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& Reliability

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MODIFICATION OF THE FUNCTIONAL REACH TEST: VALIDITY & RELIABILITY

By

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THESIS

Submitted to the Department of Physical Therapy
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MODIFICATION OF THE FUNCTIONAL REACH TEST: VALIDITY & RELIABILITY

ABSTRACT

The purpose of this study was to investigate the reliability and validity of a modified version of the Functional Reach (FR) to more accurately predict falls in elderly women. This modified version, the Lateral Functional Reach (LFR) incorporates dynamic balance testing in the scapular plane.

Fifty female volunteers were recruited from a Senior Center in Holland, Michigan. Each subject completed the Berg Balance Scale (BBS), the FR, and the LFR tests. Prior to testing, each subject was screened for depression, cognition and gross medical history.

Validity and reliability of the LFR was determined through correlational and test-retest analysis. The correlation coefficient of the LFR with the BBS was $r_s=0.5243$ ($p \leq .05$). The correlation coefficient of the FR with the BBS was $r_s=0.5299$ ($p \leq .05$). The correlation coefficient of the LFR with the FR was $r_p=0.7106$ ($p \leq .05$) and $r_s=0.6826$ ($p \leq .05$). Test-retest reliability for the LFR using the right hand was $r_p=0.4584$ ($p \leq .05$)
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DEFINITION OF TERMS

1. **Medial-lateral plane**: The plane that exists between the saggital and coronal planes.

2. **Base of support**: The comfortable distance between one’s heels upon standing.

3. **Center of Gravity**: A hypothetical point at which all mass would appear to be concentrated and is the point at which the force of gravity would appear to act in humans (Norkin & LeVangie, 1992, pg. 10).

4. **Height**: Length measured in centimeters from one’s heel to the top of his head.

5. **Intrarater Reliability**: The degree to which the rater can obtain the same rating on multiple occasions of measuring the same variable (Portney & Watkins, 1993, pg. 5).

6. **Validity**: The degree to which an instrument measures what it is intended to measure (Portney & Watkins, 1993, pg. 6).

7. **Protective Reactions**: Reactions that protect the body from injury during a fall (Shumway-Cook & Woollacott, 1995, pg. 149).

8. **Interrater Reliability**: The degree to which two or more raters can obtain the same ratings for a given variable (Portney & Watkins, 1993, pg. 5).

9. **Plane of the Scapula**: This lies approximately midway between the frontal and saggital planes.


11. **Informed Consent**: An ethical principle that requires obtaining the consent of the individual to participate in a study based on full prior disclosure of risks and benefits (Portney & Watkins, 1993, pg. 3).

12. **Guttman Scales**: These scales present a set of statements that reflect increasing intensities of the characteristics being measured. These scales are designed so that there is only one unique combination of responses that can achieve a particular score.

13. **Pertubations**: External disturbances to balance.


16. **Criterion related validity**: A type of measurement validity; the degree to which the outcomes of one test correlate with the outcomes on a criterion test; can be assessed as concurrent validity or predictive validity (Portney & Watkins, 1993, pg.681).

17. **Parametric statistics**: Statistical procedure for estimating population parameters and for testing hypothesis based on population parameters, with assumptions about the distribution of variables, and for use with interval or ratio measures (Portney & Watkins, 1993, pg 688).

18. **Non parametric statistics**: A set of statistical procedures that are not based on assumptions about population parameters, or the shape of underlying population distribution; most often used when the data are measured on a nominal or ordinal scale (Portney & Watkins, 1993, pg 687).

19. **Intraclass correlation coefficient** (ICC): A reliability coefficient that is calculated using variance estimates obtained through an analysis of variance; reflects both the degree of correspondence and the agreement among readings (Portney & Watkins, 1993, pg 509).


21. **Median**: A measure of central tendency representing the 50th percentile in a ranked distribution of scores; that is, that the point at which 50% of the scores fall below and 50% fall above (Portney & Watkins, 1993, pg 687).
22. **Mean**: A measure of central tendency, computed by summing the values of several observations and dividing by the number of observations (Portney & Watkins, 1993, pg 686).

23. **One-tailed test**: A statistical test based on a directional alternative hypothesis, in which critical values are obtained for only one tail of distribution (Portney & Watkins, 1993, pg. 688).

24. **Paired Samples**: A parametric test for comparing two means for correlated samples or repeated measures; also called a correlated t-test (Portney & Watkins, 1993, pg. 688).
LIST OF ABBREVIATIONS

1. COG: center of gravity
2. BOS: base of support
3. AP: anterior posterior
4. ML: medial lateral
5. FR: Functional Reach
6. LFR: Lateral Functional Reach
7. BBS: Berg Balance Scale
8. GDS: Geriatric Depression Scale
9. MMS: Mini-Mental State Examination
10. BM: Balance Master
11. ICC: Intraclass Correlation Coefficient
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CHAPTER 1
INTRODUCTION

Background to the Problem

Balance is the complex process that regulates the maintenance of positions, the postural adjustments of voluntary activity, and the response to external disturbances (Berg, 1989). Loss of balance that results in falls is a problem that increases with age. One third of the population over 65 years of age and one half over 80 fall at least once per year (Thorbahn & Newton, 1996). As the large "baby boomer" generation ages, this number is expected to rise.

Physical and psychological consequences are seen among the aged after a fall has occurred. Hip fractures are one physical consequence of falls. Research shows that an estimated 250,000 falls result in hip fractures each year in those persons over 65 years of age (Tibbits, G.M., 1996). Hip fractures have also been found to be the most costly and devastating fractures in older women (Nevitt, Cummings & Study of Osteoporotic Fractures Research Group, 1993). The psychological ramifications of a fall can lead to impaired mobility, loss of function, and an overall decrease in a person's quality of life (Berg, 1989). For these reasons, balance assessment becomes increasingly important in physical therapy practice.

It is important to target those elderly who are at high risk of falling in order to implement preventative strategies (Topper, Maki, & Holliday, 1993). Physical therapists need screening tests for balance that are reliable, valid, easy to implement and interpret, cost effective, and functional in measure.
Balance is measured two ways, statically and dynamically. Both static and dynamic balance are essential for the performance of activities of daily living. However, most falls in the elderly occur when performing dynamic activities such as rising, walking, turning and sitting (Mathias, Nayak & Isaacs, 1986). Since shifting the center of gravity (COG) is a fundamental of dynamic functional tasks, it follows that measures of balance should reflect this ability (Liston & Brouwer, 1996). This idea is supported by research that has shown dynamic balance measurement to be a better predictor of falls than static measurements (Thapa, Gideon, Fought, Kormicki & Ray, 1994). For these reasons an assessment of dynamic balance is most appropriate for this population.

Problem Statement

The majority of dynamic balance measurements are tested in the anterior-posterior (AP) plane. These planes are graphically displayed in Figure 1. Some examples of this are: Functional Reach (FR) (Duncan, Weiner, Chandler, & Studenski, 1990), Timed Get-Up -And Go (Matthias, Nayak, & Isaacs, 1986), and the Self-Paced Walk Test (Bassey, Fentem, MacDonald, & Scriven, 1976).

![Figure 1: Diagram of Planes of Movement](image)

The problem is that there are few tests that examine dynamic balance in the medial-lateral (ML) plane. Magee (1992) states that movement in the plane of the
scapula (scaption) is the position in which most of the functions of daily living are performed. Therefore, since the majority of daily activities are in the ML plane, it is important to examine this aspect of balance. Maki, Holliday, & Fernie (1990) agree that there is a need for including measures of ML stability to increase the success of identifying fallers.

**Purpose**

The purpose of this study was to modify the FR test to incorporate the scapular plane. This modified test is called the Lateral Functional Reach Test (LFR). The FR test is a clinical tool currently being used as a predictor of falls in the elderly. This test is also easy to administer, functionally relevant, and cost effective. The LFR test may be used in conjunction with various other tests of dynamic standing balance. This may be used as a source of predicting which elderly individuals have a high risk of falling. The researchers also initiated an investigation into the validity and reliability of the LFR test.

