 1.5071 |
| | | 70 | .3904 | .52043 | .975 | -1.4431 | 2.2239 |
| | 60 | 20 | -1.3428 | .70178 | .406 | -3.8458 | 1.1602 |
| | | 30 | .0241 | .50545 | 1.000 | -1.7589 | 1.8072 |
| | | 40 | -.4366 | .52849 | .962 | -2.2989 | 1.4258 |
| | | 50 | .2741 | .50492 | .994 | -1.5071 | 2.0553 |
| | | 70 | .6645 | .54414 | .825 | -1.2502 | 2.5793 |
| | 70 | 20 | -2.0074 | .71302 | .071 | -4.5442 | .5295 |
| | | 30 | -.6404 | .52095 | .821 | -2.4757 | 1.1949 |
| | | 40 | -1.1011 | .54333 | .339 | -3.0130 | .8108 |
| | | 50 | -.3904 | .52043 | .975 | -2.2239 | 1.4431 |
| | | 60 | -.6645 | .54414 | .825 | -2.5793 | 1.2502 |
| DVA | 20 | 30 | -.22 | .117 | .421 | -.64 | .20 |
| | | 40 | -.24 | .133 | .462 | -.72 | .23 |
| | | 50 | -.19 | .125 | .655 | -.63 | .26 |
| | | 60 | -.55 | .170 | .026 | -1.17 | .06 |
| | | 70 | -.37 | .137 | .097 | -.85 | .12 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 | 20 | .22 | .117 | .421 | -.20 | .64 |
| | | 40 | -.02 | .153 | 1.000 | -.56 | .52 |
| | | 50 | .03 | .146 | 1.000 | -.48 | .55 |
| | | 60 | -.33 | .187 | .486 | -1.00 | .33 |
| | | 70 | -.15 | .156 | .938 | -.70 | .41 |
| | 40 | 20 | .24 | .133 | .462 | -.23 | .72 |
| | | 30 | .02 | .153 | 1.000 | -.52 | .56 |
| | | 50 | .05 | .159 | .999 | -.51 | .61 |
| | | 60 | -.31 | .197 | .609 | -1.01 | .38 |
| | | 70 | -.13 | .168 | .976 | -.72 | .47 |
| | 50 | 20 | .19 | .125 | .655 | -.26 | .63 |
| | | 30 | -.03 | .146 | 1.000 | -.55 | .48 |
| | | 40 | -.05 | .159 | .999 | -.61 | .51 |
| | | 60 | -.36 | .191 | .410 | -1.04 | .31 |
| | | 70 | -.18 | .162 | .882 | -.75 | .39 |
| | 60 | 20 | .55 | .170 | .026 | -.06 | 1.17 |
| | | 30 | .33 | .187 | .486 | -.33 | 1.00 |
| | | 40 | .31 | .197 | .609 | -.38 | 1.01 |
| | | 50 | .36 | .191 | .410 | -.31 | 1.04 |
| | | 70 | .19 | .199 | .934 | -.52 | .89 |
| | 70 | 20 | .37 | .137 | .097 | -.12 | .85 |
| | | 30 | .15 | .156 | .938 | -.41 | .70 |
| | | 40 | .13 | .168 | .976 | -.47 | .72 |
| | | 50 | .18 | .162 | .882 | -.39 | .75 |
| | | 60 | -.19 | .199 | .934 | -.89 | .52 |
| SLSEOR | 20 | 30 | .4370 | .42848 | .908 | -1.1204 | 1.9943 |
| | | 40 | .9085 | .83250 | .881 | -2.1505 | 3.9675 |
| | | 50 | 1.1370 | .99084 | .858 | -2.5207 | 4.7947 |
| | | 60 | 4.9773 | 1.45984 | .020 | -.4066 | 10.3611 |
| | | 70 | 15.6060* | 1.96551 | .000 | 8.3927 | 22.8194 |
| | 30 | 20 | -.4370 | .42848 | .908 | -1.9943 | 1.1204 |
| | | 40 | .4715 | .91399 | .995 | -2.8065 | 3.7496 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 50 | .7000 | 1.06023 | .985 | -3.1351 | 4.5351 |
| | | 60 | 4.5403 | 1.50780 | .050 | -.9605 | 10.0411 |
| | | 70 | 15.1691* | 2.00138 | .000 | 7.8681 | 22.4700 |
| | 40 | 20 | -.9085 | .83250 | .881 | -3.9675 | 2.1505 |
| | | 30 | -.4715 | .91399 | .995 | -3.7496 | 2.8065 |
| | | 50 | .2285 | 1.27810 | 1.000 | -4.2869 | 4.7438 |
| | | 60 | 4.0688 | 1.66821 | .163 | -1.8841 | 10.0216 |
| | | 70 | 14.6975* | 2.12485 | .000 | 7.0655 | 22.3295 |
| | 50 | 20 | -1.1370 | .99084 | .858 | -4.7947 | 2.5207 |
| | | 30 | -.7000 | 1.06023 | .985 | -4.5351 | 3.1351 |
| | | 40 | -.2285 | 1.27810 | 1.000 | -4.7438 | 4.2869 |
| | | 60 | 3.8403 | 1.75261 | .259 | -2.3784 | 10.0589 |
| | | 70 | 14.4691* | 2.19174 | .000 | 6.6414 | 22.2967 |
| | 60 | 20 | -4.9773 | 1.45984 | .020 | -10.3611 | .4066 |
| | | 30 | -4.5403 | 1.50780 | .050 | -10.0411 | .9605 |
| | | 40 | -4.0688 | 1.66821 | .163 | -10.0216 | 1.8841 |
| | | 50 | -3.8403 | 1.75261 | .259 | -10.0589 | 2.3784 |
| | | 70 | 10.6288* | 2.43989 | .001 | 2.0171 | 19.2405 |
| | 70 | 20 | -15.6060* | 1.96551 | .000 | -22.8194 | -8.3927 |
| | | 30 | -15.1691* | 2.00138 | .000 | -22.4700 | -7.8681 |
| | | 40 | -14.6975* | 2.12485 | .000 | -22.3295 | -7.0655 |
| | | 50 | -14.4691* | 2.19174 | .000 | -22.2967 | -6.6414 |
| | | 60 | -10.6288* | 2.43989 | .001 | -19.2405 | -2.0171 |
| SLSEOL | 20 | 30 | -.0944 | .90454 | 1.000 | -3.3030 | 3.1143 |
| | | 40 | -.3163 | .91702 | .999 | -3.5646 | 2.9321 |
| | | 50 | 1.0573 | 1.27867 | .961 | -3.4860 | 5.6006 |
| | | 60 | 3.1575 | 1.54152 | .332 | -2.3574 | 8.6724 |
| | | 70 | 15.0735* | 2.09680 | .000 | 7.5122 | 22.6349 |
| | 30 | 20 | .0944 | .90454 | 1.000 | -3.1143 | 3.3030 |
| | | 40 | -.2219 | .78466 | 1.000 | -2.9891 | 2.5453 |
| | | 50 | 1.1516 | 1.18734 | .925 | -3.1080 | 5.4112 |
| | | 60 | 3.2519 | 1.46665 | .252 | -2.0462 | 8.5499 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 70 | 15.1679* | 2.04239 | .000 | 7.7530 | 22.5828 |
| | 40 | 20 | .3163 | .91702 | .999 | -2.9321 | 3.5646 |
| | | 30 | .2219 | .78466 | 1.000 | -2.5453 | 2.9891 |
| | | 50 | 1.3735 | 1.19687 | .859 | -2.9137 | 5.6607 |
| | | 60 | 3.4737 | 1.47437 | .196 | -1.8454 | 8.7929 |
| | | 70 | 15.3898* | 2.04795 | .000 | 7.9604 | 22.8191 |
| | 50 | 20 | -1.0573 | 1.27867 | .961 | -5.6006 | 3.4860 |
| | | 30 | -1.1516 | 1.18734 | .925 | -5.4112 | 3.1080 |
| | | 40 | -1.3735 | 1.19687 | .859 | -5.6607 | 2.9137 |
| | | 60 | 2.1002 | 1.72275 | .826 | -3.9910 | 8.1915 |
| | | 70 | 14.0163* | 2.23342 | .000 | 6.0579 | 21.9747 |
| | 60 | 20 | -3.1575 | 1.54152 | .332 | -8.6724 | 2.3574 |
| | | 30 | -3.2519 | 1.46665 | .252 | -8.5499 | 2.0462 |
| | | 40 | -3.4737 | 1.47437 | .196 | -8.7929 | 1.8454 |
| | | 50 | -2.1002 | 1.72275 | .826 | -8.1915 | 3.9910 |
| | | 70 | 11.9160* | 2.39363 | .000 | 3.4538 | 20.3782 |
| | 70 | 20 | -15.0735* | 2.09680 | .000 | -22.6349 | -7.5122 |
| | | 30 | -15.1679* | 2.04239 | .000 | -22.5828 | -7.7530 |
| | | 40 | -15.3898* | 2.04795 | .000 | -22.8191 | -7.9604 |
| | | 50 | -14.0163* | 2.23342 | .000 | -21.9747 | -6.0579 |
| | | 60 | -11.9160* | 2.39363 | .000 | -20.3782 | -3.4538 |
| SLSECR | 20 | 30 | 5.6768 | 2.46572 | .211 | -3.0588 | 14.4124 |
| | | 40 | 11.1469* | 2.07307 | .000 | 3.8281 | 18.4657 |
| | | 50 | 12.6900* | 2.02501 | .000 | 5.5327 | 19.8473 |
| | | 60 | 17.0447* | 1.69659 | .000 | 10.9537 | 23.1357 |
| | | 70 | 17.7230* | 1.81238 | .000 | 11.2804 | 24.1656 |
| | 30 | 20 | -5.6768 | 2.46572 | .211 | -14.4124 | 3.0588 |
| | | 40 | 5.4701 | 2.42736 | .231 | -3.1319 | 14.0721 |
| | | 50 | 7.0132 | 2.38644 | .052 | -1.4590 | 15.4855 |
| | | 60 | 11.3679* | 2.11491 | .000 | 3.7153 | 19.0206 |
| | | 70 | 12.0462* | 2.20888 | .000 | 4.1279 | 19.9646 |
