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Dissertation/Thesis Title: Effectiveness of Impairment-Specific Exercises to Improve Balance and Reduce Fall Risk in Community-Dwelling Older Adults

Author: Elizabeth Wang-Hsu, PT, MS

This dissertation/thesis is hereby accepted and approved.

Signatures:

Examining Committee

Chair: Susan S. Smith

Members: Robert Palisano

[signature]

Fay B Horak

Ed J Gracely

Academic Advisor: Lisa Chiarello

Department Head: Susan S. Smith

Effectiveness of Impairment-Specific Exercises to Improve Balance and Reduce Fall Risk in Community-Dwelling Older Adults

A Dissertation

Submitted to the Faculty

of

Drexel University

by

Elizabeth C Wang-Hsu, PT, MS

in partial fulfillment of the

requirement for the degree

of

Doctor of Philosophy

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DEDICATIONS

I dedicate this dissertation to my parents, who have always been proud of me, even now they are still watching over me from heaven. I also dedicate this to my loving husband, Dr. Fu-Chun (Robert) Hsu, and my beautiful children, Sharon and Ian, for their endless support and understanding.

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PROPOSAL

SPECIFIC AIMS

Fall-related fractures in older adults are a significant source of morbidity and decreased quality of life. By 2025, societal costs of fracture are predicted to increase to approximately $25.3 billion (CDC, 2011). A person with a high fracture risk is more likely to sustain a fracture after a low trauma fall. An overall goal of management for persons at risk for fracture is prevention. A critical component to preventing fractures is to reduce the risk of falls.

Impaired balance is a potentially modifiable factor known to contribute to falls. Exercise is an evidence-based intervention demonstrated to improve balance and to prevent falls. The Center for Disease Control and Prevention (CDC, 2011) recommends using exercise and activity to reduce falls. However, current exercises used to improve balance and to reduce fall risk tend to be multidimensional and use a "shotgun" approach that addresses several potential impairments not specific to the individual.

Tests and measures for assessing balance that are used in clinical practice were primarily designed to identify the existence of a balance deficit and to determine fall risk. None of these tests directly guides clinicians in prescribing specific intervention strategies. A recently developed new clinical balance measure, the Balance Evaluation Systems Test (BESTest), created by Horak and coworkers (2009), categorizes balance impairments into six underlying components. This tool may be useful as a guide to prescribe exercise interventions that are specific to identified impairment in one or more of the components of balance. Whether exercise prescription based on impairments in underlying components of balance can modify the specific component(s) and therefore improve balance and reduce fall risk is unknown. Such knowledge would enable clinicians to prescribe *specific* rather than *generic* interventions.

Central hypothesis: *Exercises that are prescribed based upon specific impairments associated with balance control will improve balance and reduce the risk of falling in older adults greater than no exercises or non-specific exercises.*

I plan to test the central hypothesis and, thereby, achieve the objective of this application by pursuing the following specific aims:

Aim 1. Determine whether impairments in components of balance are modifiable with specific exercises and reduce fall risk.

Working hypotheses:

1. Impairments in components of balance can be modified with specific matched exercises.

Approach: I will conduct two case series studies (n=3 each). One study will consist of specific exercises designed to reduce impairments in the BC component and the other study will be designed to reduce impairments in the APA component of balance.

Aim 2. Determine the effectiveness of impairment-specific exercises in improving balance and reducing fall risk for older adults.

Working Hypotheses:

Phase 1: Older adults who receive exercises specific to their targeted balance impairment will demonstrate improved balance and a reduced fall risk compared to older adults who receive no intervention.

Phase 2: Exercises that are matched to the targeted balance impairment will be more effective than exercises that are mismatched to the targeted impairment in improving balance and reducing fall risk for older adults.

Approach: I will conduct a two-phase, small clinical randomized control trial (RCT) to determine the effectiveness of specific exercise interventions. Phase 1 will consist comparing the outcomes between the groups that receives six weeks of impairment-matched exercises with a control group (delayed intervention group) that receives no treatment. In phase 2, the delayed intervention group will receive a 6-week exercise program opposite to the participants' targeted balance impairment (impairment-mismatched intervention). The results of the mismatched intervention group from phase 2 will be compared to the results of the intervention group (matched intervention) from phase 1.

Expected outcomes: I anticipate that these aims will yield the following impact:

1. The results of the case series will provide preliminary evidence that specific exercises can improve impairments in selected components of balance.