**Significance of the Problem**

The aged population is consistently growing. Therefore, physical therapists will be working with a larger number of elderly. Research shows that balance decreases with aging, therefore more functional methods of balance assessment are needed (Thorbahn & Newton, 1996).

A large focus of health care today is on cost containment. It becomes important to implement preventative care. If a battery of balance tests can be developed in order to effectively target those elderly at risk for falling, physical therapists can intervene before a fall occurs. This early intervention may decrease the overall cost of treatment by preventing the physical and psychological ramifications of a fall.
CHAPTER 2
REVIEW OF RELATED LITERATURE

Review of Literature

This literature review focuses on balance control, age-related changes in balance, falls resulting from impaired balance, current cognitive tests used to screen for risk of falls, and currently employed measures of balance. We believe these are the important aspects to examine when developing a test for assessing balance in the ML plane.

Balance

Balance, or postural control, has been defined as maintaining the center of gravity (COG) within the base of support (BOS). Balance can be measured both statically and dynamically. Static balance involves maintaining posture against gravity. Dynamic balance involves maintaining stability during movements of the body on a supporting surface. (Guccione, 1993).

There are three body systems responsible for maintaining balance. These are the visual, somatosensory, and vestibular systems. These systems each contribute to balance by providing information about the body's position in relation to the external environment. The visual system provides depth perception and contrast sensitivity. For example, vision helps us to distinguish color changes between the floor and the wall. The somatosensory system provides information through cutaneous receptors. For instance, the cutaneous receptors in the bottom of the foot give information about changes in terrain. The vestibular system more specifically reports the position of the head in space and also reports sudden changes in direction of head motion (Guccione, 1993).
"These inputs are important for the coordination of many motor responses and help to stabilize the eyes and to maintain postural stability during stance and walking" (Shumway-Cook and Woollacott, 1995, pg. 67). The vestibular system is the dominant system for balance. The visual and somatosensory systems are compared with the vestibular system in order to correct conflicting information and maintain balance (Guccione, 1993).

The body employs three methods of maintaining balance: ankle, hip and stepping strategies. The ankle strategy is used for relatively small perturbations or disturbances within the BOS and in instances where the standing surface is longer than the foot. The hip strategy is used with more forceful perturbations within the BOS and in situations where the standing surface is smaller than the foot. For example, this strategy is used when standing sideways on a beam. When the COG is displaced outside the BOS the stepping strategy is used in an attempt to regain balance. When the stepping response is too slow or inadequate to prevent falling, a protective response with the arms is used to keep the body from injury (Shumway-Cook & Woollacott, 1995).

Age-related Changes in Balance

There are many age-related changes seen in the elderly that affect balance. These changes occur in the three systems responsible for maintaining balance: the visual, somatosensory and vestibular systems. In addition, there are age-related changes in the musculoskeletal system. Alterations in balance can also be brought about by disuse or disease.
Changes in the visual system include changes within the eye itself. For example, less light is transmitted to the retina. In addition, there is a loss of contrast sensitivity which can lead to problems with contour and depth perception (Pitts, 1982). Conditions that may cause changes in vision include cataracts and macular degeneration. These conditions cause a decrease in visual acuity (Shumway-Cooke & Woollacot, 1995).

Changes in the somatosensory system have been documented with a decline in number of sensory receptors, afferent nerve fibers, and in peripheral nerves (Guccione, 1993). Although many changes at the cellular level have been noted as well, it is difficult to understand how these changes affect the entire somatosensory system. Assessing changes in the somatosensory system is difficult to do because current research on somatosensation is limited in focus. Many of the studies concentrate only on one variable in a single joint and use small sample sizes.

The vestibular system also undergoes significant change with age. There is a "reduction in function with a 40% loss of the vestibular hair and nerve cells by seventy years of age" (Shumway-Cooke & Woollacot, 1995, p. 176). There are also degenerative changes in the otoliths that can result in positional vertigo and imbalance during walking. Even a partial loss of vestibular function can cause reports of unsteadiness or imbalance. This can be an important factor in the decline of balance in the elderly (Gucionne, 1993).

When changes in the vestibular system are combined with changes in both the visual and somatosensory systems, significant functional balance problems may occur. Recent studies report an increase in sway during quiet stance (Hageman et al, 1995; Maki et al, 1990), suggesting a decrease in static standing balance. Changes in motor strategies
have also been cited. In one study, elderly subjects demonstrated deteriorated balance strategies due to delayed muscle contraction. This delayed muscle contraction often occurs in the reverse sequence than normal. Subjects also showed more extreme and less effective responses to perturbations as well as an increased postural sway when the standing platform was tilted (Maki, Holliday, & Topper, 1996).

Other areas shown to be affected with age are postural adjustments and postural control. Studies suggest that the elderly have difficulty with the speed and efficiency of anticipatory postural adjustments, causing problems with stabilizing the body before movement (Inglin & Woollacott, 1988; Frank, Patla & Brown, 1987). Some activities that require this stabilization are lifting or carrying objects. Changes to the musculoskeletal system can cause these same stability problems.

As we age, muscle strength declines. It has been reported we lose 1% per year of strength after age 30. Flexibility of soft tissue, skin, joint capsules, ligaments, and connective tissue lessens secondary to changes in collagen. Bone integrity diminishes due to mineral loss. Bone density decreases due to reduced levels of activity. Reaction time slows (O'Brien, 1994, pg. 38).

Due to these age-related changes, everyday activities such as lifting and carrying increase the potential for falling among the elderly.

Falls

"Falls in older people are a common source of morbidity and mortality. The risk of falls increases with age beyond the age of sixty, and is greater in men than in women." (Balah, Fife, Zwerling, Socotch, Jacobson, Bell & Beykirch, 1994, pg. 405). Further, because "most falls do not result in injury requiring medical attention, it is likely that
many falls go unreported and that fall rates go grossly unreported." (Nevitt, 1990, pg. 263).

Falls are multi-factorial in nature. For example, intrinsic factors such as poor vision, hearing problems, orthostatic hypotension (dizziness upon rapid change in position), neurological diseases, and orthopedic conditions all contribute to the incidence of falls (Campbell, Reinken, Allan & Martinez, 1981; Duncan, Studenski, Chandler & Prescott, 1992; Horak, 1987). Beyond intrinsic factors, environmental factors have been shown to contribute to the incidence of falls (Tinetti, Speechley, & Ginter, 1988). One study suggests that for a physical therapist working with the elderly, both intrinsic and extrinsic factors must be explored to ensure comprehensive and preventative care (Shumway-Cook et al., 1995).

Falling can result in a cyclical pattern of immobility and increased risk of falling again. After one fall, an elderly person is more likely to limit his/her activities because of a fear of recurrence. This limitation in activity can lead to deconditioning, muscle weakness, and joint stiffness. In turn this decline in physical conditioning can lead to additional falls and immobility (Maki et al., 1996).

It is also important to note the relationship of the direction of falls to incidence of injury. It has been shown that falling to the side increases the risk of hip fracture 59-66% (Cumming & Klineberg, 1994; Nevitt et al., 1993). One study showed that females age fifty and older are more than three times as likely to fall on their hips as are males (O'Neill, Varlow, Silman, Reeve, Reid, Todd & Woolf, 1994). For this reason we have chosen females as our sample population. Research performed by Cumming et al (1994)
illustrated that falling is more likely to occur when turning and reaching. Further evidence states that falling while reaching increased the risk of minor soft tissue injuries (Cumming et al., 1994). Given these findings, a balance test, which encompasses ML plane movement, may provide a more accurate indicator of fall risk than only AP plane measurements.

**Reliability/ Validity of Measurement Procedures**

**Indicators of Cognitive Ability**

Studies report that “between 5 and 20% of the twenty million aged (65 and older) Americans are estimated to be depressed” (Yesavage, Brink, Rose, Lum, Huang, Adey, & Leirer, 1983, pg. 37). Common symptoms of depression in the elderly are apathy, low motivation, low energy, sleep disturbances, and loss of appetite. This depression can reduce a person’s functional capacity. People who are depressed often perceive simple tasks as requiring too much energy (Guccione, 1993). An unmotivated or apathetic individual might not give a full effort if involved in a study. Harada, Chiu, Damron-Rodriguez, Fowler, Siu, & Reuben (1995) and Duncan et al. (1992) used depression as exclusion criteria in their study of balance in the elderly.