| | 40 | 20 | -11.1469* | 2.07307 | .000 | -18.4657 | -3.8281 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 30 | -5.4701 | 2.42736 | .231 | -14.0721 | 3.1319 |
| | | 50 | 1.5431 | 1.97812 | .970 | -5.4333 | 8.5195 |
| | | 60 | 5.8978* | 1.64035 | .009 | .0413 | 11.7544 |
| | | 70 | 6.5761* | 1.75983 | .006 | .3474 | 12.8048 |
| | 50 | 20 | -12.6900* | 2.02501 | .000 | -19.8473 | -5.5327 |
| | | 30 | -7.0132 | 2.38644 | .052 | -15.4855 | 1.4590 |
| | | 40 | -1.5431 | 1.97812 | .970 | -8.5195 | 5.4333 |
| | | 60 | 4.3547 | 1.57917 | .082 | -1.2831 | 9.9926 |
| | | 70 | 5.0330 | 1.70295 | .049 | -.9937 | 11.0597 |
| | 60 | 20 | -17.0447* | 1.69659 | .000 | -23.1357 | -10.9537 |
| | | 30 | -11.3679* | 2.11491 | .000 | -19.0206 | -3.7153 |
| | | 40 | -5.8978* | 1.64035 | .009 | -11.7544 | -.0413 |
| | | 50 | -4.3547 | 1.57917 | .082 | -9.9926 | 1.2831 |
| | | 70 | .6783 | 1.29531 | .995 | -3.8888 | 5.2453 |
| | 70 | 20 | -17.7230* | 1.81238 | .000 | -24.1656 | -11.2804 |
| | | 30 | -12.0462* | 2.20888 | .000 | -19.9646 | -4.1279 |
| | | 40 | -6.5761* | 1.75983 | .006 | -12.8048 | -.3474 |
| | | 50 | -5.0330 | 1.70295 | .049 | -11.0597 | .9937 |
| | | 60 | -.6783 | 1.29531 | .995 | -5.2453 | 3.8888 |
| SLSECL | 20 | 30 | 9.0178* | 2.54108 | .010 | .0404 | 17.9953 |
| | | 40 | 11.5618* | 2.24280 | .000 | 3.5928 | 19.5307 |
| | | 50 | 14.0224* | 2.13518 | .000 | 6.3889 | 21.6558 |
| | | 60 | 16.2336* | 1.97332 | .000 | 9.0689 | 23.3984 |
| | | 70 | 17.6159* | 1.99757 | .000 | 10.3861 | 24.8458 |
| | 30 | 20 | -9.0178* | 2.54108 | .010 | -17.9953 | -.0404 |
| | | 40 | 2.5439 | 2.18119 | .851 | -5.1851 | 10.2729 |
| | | 50 | 5.0045 | 2.07037 | .170 | -2.3726 | 12.3817 |
| | | 60 | 7.2158* | 1.90300 | .006 | .3338 | 14.0978 |
| | | 70 | 8.5981* | 1.92814 | .001 | 1.6471 | 15.5491 |
| | 40 | 20 | -11.5618* | 2.24280 | .000 | -19.5307 | -3.5928 |
| | | 30 | -2.5439 | 2.18119 | .851 | -10.2729 | 5.1851 |
| | | 50 | 2.4606 | 1.69100 | .693 | -3.5091 | 8.4304 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 60 | 4.6719 | 1.48138 | .031 | -.6146 | 9.9583 |
| | | 70 | 6.0542* | 1.51354 | .003 | .6710 | 11.4373 |
| | 50 | 20 | -14.0224* | 2.13518 | .000 | -21.6558 | -6.3889 |
| | | 30 | -5.0045 | 2.07037 | .170 | -12.3817 | 2.3726 |
| | | 40 | -2.4606 | 1.69100 | .693 | -8.4304 | 3.5091 |
| | | 60 | 2.2113 | 1.31275 | .548 | -2.4542 | 6.8768 |
| | | 70 | 3.5936 | 1.34894 | .099 | -1.1850 | 8.3722 |
| | 60 | 20 | -16.2336* | 1.97332 | .000 | -23.3984 | -9.0689 |
| | | 30 | -7.2158* | 1.90300 | .006 | -14.0978 | -.3338 |
| | | 40 | -4.6719 | 1.48138 | .031 | -9.9583 | .6146 |
| | | 50 | -2.2113 | 1.31275 | .548 | -6.8768 | 2.4542 |
| | | 70 | 1.3823 | 1.07453 | .791 | -2.3991 | 5.1638 |
| | 70 | 20 | -17.6159* | 1.99757 | .000 | -24.8458 | -10.3861 |
| | | 30 | -8.5981* | 1.92814 | .001 | -15.5491 | -1.6471 |
| | | 40 | -6.0542* | 1.51354 | .003 | -11.4373 | -.6710 |
| | | 50 | -3.5936 | 1.34894 | .099 | -8.3722 | 1.1850 |
| | | 60 | -1.3823 | 1.07453 | .791 | -5.1638 | 2.3991 |
| AnkleDFR | 20 | 30 | .71 | 1.205 | .992 | -3.57 | 4.98 |
| | | 40 | -1.95 | 1.025 | .413 | -5.56 | 1.67 |
| | | 50 | .03 | 1.206 | 1.000 | -4.25 | 4.31 |
| | | 60 | 1.24 | 1.375 | .944 | -3.66 | 6.14 |
| | | 70 | 5.16* | 1.046 | .000 | 1.48 | 8.85 |
| | 30 | 20 | -.71 | 1.205 | .992 | -4.98 | 3.57 |
| | | 40 | -2.65 | 1.238 | .282 | -7.03 | 1.73 |
| | | 50 | -.68 | 1.392 | .996 | -5.59 | 4.24 |
| | | 60 | .54 | 1.541 | .999 | -4.91 | 5.98 |
| | | 70 | 4.46* | 1.256 | .010 | .02 | 8.89 |
| | 40 | 20 | 1.95 | 1.025 | .413 | -1.67 | 5.56 |
| | | 30 | 2.65 | 1.238 | .282 | -1.73 | 7.03 |
| | | 50 | 1.97 | 1.239 | .607 | -2.41 | 6.36 |
| | | 60 | 3.19 | 1.404 | .225 | -1.80 | 8.18 |
| | | 70 | 7.11* | 1.084 | .000 | 3.29 | 10.92 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 50 | 20 | -.03 | 1.206 | 1.000 | -4.31 | 4.25 |
| | | 30 | .68 | 1.392 | .996 | -4.24 | 5.59 |
| | | 40 | -1.97 | 1.239 | .607 | -6.36 | 2.41 |
| | | 60 | 1.21 | 1.542 | .969 | -4.23 | 6.66 |
| | | 70 | 5.13* | 1.257 | .002 | .69 | 9.57 |
| | 60 | 20 | -1.24 | 1.375 | .944 | -6.14 | 3.66 |
| | | 30 | -.54 | 1.541 | .999 | -5.98 | 4.91 |
| | | 40 | -3.19 | 1.404 | .225 | -8.18 | 1.80 |
| | | 50 | -1.21 | 1.542 | .969 | -6.66 | 4.23 |
| | | 70 | 3.92 | 1.420 | .080 | -1.12 | 8.96 |
| | 70 | 20 | -5.16* | 1.046 | .000 | -8.85 | -1.48 |
| | | 30 | -4.46* | 1.256 | .010 | -8.89 | -.02 |
| | | 40 | -7.11* | 1.084 | .000 | -10.92 | -3.29 |
| | | 50 | -5.13* | 1.257 | .002 | -9.57 | -.69 |
| | | 60 | -3.92 | 1.420 | .080 | -8.96 | 1.12 |
| AnkleDFL | 20 | 30 | 1.35 | 1.571 | .954 | -4.30 | 7.01 |
| | | 40 | -2.88 | 1.063 | .089 | -6.64 | .88 |
| | | 50 | -1.32 | 1.215 | .883 | -5.65 | 3.00 |
| | | 60 | .06 | 1.080 | 1.000 | -3.76 | 3.88 |
| | | 70 | 4.14 | 1.294 | .027 | -.45 | 8.73 |
| | 30 | 20 | -1.35 | 1.571 | .954 | -7.01 | 4.30 |
| | | 40 | -4.23 | 1.643 | .123 | -10.10 | 1.64 |
| | | 50 | -2.68 | 1.745 | .644 | -8.87 | 3.51 |
| | | 60 | -1.29 | 1.654 | .969 | -7.19 | 4.61 |
| | | 70 | 2.79 | 1.800 | .636 | -3.58 | 9.15 |
| | 40 | 20 | 2.88 | 1.063 | .089 | -.88 | 6.64 |
| | | 30 | 4.23 | 1.643 | .123 | -1.64 | 10.10 |
| | | 50 | 1.55 | 1.306 | .840 | -3.06 | 6.17 |
| | | 60 | 2.94 | 1.181 | .144 | -1.23 | 7.10 |
| | | 70 | 7.02* | 1.380 | .000 | 2.15 | 11.89 |
| | 50 | 20 | 1.32 | 1.215 | .883 | -3.00 | 5.65 |
| | | 30 | 2.68 | 1.745 | .644 | -3.51 | 8.87 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 40 | -1.55 | 1.306 | .840 | -6.17 | 3.06 |
| | | 60 | 1.38 | 1.319 | .899 | -3.28 | 6.04 |
| | | 70 | 5.46* | 1.499 | .007 | .18 | 10.74 |
| | 60 | 20 | -.06 | 1.080 | 1.000 | -3.88 | 3.76 |
| | | 30 | 1.29 | 1.654 | .969 | -4.61 | 7.19 |
| | | 40 | -2.94 | 1.181 | .144 | -7.10 | 1.23 |
| | | 50 | -1.38 | 1.319 | .899 | -6.04 | 3.28 |
| | | 70 | 4.08 | 1.392 | .052 | -.83 | 8.99 |
| | 70 | 20 | -4.14 | 1.294 | .027 | -8.73 | .45 |
| | | 30 | -2.79 | 1.800 | .636 | -9.15 | 3.58 |
| | | 40 | -7.02* | 1.380 | .000 | -11.89 | -2.15 |
| | | 50 | -5.46* | 1.499 | .007 | -10.74 | -.18 |
| | | 60 | -4.08 | 1.392 | .052 | -8.99 | .83 |
| TUG | 20 | 30 | -.3400 | .19915 | .533 | -1.0442 | .3641 |
| | | 40 | -.5175 | .21233 | .160 | -1.2669 | .2319 |