2. The results of the two-phase small clinical RCT will provide evidence for the effectiveness of impairment-specific exercises for improving balance and reducing fall risk for older adults. The results will serve as a first step toward studies to compare the effectiveness of generic, non-specific balance improvement exercises to impairment-specific exercises.

The results of my studies will support the approach for impairment-specific intervention and serve as a guide for clinicians in prescribing specific balance exercise interventions for older adults.

SIGNIFICANCE

In the United States, one in three older adults falls every year [Center for Disease Control and Prevention (CDC), 2011]. The consequences of falls can be physically, psychologically and financially damaging to individuals and society (CDC, 2011; Das & Joseph, 2005; Velozo & Peterson, 2001). Falls can cause moderate to severe injuries and result in an increased risk of early death (Das & Joseph, 2005). In 2008, 82 % of fall-related deaths were among people 65 and older, which amounted to over 19,700 deaths (CDC, 2011). Falls are also the most common cause of nonfatal injuries and trauma-related hospital admissions in older adults. Falls are costly. In 2000, direct medical costs of falls totaled over $19 billion. This amount equals $28.2 billion in 2010 dollars. Experts estimate that the annual direct and indirect cost of fall injuries will reach $54.9 billion by 2020 (CDC, 2011).

A person with high fracture risk is more likely to sustain a fracture after a low trauma fall (Boonen et al., 2008). Fall-related fractures are a significant source of morbidity for older adults. In 2004, fall-related hip fractures accounted for 300,000 hospitalizations (CDC, 2011). Over 90% of hip fractures result from falls. An estimated 25% of older adults who sustained a fall-related fracture were admitted to a nursing home; whereas, another 25% died within a year (CDC, 2011). Older adults with both an elevated fall risk and an elevated fracture risk are more likely to sustain injuries from a fall.

The Center for Disease Control and Prevention (CDC, 2011) has systematically reviewed evidence and reported that interventions with exercises are effective in reducing falls. Exercise is an evidence-based intervention that can improve balance and prevents falls when it is performed. However, currently prescribed exercises to reduce fall risk are usually broad-based and address potential impairments generally. The exercise prescription is not necessarily specific to the individuals' balance impairment(s). An issue with generic exercise programs is motivating older adults to participate and to adhere to the program because the exercise programs typically consist of a large number of exercises, which can be overwhelming to some older adults (Baker et al., 2007). In addition, from my review of the literature, it appears that current studies of the effectiveness of exercises to improve balance have been mostly limited to older adults with a fall risk, but not necessary a fracture risk. In other words, evidence of the effectiveness of exercises to reduce fall risk in older adults with the highest risk of injury, i.e., those with both an elevated fracture and fall risk, is minimal.

My proposed studies are significant because the results will directly impact clinical practice in the following ways: 1) the exercise programs will consist of more focused, progressive and standardized exercises. Because they are more focused, the program will consist of a smaller number of exercises that are likely to be less time-consuming to perform. I expect the program to be easier to adhere to, more efficient, and produce optimal outcomes. The results will provide evidence for the effectiveness of the focused exercises for improving balance and reducing the risk of falls. 2) The sample that I plan to study is representative of community-dwelling older adults with both an elevated fall risk and an elevated fracture risk. My results will provide evidence for the effectiveness of impairment-specific exercises to reduce fall risks for individuals with the highest risk, i.e., older adults with both fall and fracture risks. Reduced fall risk can assist older adults in living independently with better quality of life and reduce costs to individuals and to society.

INNOVATION

Impaired balance is a potentially modifiable physical factor that contributes to falls. Exercise is a key evidence-based intervention demonstrated to improve balance and to prevent falls (Arnold, Busch, Schachter, Harrison, & Olszynski, 2005; Carter et al., 2002; CDC, 2011). Evidence suggests that exercises to improve balance and reduce fall risks should promote muscle strength, power and postural control (Granacher, Muehlbauer, Zahner, Gollhofer, & Kressig, 2011; Pijnappels, Reeves, Maganaris, & van Dieen, 2008; Shigematsu, Okura, Sakai, & Rantanen, 2008).