A study published by Yesavage et al. in 1983 found the Geriatric Depression Scale (GDS) to be a valid and reliable measure of geriatric depression. “The GDS was found to discriminate between groups of normal, mildly depressed, and severely depressed subjects” (Yesavage et al., 1983, pg. 45). The reliability coefficient for the GDS was found to be 0.94. Validity was demonstrated through positive correlation with existing valid depression scales. The tests used as comparisons were the Self-Rating
Depression Scale and the Hamilton Rating Scale for Depression. The corresponding correlation coefficients obtained were 0.83 and 0.84 respectively. Both of these findings were statistically significant. This research also suggested test-retest reliability of the GDS with a correlation coefficient of 0.85. The alpha coefficient for the GDS was 0.94 demonstrating a high degree of internal consistency (Yesavage et al., 1983). An earlier study by Yesavage et al., 1983, researched the sensitivity and specificity of the GDS. This study showed that there is a 0% chance for a non-depressed person to be classified as depressed.

To ensure that the subjects are participating to the best of their ability, the researchers chose to exclude those individuals suffering from depression as indicated by the GDS. Subjects scoring > 9 on the GDS were excluded from the study.

The Mini-Mental State (MMS) consists of 11 questions with a maximum possible score of 30. This exam only tests the cognitive aspects of mental function. It does not test for mood, abnormal mental experiences or form of thinking. However, it is extremely thorough within the cognitive realm. Validity of the MMS was determined by correlating its scores with scores from the Verbal and Performance sections of the Wechsler Adult Intelligence Scale. The Pearson r was 0.776 for the Verbal section and 0.660 for the Performance section. Reliability was proven on a 24-hour or a 28-day retest by single or multiple examiners. The Pearson coefficient was 0.887 for the same tester and 0.827 for different testers who tested 24 hours apart. This high correlation coefficient indicates high test-retest reliability. When the MMS was given 28 days apart the Pearson
The coefficient was 0.98, again indicating high reliability (Folstein, Folstein, & McHugh, 1975).

The use of the Mini-Mental State (MMS) as an evaluative tool when investigating balance in the elderly has been supported by several studies (Harada et al., 1995; Baloh, Spain, Socotch, Jacobson, & Bell, 1995; Baloh et al., 1994; Duncan et al., 1992). This exam is used to determine if individuals participating in the study have the cognitive ability to follow directions and answer questions accurately. Duncan et al., (1992) defined a MMS score of less than 18 as exclusion criteria for their research. Harada et al., (1995) defined a MMS score of less than 20 as exclusion criteria for their research. This test was included to ensure complete understanding of the testing procedures. Subjects were excluded if a score of < 18 on the MMS was documented.

**Current Measures of Balance**

The following is an examination of current measures of dynamic balance. Some of the most often cited tests currently used in the clinics to screen for risk of falling include the following: Balance Master, Timed Get-Up-and-Go, Self-Paced Walk Test, Tinetti Performance Mobility Index, Berg Balance Scale (BBS), and Functional Reach. Each of these tests will be reviewed briefly.

The Balance Master (BM) is a platform test which gives computer measurements of weight shift. This test has been found to be a predictor of functional balance performance (Liston & Brouwer, 1996). A study performed by Topper et al. (1993) compared platform or force plate measures and activity-based balance tests. The results showed that while the force plate measurement was a more accurate predictor of fall risk,
the time required to administer the test was 30 to 45 minutes on each individual. Comparatively, the administration of the activity-based test required only ten to fifteen minutes. The trend in health care today is toward shorter treatment time and decreased number of visits, making it unrealistic to spend 30 minutes assessing one aspect of a person's disability. Additionally, Mathias et al. (1986) stated that although the Balance Master can generate many tests of balance function, these tests are often too demanding of the geriatric population. Another study found that while the biomechanical measures of the force platform were highly correlated with each other, they did not correlate well with other functional clinical measures of balance (Thapa, Gideon, Fought, Kormicki, & Ray, 1994). These measures included functional reach, mobility maneuvers, timed walk, and chair stands, which were found to be highly intercorrelated. Therefore this suggests that the BM is not the best functional assessment tool. In addition, the Balance Master is an expensive piece of equipment and may not be found in every physical therapy practice.

The Tinetti Mobility Index is another test that evaluates functional capabilities and balance. This test is composed of nine tests of balance and seven tests of gait. Tinetti et al. found that the risk of falling increases linearly with the number of risk factors identified. When compared with other functional tests of balance, the Tinetti Mobility Index examines lower level skills. For example, basic transfers, and early gait activities are included in this exam. Their studies also indicated 85% accuracy for inter-rater reliability (Thorbahn et al., 1996). However, these findings have not been duplicated in other research.
The modified Self-Paced Walk Test is another functional measure. This test involves walking 10 meters at a self-selected pace. Stride length and cadence are measured during testing. It has been found to be reliable and valid, and it has been recommended for use with an elderly population. However, this test focuses primarily on gait rather than balance. (Piotrowski et al. 1994).

The Timed Get-Up-And-Go test is another commonly utilized balance test. It is a timed test that involves the patient standing up from a chair, walking three meters, turning 180°, and returning to a seated position. Independence in balance and mobility is assumed with a time of < 10 seconds (Shumway-Cook & Woollacott, 1995). This test has been found to be easy to administer and it is functional. However, the ease of this test makes it sensitive to only a functionally low-level population (Mathias, 1986).

The BBS, which measures "...functional balance, has three dimensions: maintenance of position, postural adjustment to voluntary movements, and reaction to external disturbances." (Harada et al., 1995, p. 464). It is a series of 14 tasks that are graded on a scale of 0 to 4, with a maximum score of 56. This test shows a high correlation with other tests of balance such as the Tinetti Balance Subscale and the Timed Get-Up-And-Go tests, which supports its validity (Thorbahn et al., 1996). Although the BBS encompasses movements in the ML plane, it has recently been found to be only 53% sensitive to predicting falls (Thorbahn et al., 1996). This decreased sensitivity occurs because those who scored well below the cut-off point for inclusion in the non-faller category fell less as a result of compensatory strategies such as assistive devices. Therefore, the BBS is a valid predictor of falls for those participants who score just below
the 45 point score. Other studies have shown that the BBS, due to its validity, is the measure of choice for the geriatric population (Piotrowski & Cole, 1994). The intra-rater correlation coefficient (ICC) for the BBS was found to be 0.98. Validity, (r), was found to be .81 when compared with global measures of balance (Thorbahn et al., 1996). Based on the proven reliability and validity of the BBS and its measurement of dynamic balance, we have chosen to use it as a tool in our study of balance tests in the elderly.

One of the purest measures of balance currently used is the Functional Reach (FR) test (Weiner, Bongiomi, Studenski, Duncan & Kochersberger, 1993). Duncan et al. (1992) defines functional reach as the maximum distance one can reach forward beyond arm’s length while maintaining a fixed base of support in the standing position. Weiner et al (1992) state that “it combines current dynamic postural control theory with a practical measurement system and demonstrates excellent test characteristics”. Weiner et al. (1992, pg. 206) states that “individuals with a FR of less than six or seven inches are very frail and limited in their daily activities.” Height has been proven to affect the outcome of FR scores. To combat this, studies have normalized the height data by dividing the FR distance by the participant’s height (Hageman et al., 1995; Duncan et al., 1990). The measure was developed in order to add a functional dimension to balance testing, making it more relevant to daily activity (Weiner et al, 1992). In a recent study by Duncan et al.(1992), it has been shown that the FR is reliable and valid for predicting falls. It is sensitive to clinically significant changes in balance in patients participating in a rehabilitation program (Duncan et al, 1992). The FR test has been proven to be easy to
administer, functionally relevant, and cost-effective. For these reasons, we chose to use FR as a template on which to base the Lateral Functional Reach test.

**Functional Movement**

Magee (1992) states that movement in the plane of the scapula (scaption) is the position in which most of the functions of daily living are performed. To accommodate these ML movements, a corresponding shift in the center of gravity (COG) occurs.