| | | 50 | -.6800 | .24369 | .074 | -1.5431 | .1830 |
| | | 60 | -1.1072* | .26754 | .002 | -2.0569 | -.1576 |
| | | 70 | -2.0965* | .36103 | .000 | -3.3901 | -.8030 |
| | 30 | 20 | .3400 | .19915 | .533 | -.3641 | 1.0442 |
| | | 40 | -.1775 | .20022 | .948 | -.8841 | .5290 |
| | | 50 | -.3400 | .23322 | .692 | -1.1684 | .4884 |
| | | 60 | -.7672 | .25803 | .049 | -1.6866 | .1522 |
| | | 70 | -1.7565* | .35405 | .000 | -3.0300 | -.4831 |
| | 40 | 20 | .5175 | .21233 | .160 | -.2319 | 1.2669 |
| | | 30 | .1775 | .20022 | .948 | -.5290 | .8841 |
| | | 50 | -.1625 | .24457 | .985 | -1.0277 | .7027 |
| | | 60 | -.5897 | .26834 | .256 | -1.5413 | .3619 |
| | | 70 | -1.5790* | .36162 | .001 | -2.8740 | -.2840 |
| | 50 | 20 | .6800 | .24369 | .074 | -.1830 | 1.5431 |
| | | 30 | .3400 | .23322 | .692 | -.4884 | 1.1684 |
| | | 40 | .1625 | .24457 | .985 | -.7027 | 1.0277 |
| | | 60 | -.4272 | .29378 | .694 | -1.4640 | .6096 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 70 | -1.4165* | .38089 | .006 | -2.7699 | -.0631 |
| | 60 | 20 | 1.1072* | .26754 | .002 | .1576 | 2.0569 |
| | | 30 | .7672 | .25803 | .049 | -.1522 | 1.6866 |
| | | 40 | .5897 | .26834 | .256 | -.3619 | 1.5413 |
| | | 50 | .4272 | .29378 | .694 | -.6096 | 1.4640 |
| | | 70 | -.9893 | .39657 | .143 | -2.3922 | .4136 |
| | 70 | 20 | 2.0965* | .36103 | .000 | .8030 | 3.3901 |
| | | 30 | 1.7565* | .35405 | .000 | .4831 | 3.0300 |
| | | 40 | 1.5790* | .36162 | .001 | .2840 | 2.8740 |
| | | 50 | 1.4165* | .38089 | .006 | .0631 | 2.7699 |
| | | 60 | .9893 | .39657 | .143 | -.4136 | 2.3922 |
| FTSS | 20 | 30 | -.6075 | .31754 | .405 | -1.7312 | .5161 |
| | | 40 | -.5230 | .32147 | .584 | -1.6594 | .6133 |
| | | 50 | -.7901 | .38593 | .329 | -2.1557 | .5755 |
| | | 60 | -1.5752* | .37584 | .001 | -2.9028 | -.2476 |
| | | 70 | -1.8707 | .61706 | .044 | -4.0857 | .3443 |
| | 30 | 20 | .6075 | .31754 | .405 | -.5161 | 1.7312 |
| | | 40 | .0845 | .29323 | 1.000 | -.9496 | 1.1186 |
| | | 50 | -.1826 | .36274 | .996 | -1.4712 | 1.1060 |
| | | 60 | -.9677 | .35199 | .082 | -2.2147 | .2794 |
| | | 70 | -1.2632 | .60283 | .310 | -3.4380 | .9117 |
| | 40 | 20 | .5230 | .32147 | .584 | -.6133 | 1.6594 |
| | | 30 | -.0845 | .29323 | 1.000 | -1.1186 | .9496 |
| | | 50 | -.2671 | .36618 | .977 | -1.5663 | 1.0322 |
| | | 60 | -1.0522 | .35554 | .049 | -2.3104 | .2060 |
| | | 70 | -1.3477 | .60491 | .247 | -3.5282 | .8328 |
| | 50 | 20 | .7901 | .38593 | .329 | -.5755 | 2.1557 |
| | | 30 | .1826 | .36274 | .996 | -1.1060 | 1.4712 |
| | | 40 | .2671 | .36618 | .977 | -1.0322 | 1.5663 |
| | | 60 | -.7851 | .41473 | .416 | -2.2480 | .6778 |
| | | 70 | -1.0806 | .64149 | .548 | -3.3675 | 1.2063 |
| | 60 | 20 | 1.5752* | .37584 | .001 | .2476 | 2.9028 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 30 | .9677 | .35199 | .082 | -.2794 | 2.2147 |
| | | 40 | 1.0522 | .35554 | .049 | -.2060 | 2.3104 |
| | | 50 | .7851 | .41473 | .416 | -.6778 | 2.2480 |
| | | 70 | -.2955 | .63547 | .997 | -2.5640 | 1.9730 |
| | 70 | 20 | 1.8707 | .61706 | .044 | -.3443 | 4.0857 |
| | | 30 | 1.2632 | .60283 | .310 | -.9117 | 3.4380 |
| | | 40 | 1.3477 | .60491 | .247 | -.8328 | 3.5282 |
| | | 50 | 1.0806 | .64149 | .548 | -1.2063 | 3.3675 |
| | | 60 | .2955 | .63547 | .997 | -1.9730 | 2.5640 |
| HeelRisesR | 20 | 30 | .00 | .000 | . | .00 | .00 |
| | | 40 | .03 | .031 | .914 | -.08 | .15 |
| | | 50 | .00 | .000 | . | .00 | .00 |
| | | 60 | 1.56 | 1.087 | .705 | -2.45 | 5.58 |
| | | 70 | 3.08 | 1.148 | .106 | -1.14 | 7.30 |
| | 30 | 20 | .00 | .000 | . | .00 | .00 |
| | | 40 | .03 | .031 | .914 | -.08 | .15 |
| | | 50 | .00 | .000 | . | .00 | .00 |
| | | 60 | 1.56 | 1.087 | .705 | -2.45 | 5.58 |
| | | 70 | 3.08 | 1.148 | .106 | -1.14 | 7.30 |
| | 40 | 20 | -.03 | .031 | .914 | -.15 | .08 |
| | | 30 | -.03 | .031 | .914 | -.15 | .08 |
| | | 50 | -.03 | .031 | .914 | -.15 | .08 |
| | | 60 | 1.53 | 1.087 | .722 | -2.49 | 5.55 |
| | | 70 | 3.05 | 1.148 | .112 | -1.17 | 7.27 |
| | 50 | 20 | .00 | .000 | . | .00 | .00 |
| | | 30 | .00 | .000 | . | .00 | .00 |
| | | 40 | .03 | .031 | .914 | -.08 | .15 |
| | | 60 | 1.56 | 1.087 | .705 | -2.45 | 5.58 |
| | | 70 | 3.08 | 1.148 | .106 | -1.14 | 7.30 |
| | 60 | 20 | -1.56 | 1.087 | .705 | -5.58 | 2.45 |
| | | 30 | -1.56 | 1.087 | .705 | -5.58 | 2.45 |
| | | 40 | -1.53 | 1.087 | .722 | -5.55 | 2.49 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 50 | -1.56 | 1.087 | .705 | -5.58 | 2.45 |
| | | 70 | 1.52 | 1.581 | .929 | -4.05 | 7.08 |
| | 70 | 20 | -3.08 | 1.148 | .106 | -7.30 | 1.14 |
| | | 30 | -3.08 | 1.148 | .106 | -7.30 | 1.14 |
| | | 40 | -3.05 | 1.148 | .112 | -7.27 | 1.17 |
| | | 50 | -3.08 | 1.148 | .106 | -7.30 | 1.14 |
| | | 60 | -1.52 | 1.581 | .929 | -7.08 | 4.05 |
| HeelRisesL | 20 | 30 | .00 | .000 | . | .00 | .00 |
| | | 40 | .12 | .125 | .914 | -.34 | .59 |
| | | 50 | .26 | .258 | .914 | -.70 | 1.21 |
| | | 60 | 1.22 | .766 | .610 | -1.61 | 4.05 |
| | | 70 | 3.50 | 1.240 | .079 | -1.05 | 8.05 |
| | 30 | 20 | .00 | .000 | . | .00 | .00 |
| | | 40 | .12 | .125 | .914 | -.34 | .59 |
| | | 50 | .26 | .258 | .914 | -.70 | 1.21 |
| | | 60 | 1.22 | .766 | .610 | -1.61 | 4.05 |
| | | 70 | 3.50 | 1.240 | .079 | -1.05 | 8.05 |
| | 40 | 20 | -.12 | .125 | .914 | -.59 | .34 |
| | | 30 | -.12 | .125 | .914 | -.59 | .34 |
| | | 50 | .13 | .287 | .997 | -.90 | 1.16 |
| | | 60 | 1.09 | .776 | .721 | -1.76 | 3.95 |
| | | 70 | 3.38 | 1.246 | .100 | -1.19 | 7.94 |
| | 50 | 20 | -.26 | .258 | .914 | -1.21 | .70 |
| | | 30 | -.26 | .258 | .914 | -1.21 | .70 |
| | | 40 | -.13 | .287 | .997 | -1.16 | .90 |
| | | 60 | .96 | .808 | .839 | -1.97 | 3.89 |
| | | 70 | 3.24 | 1.266 | .134 | -1.38 | 7.86 |
| | 60 | 20 | -1.22 | .766 | .610 | -4.05 | 1.61 |
| | | 30 | -1.22 | .766 | .610 | -4.05 | 1.61 |
| | | 40 | -1.09 | .776 | .721 | -3.95 | 1.76 |
| | | 50 | -.96 | .808 | .839 | -3.89 | 1.97 |
| | | 70 | 2.28 | 1.457 | .624 | -2.89 | 7.45 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 70 | 20 | -3.50 | 1.240 | .079 | -8.05 | 1.05 |
| | 30 | -3.50 | 1.240 | .079 | -8.05 | 1.05 |
| | 40 | -3.38 | 1.246 | .100 | -7.94 | 1.19 |
| | 50 | -3.24 | 1.266 | .134 | -7.86 | 1.38 |
| | 60 | -2.28 | 1.457 | .624 | -7.45 | 2.89 |