Current exercises used to improve balance and reduce fall risk tend to be generic and broad-based. The exercises typically consist of considerable variation and can include a large number of exercises (Ashburn et al., 2007; Ballard, McFarland, Wallace, Holiday, & Roberson, 2004; Barnett, Smith, Lord, Williams, & Baumand, 2003; Chang et al., 2004). However, these exercise programs are not necessarily specific to the individual's examination findings. In other words, current exercises for balance improvement and fall risk reduction tend to be generic rather than specific to the underlying physical impairment identified from examination and assessment. This practice is analogous to prescribing treatment without an accurate diagnosis. A tenet in healthcare is that effective treatment depends on an accurate diagnosis. Diagnosis is the basis for achieving effective patient outcomes.

My proposed studies are innovative because: 1) I will use a model to clinically identify (i.e., diagnose) impairments in selected components of balance. This approach differs from the current practice of using clinical tests or measures of fall risk that are not designed to identify specific impairments in balance. 2) I will prescribe a standardized and progressive set of exercises based on the specific balance impairment identified from the model.

I expect the results of these studies will provide evidence of the effectiveness of using an impairment-specific model upon which to prescribe exercises for older adults at risk for falls and fracture and that these exercises will reduce fall risk. Further, impairment-specific and progressive exercises that have demonstrated efficiency and effectiveness will guide clinicians in prescribing specific, individualized exercises to reduce fall risk. The results are also expected to provide the first step toward future studies that will compare the effectiveness, efficacy, and adherence between the current practice of prescribing generic broad-based exercises and impairment-specific exercises to reduce fall risk in community-dwelling older adults.

BACKGROUND

Definition of a Fall

Falling is a major concern for older adults. With the population aging, both the number of falls and the cost to treat fall-related injuries are likely to increase (CDC, 2011). Fall risk factors and fall prevention programs for older adults have been well-studied. Researchers typically determine fall history by asking a question such as, "How many times have you fallen in the past 12 months?" The response to this question is used to compare individuals with fall history, i.e., “fallers” to “non-fallers”. A concern of relying on people’s recollection is potential recall bias, which is largely unavoidable. In addition, researchers may not adequately operationally define a fall. In order to determine how individuals conceptualize a fall, Zecevic and co-workers (2006) asked 477 community-dwelling older adults and 31 healthcare providers to define “a fall”. The authors reported that a fall had different meanings for the different groups. Older adults and healthcare providers focused mainly on antecedents and consequences of falls; whereas researchers described the fall event itself. Individuals who lose their balance and land on a piece of furniture, but do not sustain an injury, may not acknowledge the event as a fall. Consequently, these individuals will answer “no fall” to questions about fall history. These individuals would be labeled as “non-fallers” when, in fact, they should have been identified as “fallers.” The accuracy of a database collected in such manner is questionable, and the subsequent information analyzed based upon the database may be misleading. Therefore, if a fall is not clearly defined, the validity of studies investigating the characteristics of “fallers” and fall prevention programs can be compromised. In this study, I will use the definition of fall as “any event in which a person inadvertently or unintentionally comes to rest on the ground or another lower level such as a chair, toilet or bed" (Tideiksaar, 2002).

Fear of falling.

Older adults who have fallen may develop a fear of falling even if they were not injured from the fall (Brouwer et al., 2004; Chantal et al., 2007; Velozo & Peterson, 2001; Ward-Griffin et al., 2004; Yardley, 2003). Fear of falling can cause older adults to limit their activities leading to reduced mobility and loss of physical fitness, which, in turn, further increases their risk of falling, acquiring other medical conditions, and experiencing a poorer quality of life (Brouwer et al., 2004; Chantal et al., 2007; Li, Fisher, Harmer, McAuley, & Wilson, 2003). Recently, investigators have found significant characteristic and functional differences between older adults who have a fear of falling compared to older adults without a fear of falling (Jorstad, Hauer, Becker, Lamb, & ProFa, 2005; Li, et al., 2003). Older adults with a high fear of falling showed lower physical functioning including weakness in their lower extremities (Brouwer et al., 2004), slower gait speed (Brouwer et al., 2004), and more activity restrictions (Li et al., 2003). Furthermore, some researchers found that a higher fear of falling correlates with the existence of a history of falling. Therefore, the self-perceived fear of falling can also serve as a predictor of falling (Li et al., 2003, Smith, Wang-Hsu, Meiers, Haswell, & Jasin, 2012).

Fall-related fractures in older adults.