Anatomists and kinesiologists have observed that during functional activities of the upper extremity, humans seldom elevate their humerus in pure cardinal planes; instead, they prefer to elevate the humerus within an intermediate plane that lies somewhere between the sagittal and frontal planes. On the basis of empirical observations, anatomists believe that healthy persons and patients elevate their humerus in an intermediate plane between pure flexion and abduction, because the inferior portion of the glenohumeral capsule is not so tightly twisted, thus permitting greater humeral excursion (Youdas, Carey, Garrett, & Suman, 1994, pg. 1137).

This information identifies a need to examine movement in the scapular plane when assessing balance in the elderly.

**Summary and Implications for the Study**

There is a need for a measure of balance in motions which mimics daily movement. This would allow physical therapists to more accurately predict balance deficits and implement proper treatment.

In an attempt to devise such a measure, we have discussed the systems involved in maintaining balance in a healthy person. Further, we show changes that occur in these maintenance systems with normal and pathological aging.
An understanding of the consequences of loss of balance is important to examine as well. It has been shown that falls cause physical as well as psychological damage to a population (65 or older) which is at a higher risk of falling. This review also details current statistics on fall characteristics. A great number of women over 65 who fall do so laterally. In addition, falls to the side in this age group cause a greater incidence of hip fractures. The need for ML plane measurements of balance is shown clearly from these statistics, from the review of studies which show that functional movement occurs in the ML plane, and from the review on current balance screens employed.

To determine the validity of a test, other valid screens must be used as a measure of comparison. The screens chosen were discussed. One must also ensure that the participants understand directions and that they are motivated. Tests that account for this were discussed.

**Hypothesis**

We proposed statistical significance with p ≤ .05 for:

1. Correlation of the LFR with the BBS.

2. Correlation of the LFR with the FR test.

and

3. Inter-rater reliability for the LFR.

4. Excellent test-retest reliability of the LFR (r ≥ 0.75).
CHAPTER 3
METHODOLOGY

Study Design

This study examined the reliability and validity of the LFR test when correlated to the BBS and the FR tests.

Study Site and Subjects

Participants were recruited on a voluntary basis from the Evergreen Commons Senior Center in Holland, Michigan. They were informed of the study during group activities at this location. A sample of convenience was gathered including 50 female subjects at least 65 years of age. The participants were independent community dwellers. Subjects were recruited according to the following exclusion criteria: use of an assistive device, inability to stand unassisted for 60 seconds (Weiner et al., 1992); a score of less than 18 on the Mini-Mental (Duncan et al., 1992); depression as reported by a GDS score of greater than nine (Yesavage et al., 1983), reports of blindness, deafness, amputations, Meniere's disease, upper motor neuron lesions, inability to raise arm to 90 degrees of flexion or abduction, lower extremity total joint replacements, and/or reports of dizziness and imbalance within the past month.

Subjects signed an informed consent form and were informed of their right to withdraw from the test at anytime. Prior to volunteering to participate in the study subjects were instructed in the test procedures. Individual testing took approximately 15-30 minutes.
Equipment and Instruments

In this study, the following instruments were used:

1. A metal tape measure to determine height of the subject.
2. A yard stick to measure LFR and FR.
3. A color poster of FR and LFR for a visual aid.
4. Masking tape to hold up the yardstick on the wall.
5. A flat piece of cardboard to assist in height measurement.
6. A paperclip to more accurately measure the LFR and FR.

Validity/Reliability

The following procedures were used to evaluate each subject in our study: the GDS, the MMS, the BBS, the FR and the LFR.

Geriatric Depression Scale

The reliability coefficient for the GDS was found to be 0.94. Validity was proven through positive correlation with the Self-Rating Depression Scale and the Hamilton Rating Scale for Depression. The corresponding correlation coefficients obtained were 0.83 and 0.84. Both of these findings were statistically significant. This research also proved test-retest reliability of the GDS with a correlation coefficient of 0.85. The alpha coefficient for the GDS was 0.94 demonstrating a high degree of internal consistency (Yesavage et al., 1983).

Mini-Mental State Exam

Validity of the MMS was determined by correlating its scores with scores from the Verbal and Performance sections of the Wechsler Adult Intelligence Scale. The
Pearson $r$ was 0.776 for the Verbal section and 0.660 for the Performance section. Reliability was proven on a twenty-four hour or a twenty-eight day retest by single or multiple examiners. The Pearson coefficient was 0.887 for the same tester and 0.827 for different testers who tested twenty-four hours apart. This high correlation coefficient indicates high test-retest reliability. When the MMS was given twenty-eight days apart the Pearson coefficient was 0.98, again indicating high reliability (Folstein, Folstein, & McHugh, 1975).

**Berg Balance Scale**

This test has been found to correlate highly with other tests of balance such as the Tinetti Balance Subscale and the Timed Get-Up-And-Go tests. This demonstrates its validity. The intra-rater correlation coefficient (ICC) for the BBS was found to be 0.98. Validity, ($r$), was found to be .81 when compared with global measures of balance (Thorbahn et al., 1996). Based on the proven reliability and validity of the BBS and its measurement of dynamic balance, we have chosen to use it as a basis of comparison for the LFR.

**Functional Reach**

Duncan et al (1992) has shown that the FR is reliable and valid in predicting falls. It is sensitive to clinically significant changes in balance in patients participating in a rehabilitation program (Duncan et al, 1992). For these reasons, we chose to use FR as a template on which to base the Lateral Functional Reach test.
**Procedures**

The testing began with a screen which included the following measures: The MMS, the GDS, a subjective medical screen which included exclusion criteria, active range of motion testing to ensure elevation of the arms to 90 degrees, a subjective fall history which spanned the previous year, and height measurement (Duncan et al., 1992). The medical screen, MMS, and GDS was administered verbally by a single tester. Height was measured inches, (to the nearest 1/4 inch), with shoes on. Subjects were asked to place their heels against the wall and stand up straight. A flat piece of cardboard was placed on top of their heads. Measurement was then taken from the floor to the cardboard with a metal tape measure. Fall history was obtained by a subjective reply according to the following definition:

> A person has a fall if they end up on the ground or floor when they didn't expect to. If a person ends up on the ground, either on their knees, their belly, their side, their bottom or their back, they have had a fall (Duncan et al. 1992, pg. M95).

Dizziness was also subjectively reported according to the following definition:

> "Dizziness can accompany feelings of unsteadiness and imbalance, as well as feelings of faintness or a sense of being light-headed" (Shumway-Cook et al., 1995, pg. 176). If participants met the criteria, further testing ensued. Further testing included the BBS (Thorbahn, 1996), the FR (Duncan et al., 1992), and the LFR.

These tests were performed in a random order determined by each subject drawing the sequence of tests out of a hat. These tests were all chosen on the basis that they have been proven reliable and valid indicators of falls (Duncan et al., 1992; Bassey, Fentem, MacDonald, & Scriven, 1976; Cunningham, Rechnitzer, & Donner, 1983;
Ekblom, Day, Hatley, Moore, & Wear, 1979; Himann, Cunningham, Rechnitzner, & Paterson, 1988; Robbins, Rubenstein, Josephson et al. 1989; Tinetti et al., 1988, Tinetti et al., 1986). The BBS and the FR were correlated with the Lateral Functional Reach Test to determine validity. Test-retest reliability and inter-tester reliability of the LFR were also examined.

**Berg Balance Scale:** Participants were verbally guided through the fourteen different items of the Berg Functional Balance Scale. Berg rates these items on a scale from 0 to 4. The scale is defined differently for each of the fourteen items (Appendix C).