Based on observed means.

The error term is Mean Square(Error) = 12.953.

*. The mean difference is significant at the .01 level.

# Appendix K

Regression: Descriptives

Appendix K

**Regression Analysis: Descriptives**

| | group | | | Statistic | Std. Error |
|---|---|---|---|---|---|
| MFRS | 20 | Mean | | 14.03 | .269 |
| | | 99% Confidence Interval for Mean | Lower Bound | 13.29 | |
| | | | Upper Bound | 14.77 | |
| | | Std. Deviation | | 1.474 | |
| | | Skewness | | -.269 | .427 |
| | | Kurtosis | | -.911 | .833 |
| | 30 | Mean | | 13.61 | .257 |
| | | 99% Confidence Interval for Mean | Lower Bound | 12.91 | |
| | | | Upper Bound | 14.32 | |
| | | Std. Deviation | | 1.430 | |
| | | Skewness | | .086 | .421 |
| | | Kurtosis | | -1.134 | .821 |
| | 40 | Mean | | 13.53 | .196 |
| | | 99% Confidence Interval for Mean | Lower Bound | 12.99 | |
| | | | Upper Bound | 14.07 | |
| | | Std. Deviation | | 1.107 | |
| | | Skewness | | -1.226 | .414 |
| | | Kurtosis | | 1.980 | .809 |
| | 50 | Mean | | 13.29 | .283 |
| | | 99% Confidence Interval for Mean | Lower Bound | 12.51 | |
| | | | Upper Bound | 14.07 | |
| | | Std. Deviation | | 1.575 | |
| | | Skewness | | -1.283 | .421 |
| | | Kurtosis | | 2.943 | .821 |
| | 60 | Mean | | 11.75 | .327 |
| | | 99% Confidence Interval for Mean | Lower Bound | 10.85 | |
| | | | Upper Bound | 12.65 | |

| | | | | | |
|---|---|---|---|---|---|
| | | Std. Deviation | | 1.849 | |
| | | Skewness | | -.784 | .414 |
| | | Kurtosis | | .129 | .809 |
| | 70 | Mean | | 10.09 | .575 |
| | | 99% Confidence Interval for Mean | Lower Bound | 8.52 | |
| | | | Upper Bound | 11.66 | |
| | | Std. Deviation | | 3.352 | |
| | | Skewness | | -.692 | .403 |
| | | Kurtosis | | 1.249 | .788 |

# Appendix L

Raw Data

Appendix L

## Raw Data

| group | age | sex | HSQ | PhyAct | MFRS |
|---|---|---|---|---|---|
| 20 | 20 | 1 | 1 | 1 | 16 |
| 20 | 24 | 1 | 1 | 1 | 16 |
| 20 | 23 | 1 | 1 | 1 | 15 |
| 20 | 23 | 1 | 1 | 1 | 14 |
| 20 | 22 | 1 | 1 | 1 | 13 |
| 20 | 25 | 1 | 1 | 0 | 16 |
| 20 | 21 | 1 | 1 | 1 | 15 |
| 20 | 23 | 1 | 1 | 1 | 15 |
| 20 | 29 | 1 | 1 | 1 | 15 |
| 20 | 23 | 1 | 1 | 1 | 13 |
| 20 | 21 | 1 | 1 | 1 | 14 |
| 20 | 20 | 1 | 1 | 1 | 15 |
| 20 | 23 | 1 | 1 | 0 | 14 |
| 20 | 27 | 1 | 1 | 0 | 15 |
| 20 | 22 | 1 | 1 | 1 | 16 |
| 20 | 29 | 0 | 1 | 1 | 13 |
| 20 | 21 | 0 | 1 | 0 | 14 |
| 20 | 29 | 0 | 1 | 1 | 12 |
| 20 | 25 | 0 | 1 | 1 | 12 |
| 20 | 27 | 0 | 1 | 1 | 14 |
| 20 | 21 | 0 | 1 | 1 | 14 |
| 20 | 26 | 0 | 2 | 0 | 11 |
| 20 | 20 | 0 | 1 | 1 | 14 |
| 20 | 21 | 0 | 1 | 1 | 13 |
| 20 | 22 | 0 | 1 | 1 | 12 |
| 20 | 22 | 0 | 1 | 1 | 16 |
| 20 | 21 | 0 | 1 | 1 | 12 |
| 20 | 22 | 0 | 1 | 1 | 14 |
| 20 | 23 | 0 | 1 | 1 | 16 |
| 20 | 20 | 0 | 1 | 1 | 12 |
| 30 | 39 | 1 | 1 | 1 | 12 |
| 30 | 33 | 1 | 1 | 1 | 12 |
| 30 | 34 | 1 | 1 | 1 | 14 |
| 30 | 37 | 1 | 1 | 1 | 16 |
| 30 | 38 | 1 | 1 | 1 | 14 |
| 30 | 36 | 1 | 1 | 1 | 16 |
| 30 | 38 | 1 | 1 | 0 | 15 |
| 30 | 37 | 1 | 1 | 0 | 13 |
| 30 | 36 | 1 | 1 | 1 | 15 |
| 30 | 34 | 1 | 1 | 1 | 12 |
| 30 | 30 | 1 | 1 | 1 | 14 |
| 30 | 38 | 1 | 1 | 1 | 13 |
| 30 | 32 | 1 | 1 | 1 | 15 |
| 30 | 30 | 1 | 1 | 1 | 12 |
| 30 | 35 | 1 | 1 | 1 | 15 |
| 30 | 35 | 0 | 2 | 1 | 11 |

| | | | | | |
|---|---|---|---|---|---|
| 30 | 30 | 0 | 1 | 1 | 14 |
| 30 | 37 | 0 | 1 | 1 | 16 |
| 30 | 39 | 0 | 1 | 1 | 12 |
| 30 | 39 | 0 | 1 | 1 | 15 |
| 30 | 37 | 0 | 1 | 0 | 14 |
| 30 | 35 | 0 | 1 | 1 | 12 |
| 30 | 30 | 0 | 1 | 1 | 15 |
| 30 | 34 | 0 | 1 | 1 | 12 |
| 30 | 31 | 0 | 2 | 1 | 13 |
| 30 | 35 | 0 | 1 | 0 | 13 |
| 30 | 37 | 0 | 1 | 1 | 13 |
| 30 | 36 | 0 | 1 | 1 | 14 |
| 30 | 34 | 0 | 1 | 1 | 15 |
| 30 | 39 | 0 | 1 | 1 | 13 |
| 30 | 36 | 0 | 1 | 0 | 12 |
| 40 | 47 | 1 | 1 | 1 | 14 |
| 40 | 45 | 1 | 1 | 1 | 14 |
| 40 | 40 | 1 | 1 | 1 | 14 |
| 40 | 42 | 1 | 1 | 1 | 14 |
| 40 | 40 | 1 | 1 | 1 | 13 |
| 40 | 48 | 1 | 1 | 1 | 12 |
| 40 | 41 | 1 | 1 | 0 | 14 |
| 40 | 45 | 1 | 1 | 1 | 14 |
| 40 | 46 | 1 | 2 | 0 | 14 |
| 40 | 45 | 1 | 1 | 1 | 14 |
| 40 | 46 | 1 | 1 | 1 | 15 |
| 40 | 49 | 1 | 1 | 1 | 13 |
| 40 | 47 | 1 | 1 | 0 | 10 |
| 40 | 41 | 1 | 1 | 1 | 15 |
| 40 | 44 | 1 | 2 | 0 | 12 |
| 40 | 40 | 1 | 1 | 1 | 14 |
| 40 | 45 | 0 | 1 | 1 | 15 |
| 40 | 43 | 0 | 1 | 1 | 14 |
| 40 | 46 | 0 | 1 | 1 | 14 |
| 40 | 40 | 0 | 1 | 0 | 13 |
| 40 | 49 | 0 | 1 | 1 | 14 |
| 40 | 44 | 0 | 2 | 0 | 13 |
| 40 | 47 | 0 | 1 | 1 | 12 |
| 40 | 42 | 0 | 1 | 1 | 12 |
| 40 | 43 | 0 | 2 | 0 | 12 |
| 40 | 47 | 0 | 2 | 1 | 14 |
| 40 | 44 | 0 | 1 | 1 | 15 |
| 40 | 48 | 0 | 1 | 1 | 14 |
| 40 | 43 | 0 | 1 | 1 | 13 |
| 40 | 46 | 0 | 1 | 1 | 14 |
| 40 | 49 | 0 | 1 | 1 | 14 |
| 40 | 44 | 0 | 1 | 1 | 14 |
| 50 | 52 | 1 | 1 | 1 | 13 |
| 50 | 57 | 1 | 1 | 1 | 11 |
| 50 | 51 | 1 | 1 | 0 | 14 |