Fall-related fractures in older adults are a significant cause of morbidity and decreased quality of life (CDC, 2011). A person with a high fracture risk is more likely to break a bone after a low trauma fall (Boonen et al., 2008). Fracture risk is primarily estimated using Dual Energy X-ray Absorptiometry (DXA). DXA scans, used to measure bone mineral density (BMD), are considered the gold standard for diagnosing low bone mass and osteoporosis. People with low bone mass (osteopenia and osteoporosis) have an elevated fracture risk. Fracture risk can also be estimated using a formula that includes risk factors based on demographic and health information [World Health Organization (WHO), 2007], i.e., age, race, sex, past history of fracture, smoking, alcohol use, etc. This model, known as the Fracture Risk Assessment (FRAX), yields an absolute 10-year fracture risk score and 10-year hip fracture risk score (WHO, 2007). The FRAX is a simple tool used to calculate adult fracture risk that can be used with or without DXA results. I will use FRAX to identify older adults with elevated fracture risk in my proposed studies. I am choosing to study older adults with elevated fracture risk and fall risk in my proposed studies because these individuals are more likely to sustain fractures from falling. An overall goal of management for persons at risk for fracture is fall prevention.

Balance and clinical fall risk tests.

Numerous investigators have studied the common causes of falls and methods to identify individuals with a high fall risk (Aizen, Shugaev, & Lenger, 2007, Arnold et al., 2005, Das et al., 2005, Neuls et al., 2011, Pijanppels et al., 2008). Results have varied. Nevertheless, the risk factors of falls are generally classified as intrinsic, i.e., those related to the individual, and extrinsic, i.e., those associated with environmental features (Aizen et al., 2007, Arnold et al., 2005). Among the intrinsic and extrinsic factors that contribute to increased fall risk, balance deficits are the key physical factors. Balance deficits can result from a number of impairments such as lower extremity weakness, postural deformity or a detrimental shift of center of gravity (Shumway-Cook, Baldwin, Polissar, & Gruber, 1997). Clinicians struggle to select an appropriate test that thoroughly evaluates functional balance. The assumption is that tasks requiring ‘good balance’ can be ranked according to difficulty. A further assumption is that generic ‘balance exercises’ can be used to improve the ‘balance system’ in individuals with balance deficits. However, dynamic balance is a complex skill based on the interactions of postural control and sensory-motor processes (Horak, 2006); therefore, using just one test to assess the entire spectrum of balance and to identify specific balance impairments is difficult.

Several clinical measures are currently available to assess balance and fall risk. For example, the Berg Balance Scale (Berg, Wood-Dauphinee, Williams, & Maki, 1992; Wang et al., 2006), Dynamic Gait Index (Tinetti, 1986), Timed Up and Go (Podsiadlo & Richardson, 1991), Functional Reach (Duncan, Weiner, Chandler, & Studenski, 1990), the Fullerton Advanced Balance Scale (Rose, Lucchese, & Wiersma, 2006), and gait speed (Ballard et al., 2004). These tests were originally developed to measure various aspects of balance. However, they are primarily used clinically to identify fall risk. The scores of these balance tests do not identify, or diagnose, specific balance impairments. Rather the scores are used to indicate fall risk. Investigators have devoted considerable effort toward reporting “cut-off scores” for these various balance tests in different populations to more accurately identify individuals at risk of falling (Duncan, Studenski, Chandler, & Prescott, 1992, Finch, Brooks, Stratford, & Mayo, 2002, Santos, Souza, Virtuoso, Tavares, & Mazo, 2011). However, as noted above, the test scores do not identify specific balance impairments. For example, a person who scored 38 of a potential, optimal score of 56 points on the Berg Balance Scale (BBS) only indicates that the individual has an elevated risk of falling. The person's specific balance impairment, or impairments, are not identified. In addition, several clinical balance measures only evaluate certain aspects of balance and not the entire spectrum of balance impairments. Moreover, some of the tests are limited by a ceiling or floor effect with different populations. In summary, none of the clinical balance measures guide clinicians in prescribing impairment-specific exercises.

Exercise interventions to improve balance and reduce fall risk for older adults.

Exercise is beneficial for older adults (Ballard, et al., 2004; CDC, 2011; Chodzko-Zajko et al., 2009). In addition to the importance of exercise for healthy aging, a growing body of knowledge supports prescription of exercise for older adults with chronic diseases and disabilities (Chodzko-Zajko, et al., 2009). Balance exercises are recommended for older adults who are frequent fallers or for individuals with mobility problems (CDC, 2011; Chodzko-Zajko, et al., 2009; Madureira et al., 2007).