**Functional Reach Test:** The acromion of the dominant arm of each participant was aligned with a yardstick mounted on a wall parallel to the ground. Subjects wore street shoes with no more than an one inch heel and stood with their feet apart in a comfortable stance. Subjects were instructed to "make a fist and reach as far forward as you can without taking a step" in the plane parallel to the measuring device. A poster was color coded and enlarged for use as a visual aid during testing (see Appendix A). One tester demonstrated the test while the other tester simultaneously read the instructions. These testers remained in the same roles for every subject. A paperclip was taped to the dorsum of the third metacarpal of each participant. The paperclip was bent to 90° at the distal end in order to more accurately read the measurements. The results were measured in inches (nearest 1/4) as instructed in papers by Duncan and colleagues (Duncan et al., 1990 & Weiner et al., 1992). The starting position was recorded for each subject along with the ending position. Measurements were taken from the third metacarpal prior to and after reaching. Subjects were given two practice trials followed
by three test trials. If the subject took a step that trial was recorded as a zero. The best of
three test trials was used during calculations to reflect the best possible score for each
participant. FR was tested on both the right and left side. Because height has been shown
to influence FR, distances of functional reach were divided by each individual’s height to
normalize the scores for height (Hageman et al, 1995; Duncan et al, 1990).

**Lateral Functional Reach Test**: The acromion of the dominant arm of each
participant was aligned with a yardstick mounted on a surface perpendicular to the floor.
A piece of tape on the ground was angled at forty-five degrees from the wall.
Each subject’s foot that was closest to the wall was aligned along this tape to ensure that
they reached in the scapular plane. Subjects were instructed to "make a fist
and reach as far to the side as you can without taking a step or allowing either foot to
completely leave the ground" in the plane parallel to the measuring device. A poster was
color coded and enlarged for use as a visual aid during testing (see Appendix A). One
tester demonstrated the test while the other tester simultaneously read the instructions.
These testers remained in the same roles for every subject. A paperclip was taped to the
dorsum of the third metacarpal of each participant. The paperclip was bent to 90° at the
distal end in order to more accurately read the measurements. The results were measured
in inches (nearest 1/4) as instructed in papers by Duncan and colleagues (Duncan et al.,
1990 & Weiner et al., 1992). The starting position was recorded for each subject along
with the ending position. Measurements were taken from the third metacarpal prior to
and after reaching. Subjects were given two practice trials followed by three test trials. If
the subject took a step that trial was recorded as a zero. The best of three test trials was
used during calculations to reflect the best possible score for each participant. LFR was tested on both the right and left side. Because height has been shown to influence FR, distances of LFR was divided by each individual's height to normalize the scores for height (Hageman et al, 1995; Duncan et al, 1990).

Inter-tester reliability of the LFR was examined by having two testers simultaneously read the measurements for the first ten subjects. Having one tester administer the LFR for all of the subjects ensured intra-tester reliability. Test-retest reliability was examined by recalling ten random subjects for a second trial of the LFR at least one week following their initial trials. Subjects recruited for retesting were determined by drawing numbers from a hat. If a chosen subject could not participate in retesting, the next highest number was chosen. Validity of the LFR was examined through correlational analysis with the BBS and the FR.
CHAPTER 4
RESULTS/DATA ANALYSIS

Techniques

Statistics were calculated using the SPSS and SAS software systems. The Pearson product-moment coefficient of correlation ($r_p$) was used to determine the criterion-related validity of the LFR as compared to the FR. This test was also used to examine test-retest reliability of the LFR. The Pearson product-moment coefficient of correlation was chosen because the data collected was ratio data. Correlation of this type of data requires the use of a parametric test. The Spearman rank correlation coefficient ($r_s$) was used to determine the criterion-related validity of the LFR as compared to the BBS. This test was chosen because the BBS data is ordinal or ranked. Correlation of this type of data requires a non-parametric test. The intraclass correlation coefficient (ICC) was used to determine the inter-rater reliability of the LFR. The t-test for paired samples was used to determine the difference between the right and left-handed trials of the LFR and FR tests.

Characteristics of Subjects

All subjects who participated in our study were females aged 65 and older who were right hand dominant. Table 1 illustrates our subject characteristics and test scores before normalizing for height. The median score for the BBS was 51. The median was used because it is a better measure of central tendency for non-parametric data.
**Table 1. Mean Values of Subject Characteristics and Test Scores**

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>MEAN (n=50)</th>
<th>STD DEV (n=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>63.68&quot;</td>
<td>2.53&quot;</td>
</tr>
<tr>
<td>Age</td>
<td>74.46</td>
<td>6.1</td>
</tr>
<tr>
<td>LLFR</td>
<td>6.24&quot;</td>
<td>2.63&quot;</td>
</tr>
<tr>
<td>RLFR</td>
<td>5.92&quot;</td>
<td>2.78&quot;</td>
</tr>
<tr>
<td>LFR</td>
<td>6.42&quot;</td>
<td>2.56&quot;</td>
</tr>
<tr>
<td>RFR</td>
<td>10.25&quot;</td>
<td>3.28&quot;</td>
</tr>
</tbody>
</table>

LLFR: Left lateral functional reach  
RLFR: Right lateral functional reach  
LFR: Left functional reach  
RFR: Right functional reach

**Hypothesis**

We proposed statistical significance with $p \leq .05$ for:

1. Correlation of the LFR with the BBS.
2. Correlation of the LFR with the FR test.

and

3. Inter-rater reliability for the LFR.
4. Excellent test-retest reliability of the LFR ($r \geq 0.75$).

All statistical calculations that follow were performed with test score data that has been normalized for height. Upon examination of the data, the inter-rater reliability of the LFR was determined using the ICC to be 0.99 on the right hand and 0.99 on the left hand. The longest reach for each individual for each hand was used for these calculations. These findings strongly support our hypothesis.
Before correlational analysis of the LFR with the BBS and FR was done, a paired t-test was performed. This was done in order to determine if there was a statistically significant, \(p \leq 0.05\), difference between the right and the left hand scores in both the FR and the LFR. Paired t-tests of both revealed that there was not a statistically significant, \(p \leq 0.05\), difference between the right and the left hand scores. Therefore, only the right hand scores were used for correlational analysis. The right hand scores were chosen because this was the dominant hand of each subject.

Data from the BBS, FR, and LFR was correlated using a one-tailed design with either the Spearman or Pearson correlation coefficients. Please see Table 2 for a summary of this statistical data. Correlational analysis of the LFR with the BBS was determined using the Spearman rank correlation coefficient. The \(r_s\) was 0.5243 with a statistically significant \(\alpha\)-value of \(p=0.0001\). See Appendix F; figure 1, for a scatter plot of this data. The Spearman correlation was used because the scores of the BBS were ordinal or ranked data. According to Portney and Watkins (1993), this correlation is determined to have a fair degree of relationship. This meets with the standard set forth in our hypothesis.

Correlational analysis of the FR with the BBS was also determined using the Spearman rank correlation coefficient. This was calculated to be 0.5299 with a statistically significant \(\alpha\)-value of \(p=0.0001\). Again this showed a fair degree of relationship and meets with the standards set in our hypothesis. See Appendix F; figure 2, for a scatter plot of this data.
Correlational analysis of the LFR with the FR was determined using the Pearson product-moment coefficient of correlation. The $r_p$ was 0.7106 with a statistically significant $\alpha$-value of $p=0.0001$. See Appendix F; figure 3, for a scatter plot of this data. This value was reached after removing one outlier as defined by Portney and Watkins (1993, pg. 688). This subject was removed because she was unable to complete the LFR due to shoulder pain from repeated elevation and scored a 0 (this subject was included in both the BBS and FR data because she was able to complete these tests). The correlation between the BBS and LFR was determined to have a moderate to good degree of relationship (Portney and Watkins, 1993). In addition, a Spearman rank correlation was performed with this same data. Since our data was altered to normalize for height it could be argued that the data is defined as rank data. The outlier was also removed before analyzing this data. The results of this correlation were 0.6826 with a statistically significant $\alpha$-value of $p=0.0001$. As expected, this was slightly lower than the Pearson correlation due to the fact that the Spearman rank correlation is a stronger statistical test. Again, this meets with the standards set forth in our hypothesis.