| | | | | | |
|---|---|---|---|---|---|
| 50 | 57 | 1 | 1 | 1 | 12 |
| 50 | 52 | 1 | 1 | 1 | 14 |
| 50 | 58 | 1 | 1 | 1 | 15 |
| 50 | 55 | 1 | 1 | 1 | 14 |
| 50 | 58 | 1 | 1 | 1 | 14 |
| 50 | 58 | 1 | 1 | 1 | 15 |
| 50 | 55 | 1 | 1 | 1 | 12 |
| 50 | 50 | 1 | 1 | 0 | 14 |
| 50 | 58 | 1 | 2 | 0 | 13 |
| 50 | 51 | 1 | 2 | 0 | 13 |
| 50 | 58 | 1 | 1 | 0 | 13 |
| 50 | 53 | 1 | 1 | 1 | 15 |
| 50 | 54 | 0 | 1 | 1 | 12 |
| 50 | 58 | 0 | 1 | 1 | 14 |
| 50 | 52 | 0 | 2 | 1 | 14 |
| 50 | 52 | 0 | 1 | 1 | 15 |
| 50 | 57 | 0 | 1 | 1 | 14 |
| 50 | 54 | 0 | 1 | 1 | 12 |
| 50 | 54 | 0 | 2 | 0 | 12 |
| 50 | 58 | 0 | 1 | 1 | 14 |
| 50 | 58 | 0 | 1 | 1 | 14 |
| 50 | 53 | 0 | 1 | 1 | 11 |
| 50 | 54 | 0 | 1 | 1 | 14 |
| 50 | 51 | 0 | 2 | 1 | 8 |
| 50 | 52 | 0 | 1 | 0 | 12 |
| 50 | 59 | 0 | 1 | 1 | 16 |
| 50 | 53 | 0 | 1 | 1 | 14 |
| 50 | 58 | 0 | 1 | 1 | 14 |
| 60 | 54 | 1 | 2 | 1 | 12 |
| 60 | 63 | 1 | 1 | 1 | 12 |
| 60 | 64 | 1 | 1 | 1 | 7 |
| 60 | 61 | 1 | 1 | 1 | 12 |
| 60 | 60 | 1 | 1 | 1 | 13 |
| 60 | 63 | 1 | 1 | 0 | 13 |
| 60 | 65 | 1 | 1 | 0 | 14 |
| 60 | 64 | 1 | 1 | 1 | 14 |
| 60 | 62 | 1 | 2 | 1 | 12 |
| 60 | 68 | 1 | 1 | 0 | 12 |
| 60 | 61 | 1 | 1 | 1 | 10 |
| 60 | 60 | 1 | 1 | 1 | 12 |
| 60 | 66 | 1 | 2 | 1 | 11 |
| 60 | 60 | 1 | 1 | 1 | 12 |
| 60 | 66 | 1 | 2 | 0 | 13 |
| 60 | 67 | 0 | 2 | 0 | 8 |
| 60 | 61 | 0 | 1 | 1 | 12 |
| 60 | 62 | 0 | 1 | 1 | 11 |
| 60 | 63 | 0 | 2 | 1 | 9 |
| 60 | 60 | 0 | 2 | 1 | 10 |
| 60 | 65 | 0 | 2 | 0 | 10 |
| 60 | 66 | 0 | 1 | 1 | 13 |

| | | | | | |
|---|---|---|---|---|---|
| 60 | 64 | 0 | 1 | 1 | 14 |
| 60 | 60 | 0 | 2 | 1 | 14 |
| 60 | 65 | 0 | 1 | 1 | 10 |
| 60 | 65 | 0 | 1 | 1 | 12 |
| 60 | 60 | 0 | 1 | 0 | 13 |
| 60 | 64 | 0 | 2 | 1 | 9 |
| 60 | 63 | 0 | 2 | 1 | 14 |
| 60 | 65 | 0 | 2 | 0 | 11 |
| 60 | 65 | 0 | 1 | 1 | 13 |
| 60 | 67 | 0 | 1 | 1 | 14 |
| 70 | 79 | 1 | 2 | 1 | 8 |
| 70 | 72 | 1 | 2 | 1 | 8 |
| 70 | 72 | 1 | 2 | 1 | 7 |
| 70 | 73 | 1 | 1 | 1 | 12 |
| 70 | 73 | 1 | 1 | 1 | 9 |
| 70 | 70 | 1 | 1 | 1 | 16 |
| 70 | 73 | 1 | 1 | 1 | 10 |
| 70 | 71 | 1 | 1 | 1 | 10 |
| 70 | 71 | 1 | 1 | 1 | 11 |
| 70 | 73 | 1 | 1 | 1 | 14 |
| 70 | 77 | 1 | 1 | 1 | 14 |
| 70 | 77 | 1 | 1 | 1 | 11 |
| 70 | 76 | 1 | 2 | 0 | 12 |
| 70 | 74 | 1 | 1 | 1 | 14 |
| 70 | 78 | 1 | 2 | 1 | 9 |
| 70 | 78 | 0 | 2 | 1 | 9 |
| 70 | 70 | 0 | 2 | 0 | 7 |
| 70 | 74 | 0 | 1 | 1 | 12 |
| 70 | 78 | 0 | 1 | 0 | 9 |
| 70 | 79 | 0 | 2 | 1 | 8 |
| 70 | 70 | 0 | 1 | 1 | 9 |
| 70 | 73 | 0 | 2 | 1 | 5 |
| 70 | 72 | 0 | 1 | 1 | 12 |
| 70 | 73 | 0 | 1 | 0 | 9 |
| 70 | 77 | 0 | 2 | 1 | 11 |
| 70 | 76 | 0 | 2 | 0 | 4 |
| 70 | 70 | 0 | 2 | 1 | 8 |
| 70 | 73 | 0 | 2 | 1 | 0 |
| 70 | 76 | 0 | 1 | 1 | 14 |
| 70 | 79 | 0 | 2 | 0 | 9 |
| 70 | 72 | 0 | 1 | 0 | 15 |
| 70 | 79 | 0 | 2 | 0 | 10 |
| 70 | 71 | 0 | 1 | 1 | 13 |
| 70 | 70 | 0 | 1 | 1 | 14 |