Table 2. Correlational Data for Functional Tests

<table>
<thead>
<tr>
<th>Correlation</th>
<th>$r$ (Pearson)</th>
<th>$r$ (Spearman)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFR vs. BBS</td>
<td></td>
<td>0.5243</td>
<td>0.0001</td>
</tr>
<tr>
<td>FR vs. BBS</td>
<td></td>
<td>0.5299</td>
<td>0.0001</td>
</tr>
<tr>
<td>LFR vs. FR</td>
<td>0.7106</td>
<td>0.6826</td>
<td>0.0001</td>
</tr>
<tr>
<td>Test-Retest</td>
<td>0.4584</td>
<td></td>
<td>0.107</td>
</tr>
</tbody>
</table>

LFR: Lateral functional reach  
BBS: Berg balance scale  
FR: Functional reach  
r: Correlation coefficient  
p: Alpha value
Test-retest reliability for the LFR was determined using the Pearson product-
moment coefficient of correlation to be 0.4584 with the right hand. This was not found to
be statistically significant with an $\alpha$-value of $p=0.107$. This does not meet with the
standard stated in our hypothesis.

Other findings of interest included comparing LFR scores with increasing age in
order to investigate age related changes. The Pearson product-moment coefficient of
correlation, $r_p = -0.2114$, did not show a statistically significant, $p=0.075$, relationship
between increasing age and scores of the LFR. See Appendix F, figure 4, for a scatter
plot of this data.
CHAPTER 5

DISCUSSION AND IMPLICATIONS

Discussion of Findings and Limitations

Although most of the findings were statistically significant, the results of this study do not suggest a strong correlation of the LFR nor the FR when compared with the BBS. One possibility for this could be that the reach tests only examine postural adjustments to voluntary movements. The BBS examines this factor, but also examines maintenance of position and reaction to external disturbances. Because these tests do not completely measure the same aspect of balance, this fair correlation may be understood. Possibly the researchers should not have used the BBS to establish the validity of the LFR. Instead, another test that resembled the LFR more closely should have been used to establish validity.

Correlational analysis of the LFR with the FR was determined to be moderate to good with both the Spearman and Pearson correlation coefficients. This higher correlation may be due to the similarity between the two tests since the LFR is a modified version of the FR. Again, there is statistical evidence that suggests validity of the LFR. These values justify further research into the validity of the LFR.

Investigation into the relationship between age and LFR scores showed no significant correlation. The researchers anticipated that there would be a negative correlation between age and LFR scores, however, our results did not suggest this. These results are inconsistent with previous research of the FR that confirmed younger adults
reach further than older adults (Hagman et al., 1995; Duncan et al., 1990). Excellent inter-rater reliability was calculated for the LFR. The same two testers simultaneously read the LFR for the first ten subjects. Having the same examiner administer and read all of the tests of balance ensured intra-rater reliability.

Test-retest reliability of the LFR was measured by the Pearson correlation coefficient. The results were not found to be statistically significant. This finding was surprising because the FR has been shown to have high test-retest reliability (Hagman et al., 1995; Duncan et al., 1990). One possibility to account for the low test-retest reliability in this study could be that a "warm-up" effect occurred. Various subjects participated in aerobic exercise prior to testing. If a subject participated in an aerobic activity prior to one testing session and not the other, it may have significantly changed the results. This variable was not controlled throughout the study.

There are other factors that may have contributed to the study's less than excellent correlations. Lack of privacy when performing tests and varying noise levels during the testing procedures may have distracted some individuals. This may have contributed to varying performance levels in individuals as they performed each test.

In addition, we did not control for the strategy of reach used by each individual. This is in accordance with research done by Duncan et al., 1992. Participants were allowed to complete the reaching task in any manner as long as their feet did not leave the ground. Some strategies observed included trunk rotation, knee bending and squatting.

Although the results of this study are interesting, they cannot be generalized to the elderly population due to the following reasons: 1) the subjects were all female, 2) the
majority of participants resided in western Michigan, and because 3) exclusion criteria were used. Another limitation is that the medical history used was subjectively reported. This may have lead to falsification of information.

Practical Application

The correlations found in this study show statistical evidence that suggests the validity of the LFR. Unlike the FR, the LFR incorporates reach into the scapular plane. Therefore, this test becomes an even more functional test of balance because most functions of daily activities are performed in this plane (Magee, 1992). Although further research needs to be done on the reliability and validity of the LFR, findings in this study provide justification for further research. The researchers speculate that the LFR may be another valid and reliable predictor of falls that can be used effectively in a comprehensive balance assessment.

Similar to the FR, the LFR is also easy to implement, cost effective, and functionally relevant. The equipment needed to perform this test is most likely already present in the clinic, therefore there are no additional costs. Special training is not required to administer this test so it can easily be implemented as a balance assessment tool. These qualities make the LFR a potentially useful tool in the clinic.

Results did not indicate a significant correlation between age and LFR scores. Therefore, balance deficits may not necessarily linearly increase with age, especially in an active group of elderly persons. Based on the volunteer population of this study, the subject pool consisted of active individuals. This data becomes clinically relevant to the physical therapist that may expect less from the geriatric population based solely on age.
It would be interesting to examine the differences in balance among the active and sedentary elderly.

Suggestions for Further Research

Although there was a statistically significant correlation between the LFR and the FR, validity of the LFR requires further research. The researchers suggest repeating this study using a greater number of subjects and a more similar test of balance other than the BBS for determining criterion related validity of the LFR. Sensitivity and specificity of the LFR should be examined as well.

Moreover, the researchers feel that they have determined a need for testing in the ML plane in order to have a more functional assessment of balance. In addition to the LFR, more tests that incorporate the ML plane need to be developed to address this issue. It is necessary for clinicians to have functional tools for balance assessment in order to get an accurate picture of a patient’s deficits.

In addition, research states clearly that "a battery of tests is necessary to approach a client’s balance abilities, but as of this date no particular battery has been found to be the best overall assessment" (Light, Rose, & Purser, 1996, p. 40). Further research as to the most effective battery of tests in determining balance deficits should be performed. The researchers suggest consideration of the LFR in determining this most effective battery of tests.

Conclusion

In Chapter 2, the researchers have documented the increased incidence of falls among the elderly population. This is important because with these increased falls, the
incidence of serious injury increases as well. Furthermore, current literature supports that measurement of postural responses to lateral translations is important to assess when predicting falls in the elderly (Maki, Holliday, and Topper, 1994). In conclusion, to best prevent falls in the elderly, a battery of tests are needed that are cost-effective, easy to implement, and accurate in measurement of balance. The researchers propose that inclusion of the ML plane, as measured in the LFR, should be included in a balance assessment.
Reference List


APPENDIX A:
Diagram of FR and LFR
Figure 1. Functional Reach

Figure 2. Lateral Functional Reach
APPENDIX B
Medical History Questionnaire
Medical History Questionnaire

Subject #___

1. Age: _____

2. **Hand Dominance**: Right / Left

3. **Height**: _______(inches)

4. **Range of Motion**
   
   **Flexion**:  
   - (R) < 90°  
   - ≥ 90°  
   - (L) < 90°  
   - ≥ 90°

   **Abduction**:  
   - (R) < 90°  
   - ≥ 90°  
   - (L) < 90°  
   - ≥ 90°

5. Ability to stand for at least 60 seconds unassisted.  
   Yes / No

*Please answer the following questions concerning your medical history.*

1. In case of emergency whom should be contacted?  
   Name: _______________________
   Relationship: __________________
   Phone #: _____________________

2. Do you require the use of an assistive device (i.e.: cane, walker, crutches) for daily activities or getting around in your residence or community?  
   Yes / No

3. Are you able to live and function safely in your residence and community without the assistance of another person?  
   Yes / No

4. Have you fallen within the last year according to the following definition?  
   Yes / No
   **Fall**: A person has a fall if they end up on the ground or floor when they didn’t expect to. If a person ends up on the ground, either on their knees, their belly, their side, their bottom or their back, they have had a fall (Duncan et al., 1992, pg. M95).

   If yes:
   **Where**: ________________________________
   **How**: ________________________________
   **Surface Type**: ________________________________
5. Have you had any feelings of dizziness within the past month according to the following definition? \[ \text{Yes / No} \]
   Dizziness: “Dizziness can accompany feelings of unsteadiness and imbalance, as well as feelings of faintness or a sense of being light-headed” (Shumway-Cook et al., 1995, pg. 176).

6. Do you have a history of any of the following conditions?
   - Meniere’s Disease
   - Legally Blind
   - Deaf
   - Amputations
   - Upper Motor Neuron Lesions (Multiple Sclerosis, Parkinson’s Disease)

7. Do you regularly exercise at least three times per week for at least 15 minutes per session (i.e. walk, jog, bike, run, water)? \[ \text{Yes / No} \]
   If yes:
   Type: ______________________________
   Sessions/Week: _______________________
   Minutes/Session: _____________________

8. Mini-Mental Score: ______

9. Geriatric Depression Score: ______

10. Would you like to receive a copy of the results of this study? \[ \text{Yes / No} \]
    Name: _______________________________
    Address: _____________________________
    Phone #: _____________________________
APPENDIX C

Tests
Geriatric Depression Scale

1. Are you basically satisfied with your life? (no)
2. Have you dropped many of your activities and interests? (yes)
3. Do you feel that your life is empty? (yes)
4. Do you often get bored? (yes)
5. Are you hopeful about the future? (no)
6. Are you bothered by thoughts that you just can not get out of your head? (yes)
7. Are you in good spirits most of the time? (no)
8. Are you afraid that something bad is going to happen to you? (yes)
9. Do you feel happy most of the time? (no)
10. Do you often feel helpless? (yes)
11. Do you often get restless and fidgety? (yes)
12. Do you prefer to stay home at night, rather than go out and do new things? (yes)
13. Do you frequently worry about the future? (yes)
14. Do you feel that you have more problems with memory than most? (yes)
15. Do you think it is wonderful to be alive now? (no)
16. Do you often feel downhearted and blue? (yes)
17. Do you feel pretty worthless the way you are now? (yes)
18. Do you worry a lot about the past? (yes)
19. Do you find life very exciting? (no)
20. Is it hard for you to get started on new projects? (yes)
21. Do you feel full of energy? (no)
22. Do you feel that your situation is hopeless? (yes)
23. Do you think that most persons are better off than you are? (yes)
24. Do you frequently get upset over little things? (yes)
25. Do you frequently feel like crying? (yes)
26. Do you have trouble concentrating? (yes)
27. Do you enjoy getting up in the morning? (no)
28. Do you prefer to avoid social gatherings? (yes)
29. Is it easy for you to make decisions? (no)
30. Is your mind as clear as it used to be? (no)

Score one point for each response that matches the yes or no answer after the question.

---

**BERG BALANCE SCALE WORK SHEET**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>SCORE (0-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sitting to standing</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Standing unsupported</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sitting unsupported</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Standing to sitting</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Transfers</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Standing with eyes closed</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Standing with feet together</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Reaching forward with outstretched arm</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Retrieving object from floor</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Turning to look behind</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Turning 360 degrees</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Placing alternate foot on stool</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Standing with one foot in front</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Standing on one foot</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL**

---

**BALANCE SCALE**

Developed in partial fulfillment of Master of Science degree - McGill University: K Berg 1988

1. **SITTING TO STANDING**

   **INSTRUCTION:** Please stand up. Try not to use your hands for support.

   **GRADING:** Please mark the lowest category which applies.

   |   |   |   |   |   |
   | 4 | 3 | 2 | 1 | 0 |
   | able to stand | able to stand indep using hands | able to stand using hands after several tries | needs minimal assist to stand or to stabilize | needs moderate or maximal assist to stand |

2. **STANDING UNSUPPORTED**

   **INSTRUCTION:** Stand for two minutes without holding.

   **GRADING:** Please mark the lowest category which applies.

   |   |   |   |   |   |
   | 4 | 3 | 2 | 1 | 0 |
   | able to stand safely 2 min | able to stand 2 min. with supervision | able to stand 30 sec. unsupported | needs several tries to stand 30 sec. unsupported | unable to stand 30 sec. unassisted |
3. SITTING UNSUPPORTED FEET ON FLOOR
INSTRUCTION: Sit with arms folded for two minutes.
GRADING: Please mark the lowest category which applies.

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>able to sit safely and securely 2min</td>
<td>able to sit 2min under supervision</td>
<td>able to sit 30 sec</td>
<td>able to sit 10 seconds</td>
<td>unable to sit without support 10 sec</td>
</tr>
</tbody>
</table>

4. STANDING TO SITTING
INSTRUCTION: Please sit down.
GRADING: Please mark the lowest category which applies.

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>sits safely with minimal use of hands</td>
<td>controls descent by using hands</td>
<td>uses back of legs against chair to control descent</td>
<td>sits indep. but uncontrolled descent</td>
<td>needs assistance to sit</td>
</tr>
</tbody>
</table>

5. TRANSFERS
INSTRUCTION: Please move from chair to bed and back again. One way toward a seat with armrests and one way toward a seat without armrests.
GRADING: Please mark the lowest category which applies.

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>able to transfer safely with minor use of hands</td>
<td>able to transfer safely with definite use of hands</td>
<td>able to transfer with verbal cues and/or supervision</td>
<td>needs one person to assist</td>
<td>needs two people to assist or supervise to be safe</td>
</tr>
</tbody>
</table>

6. STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTION: Close your eyes and stand still for 10 seconds.
GRADING: Please mark the lowest category which applies.

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>able to stand 10 seconds safely</td>
<td>able to stand 10 seconds with supervision</td>
<td>able to stand 3 seconds</td>
<td>unable to keep eyes closed 3 sec. but stays steady</td>
<td>needs help to keep from falling</td>
</tr>
</tbody>
</table>

7. STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTION: Place your feet together and stand without holding.
GRADING: Please mark the lowest category which applies.

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>able to place feet together indep. and stand 1min. safely</td>
<td>able to place feet together indep. and stand for 1min. with supervision</td>
<td>able to place feet together indep. but unable to hold for 30 sec.</td>
<td>needs help to attain position but able to stand 15sec. with feet together</td>
<td>needs help to attain position and unable to hold for 15 seconds</td>
</tr>
</tbody>
</table>
THE FOLLOWING ITEMS ARE TO BE PERFORMED WHILE STANDING UNSUPPORTED.

8. REACHING FORWARD WITH OUTSTRETCHED ARM
   INSTRUCTION: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measures is the distance forward that the fingers reach while the subject is in the most forward lean position.)
   GRADING: Please mark the lowest category which applies.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>can reach forward confidently &gt;10 inches</td>
<td>3</td>
<td>can reach forward &gt;5 inches safely</td>
<td>2</td>
</tr>
</tbody>
</table>

9. PICKING UP OBJECT FROM THE FLOOR
   INSTRUCTION: Pick up the shoe/slipper which is placed in front of your feet.
   GRADING: Please mark the lowest category which applies.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>able to pick up slipper safely and easily</td>
<td>3</td>
<td>able to pick up slipper but needs supervision</td>
<td>2</td>
</tr>
</tbody>
</table>

10. TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS
    INSTRUCTION: Turn to look behind you over toward left shoulder. Repeat to the right.
    GRADING: Please mark the lowest category which applies.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>looks behind from both sides and weight shifts well</td>
<td>3</td>
<td>looks behind one side only other side shows less weight shift</td>
<td>2</td>
</tr>
</tbody>
</table>

11. TURN 360 DEGREES
    INSTRUCTION: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
    GRADING: Please mark the lowest category which applies.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>able to turn 360° safely in &lt; 4 sec. each side</td>
<td>3</td>
<td>able to turn 360° safely one side only &lt; 4 sec</td>
<td>2</td>
</tr>
</tbody>
</table>
12. COUNT NUMBER OF TIMES STEP TOUCH MEASURED STOOL

**INSTRUCTION:** Place each foot alternately on the stool. Continue until each foot has touched the stool four times.

**GRADING:** Please mark the lowest category which applies.

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>able to stand indep. and complete 8 steps in 20sec.</td>
<td>able to stand indep. and complete 8 steps &gt;20 sec</td>
<td>able to complete 4 steps without aid and with supervision</td>
<td>able to complete &gt;2 steps and needs minimal assist</td>
<td>needs assistance to keep from falling / unable to try</td>
</tr>
</tbody>
</table>