| HabGaitSpeed | MDRTF | MDRTB | MDRTR | MDRTL | DVA |
|---|---|---|---|---|---|
| 4.55 | 14.00 | 10.50 | 11.50 | 11.50 | 0 |
| 3.64 | 16.50 | 14.00 | 13.50 | 14.00 | 0 |
| 4.17 | 20.00 | 14.00 | 18.50 | 18.00 | 0 |
| 6.17 | 16.50 | 12.50 | 13.25 | 14.00 | 0 |
| 5.03 | 12.50 | 12.00 | 11.50 | 11.00 | 0 |
| 6.25 | 18.00 | 16.00 | 13.00 | 11.00 | 0 |
| 4.57 | 15.00 | 13.50 | 16.50 | 13.50 | 0 |
| 6.28 | 15.15 | 10.50 | 12.50 | 10.50 | 0 |
| 5.35 | 15.00 | 12.00 | 12.50 | 12.00 | 0 |
| 5.07 | 15.00 | 9.00 | 8.50 | 9.00 | 0 |
| 5.58 | 18.00 | 9.75 | 15.00 | 14.00 | 0 |
| 6.02 | 14.00 | 11.00 | 22.00 | 23.00 | 0 |
| 5.52 | 19.00 | 16.00 | 12.00 | 10.00 | 0 |
| 5.61 | 16.50 | 8.50 | 11.00 | 11.50 | 0 |
| 4.78 | 17.00 | 9.00 | 12.00 | 11.00 | 0 |
| 4.64 | 12.50 | 11.50 | 7.00 | 8.50 | 0 |
| 4.35 | 14.00 | 10.50 | 7.50 | 9.00 | 0 |
| 5.00 | 13.00 | 8.50 | 10.00 | 7.75 | 0 |
| 4.00 | 16.50 | 14.00 | 12.00 | 11.00 | 0 |
| 4.05 | 15.00 | 8.50 | 10.50 | 9.00 | 1 |
| 6.02 | 14.00 | 12.00 | 12.00 | 12.00 | 1 |
| 4.21 | 13.50 | 8.50 | 9.50 | 11.50 | 0 |
| 6.29 | 13.50 | 11.00 | 11.00 | 7.50 | 0 |
| 5.24 | 15.00 | 14.00 | 9.50 | 10.00 | 1 |
| 5.62 | 14.50 | 15.50 | 14.75 | 8.50 | 0 |
| 4.50 | 15.50 | 8.50 | 12.00 | 10.00 | 1 |
| 4.57 | 12.00 | 11.00 | 11.00 | 9.50 | 0 |
| 4.10 | 14.00 | 7.50 | 8.00 | 7.00 | 0 |
| 3.33 | 17.00 | 13.00 | 10.50 | 8.00 | 0 |
| 3.37 | 18.75 | 9.00 | 10.50 | 10.50 | 0 |
| 4.69 | 14.50 | 9.00 | 9.00 | 8.00 | 1 |
| 4.10 | 13.50 | 5.00 | 11.00 | 8.25 | 1 |
| 5.26 | 17.75 | 8.00 | 11.50 | 10.50 | 1 |
| 5.41 | 16.00 | 7.00 | 9.25 | 10.00 | 0 |
| 4.57 | 15.00 | 14.75 | 9.00 | 12.50 | 0 |
| 4.26 | 16.50 | 13.00 | 10.00 | 10.00 | 0 |
| 3.85 | 15.00 | 8.50 | 8.00 | 8.00 | 0 |
| 4.44 | 14.00 | 11.00 | 12.50 | 10.75 | 1 |
| 5.24 | 15.25 | 12.00 | 11.75 | 10.50 | 0 |
| 4.85 | 16.50 | 10.00 | 11.00 | 12.00 | 0 |
| 5.92 | 15.75 | 10.50 | 12.50 | 13.50 | 0 |
| 5.00 | 13.50 | 8.50 | 11.00 | 10.00 | 1 |
| 5.71 | 16.50 | 9.50 | 13.50 | 13.00 | 0 |
| 4.57 | 15.50 | 13.00 | 11.50 | 13.00 | 1 |
| 4.27 | 16.50 | 15.00 | 10.00 | 9.75 | 0 |
| 3.72 | 4.50 | 6.50 | 8.50 | 6.75 | 2 |
| 4.93 | 15.75 | 7.00 | 8.50 | 8.50 | 0 |
| 5.81 | 15.00 | 10.00 | 11.00 | 10.75 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| 5.52 | 12.50 | 8.00 | 8.00 | 7.00 | 0 |
| 4.22 | 13.00 | 11.00 | 12.00 | 9.50 | 0 |
| 4.37 | 12.75 | 11.50 | 9.00 | 10.00 | 0 |
| 4.41 | 15.50 | 6.00 | 9.75 | 9.75 | 0 |
| 3.76 | 14.50 | 10.00 | 9.00 | 9.50 | 0 |
| 3.89 | 13.00 | 6.00 | 5.50 | 6.50 | 1 |
| 5.88 | 16.50 | 5.00 | 7.50 | 8.00 | 0 |
| 4.27 | 12.50 | 10.00 | 9.00 | 9.00 | 0 |
| 4.76 | 13.75 | 10.00 | 9.25 | 9.00 | 0 |
| 5.81 | 14.00 | 8.00 | 10.00 | 12.00 | 0 |
| 4.69 | 13.75 | 9.00 | 9.50 | 11.00 | 0 |
| 4.55 | 16.00 | 10.00 | 9.00 | 8.00 | 0 |
| 2.76 | 16.00 | 8.00 | 8.50 | 7.50 | 1 |
| 4.57 | 16.00 | 11.00 | 12.00 | 11.00 | 0 |
| 4.57 | 16.50 | 19.00 | 16.00 | 14.50 | 1 |
| 3.48 | 15.00 | 8.00 | 14.00 | 14.00 | 0 |
| 4.50 | 15.00 | 12.00 | 10.00 | 10.00 | 0 |
| 5.26 | 14.00 | 8.00 | 10.75 | 13.75 | 1 |
| 4.05 | 11.00 | 8.00 | 6.25 | 9.25 | 0 |
| 4.78 | 18.00 | 11.00 | 13.50 | 13.00 | 0 |
| 3.68 | 14.50 | 14.00 | 8.50 | 9.50 | 0 |
| 4.61 | 14.00 | 12.50 | 8.50 | 9.00 | 0 |
| 4.93 | 12.50 | 8.00 | 9.00 | 10.50 | 0 |
| 6.06 | 15.00 | 12.00 | 10.75 | 11.25 | 0 |
| 4.50 | 14.00 | 11.50 | 10.50 | 10.75 | 0 |
| 4.93 | 11.00 | 9.50 | 12.00 | 13.00 | 3 |
| 5.41 | 18.00 | 11.00 | 12.50 | 12.00 | 0 |
| 4.78 | 15.50 | 7.00 | 6.00 | 8.00 | 1 |
| 4.33 | 15.50 | 12.00 | 8.75 | 8.75 | 0 |
| 3.52 | 17.00 | 12.00 | 10.50 | 9.50 | 1 |
| 4.20 | 17.00 | 16.00 | 8.00 | 11.00 | 1 |
| 4.93 | 17.00 | 16.00 | 8.00 | 11.00 | 0 |
| 3.69 | 13.00 | 10.00 | 9.50 | 9.00 | 0 |
| 4.00 | 13.50 | 11.00 | 11.25 | 7.50 | 1 |
| 3.44 | 11.00 | 11.50 | 8.00 | 10.00 | 0 |
| 4.27 | 15.00 | 9.00 | 12.00 | 11.00 | 0 |
| 4.72 | 16.00 | 9.00 | 10.50 | 9.50 | 0 |
| 5.62 | 14.50 | 11.50 | 8.75 | 8.00 | 0 |
| 5.08 | 13.00 | 7.00 | 10.00 | 13.00 | 0 |
| 6.02 | 14.50 | 13.50 | 7.50 | 7.50 | 1 |
| 5.00 | 11.75 | 10.00 | 9.50 | 7.50 | 1 |
| 4.32 | 13.00 | 10.50 | 10.50 | 6.00 | 0 |
| 3.95 | 13.00 | 10.00 | 9.75 | 9.75 | 1 |
| 4.39 | 16.75 | 13.00 | 8.25 | 8.00 | 0 |
| 3.96 | 14.00 | 9.50 | 13.00 | 10.50 | 0 |
| 4.07 | 11.50 | 8.00 | 11.50 | 8.50 | 2 |
| 3.88 | 16.00 | 10.00 | 12.00 | 12.50 | 0 |
| 4.44 | 18.50 | 12.00 | 9.00 | 9.00 | 0 |
| 3.33 | 12.50 | 12.00 | 12.00 | 7.75 | 0 |
| 5.71 | 16.00 | 12.00 | 15.50 | 14.00 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| 5.24 | 13.50 | 8.00 | 9.00 | 10.25 | 1 |
| 3.77 | 14.00 | 11.00 | 9.00 | 8.50 | 0 |
| 3.64 | 15.00 | 10.00 | 10.00 | 10.00 | 0 |
| 4.50 | 13.00 | 13.00 | 8.50 | 8.00 | 0 |
| 6.80 | 11.50 | 12.00 | 12.00 | 8.50 | 1 |
| 4.20 | 12.50 | 9.00 | 12.00 | 10.50 | 0 |
| 5.35 | 15.00 | 15.00 | 12.00 | 10.50 | 0 |
| 4.78 | 15.00 | 7.50 | 12.50 | 8.75 | 0 |
| 5.06 | 18.50 | 11.00 | 13.00 | 9.00 | 2 |
| 3.64 | 17.75 | 14.00 | 10.50 | 10.00 | 1 |
| 3.88 | 13.00 | 10.00 | 9.00 | 9.50 | 0 |
| 3.80 | 17.00 | 13.00 | 16.00 | 12.00 | 0 |
| 3.68 | 17.00 | 13.00 | 15.00 | 10.50 | 0 |
| 4.00 | 15.50 | 10.00 | 10.50 | 8.50 | 0 |
| 4.44 | 12.75 | 9.50 | 7.75 | 7.00 | 0 |
| 4.79 | 11.00 | 6.50 | 9.75 | 8.50 | 0 |
| 4.44 | 15.00 | 9.00 | 9.50 | 11.50 | 1 |
| 4.27 | 14.50 | 12.00 | 7.50 | 8.75 | 0 |
| 4.15 | 12.00 | 9.00 | 7.25 | 6.50 | 0 |
| 4.39 | 13.50 | 11.00 | 10.00 | 9.00 | 0 |
| 3.59 | 15.25 | 10.00 | 6.50 | 6.50 | 0 |
| 3.76 | 14.25 | 8.25 | 8.50 | 10.25 | 0 |
| 4.31 | 14.50 | 11.00 | 8.50 | 7.50 | 0 |
| 4.20 | 12.50 | 13.50 | 10.50 | 14.00 | 0 |
| 4.76 | 13.00 | 13.50 | 10.50 | 8.50 | 0 |
| 5.71 | 14.75 | 10.50 | 12.50 | 10.50 | 1 |
| 3.37 | 10.75 | 7.75 | 9.50 | 11.50 | 1 |
| 4.26 | 12.50 | 10.00 | 11.25 | 11.00 | 0 |
| 3.23 | 12.00 | 5.00 | 9.50 | 12.00 | 3 |
| 4.44 | 10.00 | 9.00 | 10.00 | 11.00 | 0 |
| 3.94 | 14.00 | 8.00 | 13.50 | 12.50 | 2 |
| 4.27 | 16.50 | 8.00 | 10.00 | 11.50 | 0 |
| 4.76 | 14.00 | 13.00 | 10.00 | 10.00 | 0 |
| 4.10 | 15.00 | 12.00 | 13.00 | 13.00 | 0 |
| 3.60 | 11.50 | 9.00 | 11.00 | 11.00 | 0 |
| 4.30 | 18.00 | 11.00 | 9.50 | 12.50 | 0 |
| 4.85 | 10.50 | 9.50 | 9.00 | 9.00 | 0 |
| 5.24 | 14.00 | 13.00 | 9.00 | 7.78 | 0 |
| 3.56 | 16.00 | 10.00 | 10.00 | 11.50 | 1 |
| 3.80 | 14.00 | 13.00 | 12.00 | 9.50 | 2 |
| 4.20 | 12.00 | 9.00 | 10.00 | 10.00 | 0 |
| 3.21 | 9.50 | 6.00 | 10.00 | 8.50 | 0 |
| 3.95 | 13.25 | 6.50 | 13.50 | 11.50 | 0 |
| 4.00 | 15.25 | 5.50 | 10.25 | 11.25 | 0 |
| 5.35 | 14.00 | 4.75 | 7.50 | 9.50 | 2 |
| 4.00 | 12.50 | 6.00 | 5.50 | 5.00 | 2 |
| 3.60 | 13.50 | 4.00 | 9.50 | 5.00 | 1 |
| 4.05 | 12.50 | 7.00 | 8.00 | 8.00 | 0 |
| 5.24 | 11.75 | 10.00 | 12.00 | 9.50 | 1 |
| 5.62 | 12.00 | 10.00 | 9.50 | 10.50 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| 5.26 | 11.00 | 8.00 | 9.00 | 8.50 | 1 |
| 5.59 | 13.75 | 13.00 | 9.50 | 9.50 | 2 |
| 4.69 | 13.75 | 13.00 | 11.00 | 11.00 | 0 |
| 3.60 | 10.50 | 8.00 | 9.50 | 8.50 | 0 |
| 4.58 | 14.00 | 9.00 | 10.00 | 9.00 | 1 |
| 4.44 | 12.00 | 9.00 | 9.50 | 4.50 | 0 |
| 4.33 | 17.00 | 9.50 | 10.50 | 9.00 | 2 |
| 4.84 | 14.75 | 11.00 | 10.75 | 10.50 | 1 |
| 3.86 | 11.00 | 5.00 | 8.50 | 11.50 | 0 |
| 3.86 | 13.00 | 10.50 | 10.00 | 10.00 | 1 |
| 4.02 | 13.00 | 9.00 | 10.00 | 8.00 | 0 |
| 3.95 | 11.75 | 6.50 | 10.50 | 10.00 | 2 |
| 3.25 | 14.00 | 10.50 | 12.00 | 14.00 | 0 |
| 4.41 | 12.50 | 7.50 | 9.50 | 9.00 | 0 |
| 3.45 | 11.25 | 5.75 | 6.75 | 6.25 | 1 |
| 3.46 | 14.00 | 11.50 | 9.75 | 8.50 | 1 |
| 4.33 | 11.50 | 8.00 | 8.00 | 8.50 | 1 |
| 3.29 | 13.00 | 9.00 | 11.00 | 8.50 | 0 |
| 4.05 | 11.75 | 7.50 | 5.50 | 7.00 | 1 |
| 4.20 | 13.75 | 10.50 | 8.75 | 8.00 | 0 |
| 3.88 | 16.00 | 14.00 | 10.50 | 9.00 | 0 |
| 6.17 | 12.00 | 12.00 | 12.50 | 13.50 | 0 |
| 3.36 | 13.00 | 5.50 | 8.00 | 6.50 | 0 |
| 3.68 | 10.25 | 5.50 | 7.00 | 9.75 | 1 |
| 3.02 | 11.50 | 9.00 | 11.00 | 11.50 | 1 |
| 5.08 | 12.50 | 6.50 | 10.75 | 11.00 | 1 |
| 3.23 | 10.00 | 12.50 | 9.00 | 9.00 | 0 |
| 3.19 | 14.00 | 6.00 | 10.50 | 12.00 | 0 |
| 3.19 | 9.25 | 4.00 | 10.50 | 8.75 | 0 |
| 3.13 | 10.50 | 4.00 | 5.00 | 6.50 | 0 |
| 3.93 | 13.00 | 4.00 | 13.50 | 10.00 | 0 |
| 3.16 | 12.50 | 7.00 | 9.50 | 6.00 | 0 |
| 3.41 | 11.75 | 7.00 | 14.00 | 11.00 | 0 |
| 3.33 | 12.00 | 5.00 | 6.00 | 6.00 | 2 |
| 4.44 | 9.00 | 7.00 | 9.25 | 9.00 | 2 |
| 2.81 | 5.50 | 1.50 | 3.00 | 3.00 | 0 |
| 4.44 | 14.00 | 9.00 | 8.50 | 7.50 | 0 |
| 3.95 | 7.50 | 4.00 | 10.00 | 8.50 | 2 |
| 4.63 | 16.50 | 9.00 | 8.00 | 12.00 | 0 |
| 3.55 | 13.50 | 7.00 | 9.50 | 9.50 | 0 |
| 4.76 | 11.00 | 10.00 | 10.50 | 9.75 | 1 |
| 4.44 | 12.50 | 6.00 | 10.50 | 11.00 | 0 |