13. STANDING UNSUPPORTED ONE FOOT IN FRONT

**INSTRUCTION:** (Demonstrate to subject) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot.

**GRADING:** Please mark the lowest category which applies.

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>able to place foot tandem indep. and hold 30 sec.</td>
<td>able to place foot ahead of other indep. and hold 30 sec.</td>
<td>able to take small step indep. and hold 30 sec.</td>
<td>needs help to step but can hold 15 sec.</td>
<td>loses balance while stepping or standing</td>
</tr>
</tbody>
</table>

14. STANDING ON ONE LEG

**INSTRUCTION:** Stand on one leg as long as you can without holding.

**GRADING:** Please mark the lowest category which applies.

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>able to lift leg indep. and hold &gt; 10 sec.</td>
<td>able to lift leg indep. and hold 5-10 sec.</td>
<td>able to lift leg indep. and hold = or &gt;3 seconds</td>
<td>tries to lift leg unable to hold 3 sec. but remains standing indep.</td>
<td>unable to try or needs assist to prevent fall</td>
</tr>
</tbody>
</table>

**TOTALSCORE:**

Maximum = 56
## Mini-Mental State Exam

**Orientation**

<table>
<thead>
<tr>
<th><strong>Maximum Score</strong></th>
<th><strong>Score</strong></th>
<th><strong>Instructions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the (year) (season) (date) (day) (month)?</td>
<td>5</td>
<td>Ask for the date. Then proceed to ask other parts of the question. One point for each correct segment of the question.</td>
</tr>
<tr>
<td>Where are we: (state) (county) (town) (hospital)</td>
<td>5</td>
<td>Ask for the facility then proceed to parts of the question. One point for each correct segment of the question.</td>
</tr>
</tbody>
</table>

**Registration**

<table>
<thead>
<tr>
<th><strong>Score</strong></th>
<th><strong>Instructions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name three objects (bed, apple, shoe). Ask the patient to repeat them.</td>
<td>3</td>
</tr>
</tbody>
</table>

**Attention and Calculation**

<table>
<thead>
<tr>
<th><strong>Score</strong></th>
<th><strong>Instructions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Count backwards by 7s. Start with 100. Stop after 5 calculations.</td>
<td>5</td>
</tr>
</tbody>
</table>

**Alternate Question**

<table>
<thead>
<tr>
<th><strong>Score</strong></th>
<th><strong>Instructions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Spell the word “world” backwards.</td>
<td>5</td>
</tr>
</tbody>
</table>

**Recall**

<table>
<thead>
<tr>
<th><strong>Score</strong></th>
<th><strong>Instructions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask for the three objects used in question 2 to be repeated.</td>
<td>3</td>
</tr>
</tbody>
</table>

**Language**

<table>
<thead>
<tr>
<th><strong>Score</strong></th>
<th><strong>Instructions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Naming: Name this object. (watch, pencil)</td>
<td>2</td>
</tr>
<tr>
<td>2. Repetition: Repeat the following - “No ifs, ands or buts.”</td>
<td>1</td>
</tr>
<tr>
<td>3. Follow a 3-stage command: “Take the paper in your right hand, fold it in half, and put it on the floor.”</td>
<td>3</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Language</th>
<th>Maximum Score</th>
<th>Score</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Reading: Read and obey the following: Close your eyes.</td>
<td>1</td>
<td></td>
<td>Instruction should be printed on a page. Allow patient to read it. Score by a correct response.</td>
</tr>
<tr>
<td>5. Writing: Write a sentence.</td>
<td>1</td>
<td></td>
<td>Provide paper and pencil. Allow patient to write any sentence. It must contain a noun, verb, and be sensible.</td>
</tr>
<tr>
<td>6. Copying: Copy this design.</td>
<td>1</td>
<td></td>
<td>All 10 angles must be present. Figures must intersect. Tremor and rotation are ignored.</td>
</tr>
</tbody>
</table>

Total Score | Maximum 30. Test is not timed.
APPENDIX D
Data Collection Sheet
DATA COLLECTION SHEET

Subject Number:_________
Age:______________
Height:______________
Dominant Hand:_________

TESTING

Berg Balance Scale

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Score (0-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sitting to standing</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Standing unsupported</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sitting unsupported</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Standing to sitting</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Transfers</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Standing with eyes closed</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Standing with feet together</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Reaching forward with outstretched arm</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Retrieving object from floor</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Turning to look behind</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Turning 360 degrees</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Placing alternate foot on stool</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Standing with one foot in front</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Standing on one foot</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL _____

Functional Reach Test

Demonstration of starting position.

*Instructions:* “Stand comfortably with your toes along the white tape on the floor. Bring your arm straight out in front of you with your shoulder relaxed. Make a fist with your right/left hand and hold this position. Reach as far forward as you can without taking a step or allowing either foot to completely leave the ground. We will do two practice trials and then record three test trials.”

<table>
<thead>
<tr>
<th>Right</th>
<th>Start</th>
<th>End</th>
<th>Total Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial #1:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial #2:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial #3:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Best:**

<table>
<thead>
<tr>
<th>Left</th>
<th>Start</th>
<th>End</th>
<th>Total Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial #1:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial #2:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial #3:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Best:**
Lateral Functional Reach Test

Demonstration of starting position.

*Instructions:* “Stand comfortably with your toes along the white tape on the floor. Place your right/left foot along the red tape on the floor. Bring your arm straight out in front of you with your shoulder relaxed. Move your arm to the right/left so you will reach along the yardstick on the wall. Make a fist with your right/left hand and hold this position. Reach as far to the side as you can without taking a step or allowing either foot to completely leave the ground. We will do two practices trial and then record three test trials.”

<table>
<thead>
<tr>
<th>Right</th>
<th>Start</th>
<th>End</th>
<th>Total Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial #1:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial #2:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial #3:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Left</th>
<th>Start</th>
<th>End</th>
<th>Total Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial #1:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial #2:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial #3:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX E
Consent Form
CONSENT FORM
Subject Number _______
I understand that this is a study designed to develop a way to identify elderly women who are at a high risk for falling to the side. The information gained in this study will be used by health professionals to help prevent falls among older people.

I also understand that:

1. I have been selected to participate in this study because I am female, am 65 years of age or older, and live independently within the community.

2. I am one of 60 subjects being tested for this study.

3. Participation in this study consists of an interview, cognitive testing, and balance testing. Balance testing will include going from sit to stand, standing on one leg, standing with my eyes closed and standing and reaching. Testing is anticipated to take 45 minutes.

4. It is not anticipated that my participation in this study will lead to physical or emotional risk. However, due to the nature of this study, there is a slight risk of falling during the testing procedure. To prevent injury a belt will be placed around my waist and a person will stand within an arms distance of me in case of any loss of balance.

5. The information I provide will remain strictly confidential and the data will be coded so that identification of individual participants will not be possible.

6. A summary of the results will be made available upon my request.
I acknowledge that:

"I have been given an opportunity to ask questions regarding this research study, and that these questions have been answered to my satisfaction."

"In giving my consent, I understand that my participation in this study is voluntary and that I may withdraw at any time without penalty."

"I hereby authorize the investigator to release the information obtained in this study to scientific literature. I understand that I will not be identified by name."

"I have been given the phone numbers of researchers Jolene Bennett (616-364-6484), Jessica Chesser (517-647-0107), Mary Yeager (517-347-4158), and Jennifer Werley (616-396-8790) and the Chair of the Human Research Review Committee, Paul Huizenga (616-895-2472), so that I may contact them at any time if I have questions."

"I acknowledge that I have read and understand the above information, and that I agree to participate in this study."

_________________________________  __________________________
(Participant Signature)             Date

_________________________________  __________________________
Witness                             Date
APPENDIX F: SCATTER PLOTS
*RLFR scores measured in inches and normalized for height.

Figure 1: Scatter plot of BBS vs. right LFR
Figure 2: Scatter plot of BBS vs. right FR

*RFR scores measured in inches and normalized for height.
RLFR

*RLFR and RFR scores measured in inches and normalized for height.

Figure 3: Scatter plot of right LFR vs. right FR
Figure 4: Scatter plot of right LFR vs. age

*RLFR scores measured in inches and normalized for height.