# Appendix M

## IRB Consent Form

# CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY

**INVESTIGATOR'S NAME: CARMEN CASANOVA ABBOTT, MA, PT**
**PROJECT # 1119477**
DATE OF PROJECT APPROVAL: OCTOBER 22, 2008

| FOR HS IRB USE ONLY |
|---|
| **APPROVED**<br><br>________________________________________<br>HS IRB Authorized Representative Date<br><br>**EXPIRATION DATE:** ________________________ |

## STUDY TITLE: COMMUNITY MULTIDIMENSIONAL FALL RISK SCREENING

## INTRODUCTION

This consent may contain words that you do not understand. Please ask the investigator or the study staff to explain any words or information that you do not clearly understand.

**This is a research study. Research studies include only people who choose to participate. As a study participant you have the right to know about the procedures that will be used in this research study so that you can make the decision whether or not to participate. The information presented here is simply an effort to make you better informed so that you may give or withhold your consent to participate in this research study.**

Please take your time to make your decision and discuss it with your family and friends.

You are being asked to take part in this study because you are an adult with an age between 20 and 79 years of age.

In order to participate in this study, it will be necessary to give your written consent.

## WHY IS THIS STUDY BEING DONE?

Falls and fall related injuries are important national health concerns. Falls are seen a markers of poor health, declining function and associated with hospitalizations and increased costs to the individual and family. Research in the area of falls has clearly shown that a balance screen and appropriate referrals can greatly reduce the risk of falling as well as subsequent falls.

The purpose of this study is to develop a set of reference values for eight tests of balance and physical performance that can be used in the community as part of a primary fall prevention strategy. Information from this study will help determine if changes related to strength, balance, and mobility occur in the younger and middle-aged adult. The reference values will be able to be used to identify deficits in gait, strength, and power of the legs. The results of this study will hope to emphasize the need for fall prevention earlier in life, when physical changes can be made easily and as a result the adult will be able to age at a healthier and higher functional level.

## HOW MANY PEOPLE WILL TAKE PART IN THE STUDY?

About 180 people will take part in this study at this institution and other community sites.

## WHAT IS INVOLVED IN THE STUDY?

If you take part in this study, you will be asked to participate in a balance and physical performance screen. The following procedure will take place:

1. A health status questionnaire will be completed that asks you about your current fall risk status
2. You will be taken through eight physical performance tests that assess your gait, reach, functional vision, single leg stability, ankle range of motion and sensation, ability to stand up from a chair-walk 10 feet-turn around-sit back down, sit to stand ability, and leg strength by completing single heel rises
3. When the screening is completed you will be given a summary of the findings. Recommendations from a physical therapist will be included if modifiable fall risk factors are found during the screening.

## HOW LONG WILL I BE IN THE STUDY?

We believe you will be in the study for about 30 minutes.

You can stop participating at any time. Your decision to withdraw from the study will not affect you in any way.

## WHAT ARE THE RISKS OF THE STUDY?

**Risks of participating in this study are minimal. You may experience muscle fatigue or minimal soreness from performing some of the tests if you have not performed them in a while. Precautions will be taken to minimize risk. You will be given instructions and precautions prior to and during the screening. Trained investigator will be closely monitoring your performance. If there are signs of fatigue, poor body mechanics and discomfort the testing will be stopped.**

For the reasons stated above the investigator will observe you closely while taking you through the screening described and, if you have any worrisome symptoms or symptoms that the investigator or associates have described to you, notify the investigator immediately. Carmen Casanova Abbott's telephone number is 573-882-8699.

## ARE THERE BENEFITS TO TAKING PART IN THE STUDY?

If you agree to take part in this study, there may or may not be direct medical benefit to you. You may expect to benefit from taking part in this research to the extent that you are contributing to medical knowledge. We hope the information learned from this study will benefit other adults in the future.
As a result of the screening today, you will be made aware of your own personal fall risk factors, some that are modifiable and some that may not be modifiable. You will also receive advice from a physical therapist in the area of fall prevention as it applies to your screening results.

## WHAT OTHER OPTIONS ARE THERE?

An alternative is to not participate in this research study.

## WHAT ABOUT CONFIDENTIALITY?

Information produced by this study will be stored in the investigator's file and identified by a code number only. The code key connecting your name to specific information about you will be kept in a separate, secure location. Information contained in your records may not be given to anyone unaffiliated with the study in a form that could identify you without your written consent, except as required by law. Only those individuals directly involved with this research project will have access to these files.

**The results of this study may be published in a medical book or journal or used for teaching purposes. However, your name or other identifying information will not be used in any publication or teaching materials without your specific permission.**

## WHAT ARE THE COSTS?

There are no costs associated with your participation in this study.

## WILL I BE PAID FOR PARTICIPATING IN THE STUDY?

You will receive no payment for taking part in this study.

## WHAT IF I AM INJURED?

**It is not the policy of the University of Missouri to compensate human subjects in the event the research results in injury. The University of Missouri, in fulfilling its public responsibility, has provided medical, professional and general liability insurance coverage for any injury in the event such injury is caused by the negligence of the University of Missouri, its faculty and staff. The University of Missouri also will provide, within the limitations of the laws of the State of Missouri, facilities and medical attention to subjects who suffer injuries while participating in the research projects of the University of Missouri. In the event you have suffered injury as the result of participation in this research program, you are to contact the Risk Management Officer, telephone number (573) 882-1181, at the Health Sciences Center, who can review the matter and provide further information. This statement is not to be construed as an admission of liability.**

## WHAT ARE MY RIGHTS AS A PARTICIPANT?

**Participation in this study is voluntary. You do not have to participate in this study. Your present or future care will not be affected should you choose not to participate.** If you decide to participate, you can change your mind and drop out of the study at any time without affecting your present or future association with the university. Leaving the study will not result in any penalty or loss of benefits to which you are entitled. In addition, the investigator of this study may decide to end your participation in this study at any time after she has explained the reasons for doing so and has helped arrange for your continued care by your own doctor, if needed.

## WHOM DO I CALL IF I HAVE QUESTIONS OR PROBLEMS?

If you have any questions regarding your rights as a participant in this research and/or concerns about the study, or if you feel under any pressure to enroll or to continue to participate in this study, you may contact the University of Missouri Health Sciences Institutional Review Board (which is a group of people who review the research studies to protect participants' rights) at (573) 882-3181.

You may ask more questions about the study at any time. For questions about the study or a research-related injury, contact Carmen Casanova Abbott at 573-882-8699.

A copy of this consent form will be given to you to keep.

## SIGNATURE

I confirm that the purpose of the research, the study procedures, the possible risks and discomforts as well as potential benefits that I may experience have been explained to me. Alternatives to my participation in the study also have been discussed. I have read this consent form and my questions have been answered. My signature below indicates my willingness to participate in this study.

______________________________________________ ______________

Subject/Patient* Date

______________________________________________ ______________

Legal Guardian/Advocate/Witness (if required)** Date

______________________________________________ ______________

Additional Signature (if required) (identify relationship to subject)*** Date

*A minor's signature on this line indicates his/her assent to participate in this study. A minor's signature is not required if he/she is under 7 years old. Use the "Legal Guardian/Advocate/Witness" line for the parent's signature, and you may use the "Additional Signature" line for the second parent's signature, if required.

**The presence and signature of an impartial witness is required during the entire informed consent discussion if the patient or patient's legally authorized representative is unable to read.

***The "Additional Signature" line may be used for the second parent's signature, if required. This line may also be used for any other signature which is required as per federal, state, local, sponsor and/or any other entity requirements.

"If required" means that the signature line is signed only if it is required as per federal, state, local, sponsor and/or any other entity requirements.

## SIGNATURE OF STUDY REPRESENTATIVE

I have explained the purpose of the research, the study procedures, identifying those that are investigational, the possible risks and discomforts as well as potential benefits and have answered questions regarding the study to the best of my ability.

**Study Representative****  Date**

****Study Representative is a person authorized to obtain consent. Per the policies of the University of Missouri Health Care, for any 'significant risk/treatment' study, the Study Representative must be a physician who is either the Principal or Co-Investigator. If the study is deemed either 'significant risk/non-treatment' or 'minimal risk,' the Study Representative may be a non-physician study investigator.

# Appendix N

## Participant Recruitment Flyer

# Would you like to know how well you can balance?

Balance screenings are available free of charge by appointment. The screenings are a part of a doctoral research project whose aim is to develop a set of reference values for eight balance and physical performance tests throughout the adult life span**.** Currently, we are looking for volunteers in the **male age groups 50-79**.This information will be analyzed to determine aging changes related to fall risk that occur in the younger and middle-aged adult. The screening takes 20 – 30 minutes.

Each participant will receive a summary of their results indicating which fall risk factors were identified and balance activity recommendations if indicated by their results.

To schedule appointments, please call
Jackie Bohm
Department of Physical Therapy
University of Missouri
104 Lewis Hall
882-7103

# Appendix O

HIPPA Authorization Form

*UNIVERSITY OF MISSOURI-COLUMBIA*

**Institutional Review Board**

# *HIPAA AUTHORIZATION FORM*

**Authorization for the Use and Disclosure of Personal Health Information Resulting from Participation in a Research Study**

| **FOR IRB USE ONLY** |
|---|
| **APPROVED**<br><br>______________________________________<br>IRB Authorized Representative Date |

**Principal Investigator's Name: Carmen Casanova Abbott**
**Project # 1119477**
**Project Title: Community Multidimensional Fall Risk Screening**

You have agreed to participate in the study mentioned above. This authorization form gives more detailed information about how your health information will be protected.

**1.** Description of the information
My authorization applies to the information described below. Only this information may be used and/or disclosed in accordance with this authorization: demographic information (e.g., gender, fall history, physical activity level): medical history as it pertains to fall risk -medications, chronic diseases, problems with walking or performing activities of daily living, dizziness, pain, fear of falling, self perception of health status.

**2.** Who may use and/or disclose the information
I authorize the following persons (or class of persons) to make the authorized use and disclosure of my PHI: The principal investigator, Carmen Casanova Abbott, MA, PT and co-investigator, Alex Waigandt, PHD in completion of the dissertation research project.

**3.** Who may receive the information
I authorize the following persons (or class of persons) to receive my personal health information: HS IRB, and the U of MO Dissertation committee, Department of Educational Psychology.

**4.** Purpose of the use or disclosure
My PHI will be used and/or disclosed upon request for the following purposes:
Publications and presentation that will not identify me, study outcomes including safety and efficacy in determining reference values for eight risk factor tests throughout the adult lifespan.

**5.** Expiration date or event
This authorization expires upon:
☐ The following date: ______________________________________________

x☐ End of research study
☐ No expiration date
☐ Other: ______________________________________________

______________________________________________

**6.** Right to revoke authorization
I understand that I have a right to revoke this authorization at any time. My revocation must be in writing in a letter sent to the Principal Investigator at Department of Physical Therapy, University of MO, 117 Lewis Hall, Columbia, MO 65211. I am aware that my revocation is not effective to the extent that the persons I have authorized to use and/or disclose my PHI have already acted in reliance upon this authorization.

**7.** Statement that re-disclosures are no longer protected by the HIPAA Privacy Rule
I understand that my personal health information will only be used as described in this authorization in relation to the research study. I am also aware that if I choose to share the information defined in this authorization to anyone not directly related to this research project, the law would no longer protect this information. In addition, I understand that if my personal health information is disclosed to someone who is not required to comply with privacy protections under the law, then such information may be re-disclosed and would no longer be protected.

**8.** Right to refuse to sign authorization and ability to condition treatment, payment, enrollment or eligibility for benefits for research related treatment
I understand that I have a right not to authorize the use and/or disclosure of my personal health information. In such a case I would choose not to sign this authorization document I understand I will not be able to participate in a research study if I do not do so. I also understand that treatment that is part of the research project will be conditioned upon my authorization for the use and/or disclosure of my personal health information to and for use by the research team.

**9.** Suspension of right to access personal health information
I agree that I will not have a right to access my personal health information obtained or created in the course of the research project until the end of the study.

**10.** If I have not already received a copy of the University of Missouri Healthcare Privacy Notice, I may request one. If I have any questions or concerns about my privacy rights I should contact, the HS Privacy Officer at 573-882-9054 or the Campus Privacy Officer at 573-882-7254.

**11.** Individuals' signature and date
I certify that I have received a copy of the authorization.

______________________________________________ ____________________

Signature of Research Participant Date

______________________________________________ ____________________

Research Participant's Legally Authorized Representative Date

# VITA

Carmen Casanova Abbott received her Bachelor of Science in Physical Therapy from the University of Missouri-Columbia in 1973. She received her Master of Arts in Adaptive Physical Education from the University of Missouri-Columbia in 1980. This dissertation is in partial fulfillment of a Doctorate of Philosophy, Department of Educational, School & Counseling Psychology, with an emphasis area in Health, Education and Promotion.

Carmen is a clinical associate professor at the University of Missouri-Columbia Department of Physical Therapy. She continues to practice as a physical therapist in the area of vestibular disorders. She is active in the Missouri Physical Therapy Association, serving as Practice Chairman, Ethics Committee member, and liaison to the Missouri State Coalition on Fall Prevention. Expertise in neurological and vestibular rehabilitation provides the framework for her teaching and research endeavors. Her research activities are carried out in conjunction with the University of Missouri-Columbia Interdisciplinary Technology for Eldercare Research Group.