Literature supports the effectiveness and the efficacy of exercise programs to improve balance and to reduce the risk of falls (CDC, 2011; DiStefano, Clark, & Padua, 2009; Howe, Rochester, Jackson, Banks, & Blair, 2007; Madureira, et al., 2007; Shumway-Cook, Silver, LeMier, Cummings & Koepsell, 2007). Shumway-Cook and colleagues (2007) evaluated the effectiveness of a 12-month community-based intervention program on improving balance, lower extremity strength, mobility and falls. The researchers randomized 453 community-dwelling older adults to either a multi-factorial intervention group or a control group. The exercise intervention consisted of 1 hour, 3 times per week for 12 months and included progressive strength training, flexibility exercises, aerobic conditioning, and static and dynamic balance exercises. The authors reported significant but small improvement in the 30-second Chair-stand test (lower extremity strength), Timed Up and Go (mobility), and Berg Balance Scale (fall risk).

Barnett and coworkers (2003) studied the effectiveness of a 1-year long, weekly group exercise program with ancillary home exercises on balance, muscle strength, reaction time, physical functioning, health status and fall prevention in 163 community-dwelling older adults with the risk of falling. Subjects were randomized into either an exercise or a control group. The exercise intervention consisted of lower limb stretching followed by exercises designed to improve balance, coordination, aerobic capacity and muscle strength such practicing as sit-to-stand, weight transference and reaching, and balance, and coordination exercises including modified Tai Chi exercises, stepping practice, change of direction, dance steps and catching/throwing a ball. A home exercise program was also provided for the participants along with diaries to record adherence. The authors reported significantly better performance in the exercise group than the controls in three of six balance measures: postural sway on the floor with eyes open and eyes closed and leaning out of base of support. The authors also reported 40% lower incidence of falls in the intervention group than in the control group during the 12-month study period.

A Cochrane systematic review presented evidence for the effectiveness of exercises to improve balance (Howe, et al., 2007). The authors evaluated the outcomes from 34 studies with total of 2,883 participants. The authors concluded that exercises provide statistically significant benefits for improved balance ability at least in the short term. The authors also pointed out that the overall strength of the evidence for the effectiveness of exercises to improve balance provided is limited owing to a major failure across the studies; i.e., the lack of a core set of standardized outcome measures to assess balance. In addition, because of insufficient evidence, no standardized exercise prescription for older adults to improve balance and reduce fall risk has evolved.

As mentioned previously, an older adult who scored 36 out of an optimal 56 points on the Berg Balance Scale would be identified with fall risk and would be, therefore, a candidate for balance exercises. This individual may receive a set of balance exercises from one clinician but perhaps a different set of exercises from another clinician. Currently, there is no standardized guide for prescribing balance exercise for older adults to improve their balance and reduce fall risk.

This lack of a guide for prescribing balance exercises is a concern amongst clinicians. As a result, investigators have attempted to provide recommendations for prescribing balance exercises for older adults. For example, the American College of Sport Medicine (ACSM) Exercise Prescription Guidelines recommend using activities that include the following: 1) progressively difficult postures that gradually reduce the base of support, e.g., two-legged stand, semi-tandem stand, tandem stand, one-legged stand; 2) dynamic movements that perturb the center of gravity, e.g., tandem walk, circle turns; 3) stressing postural muscle groups, e.g., heel stands, toe stands; or 4) reducing sensory input, e.g., standing with eyes closed (Chodzko-Zajko, et al., 2009).

The American Physical Therapy Association (APTA) also recommends balance and fall reduction exercise interventions that include the following elements: a) strengthening for lower extremities, b) reducing joint pain/instability, c) correcting postural faults; d) targeting the neuromuscular systems that control balance comprised of controlling the center of gravity (COG) over the base of support, e) challenging the regulation of balance and postural stability, specifically engaging visual, vestibular, somatosensory and cognitive systems; f) eliciting postural reactions and ankle, hip and step strategies, and g) Tai Chi (APTA, 2007).

Other researchers (Mazzeo & Tanaka, 2001; McDermott & Mernitz, 2006) have recommended a combination of aerobic activity, strength training and flexibility exercises. Some researchers have also proposed that effective exercise prescriptions need to include recommendations on frequency, intensity, type, time, and progression of exercises that follow specific guidelines (McDermott & Mernitz, 2006). In summary, these recommendations for balance exercises are generic, broad-based, and consist of a large variety and number of exercises with an apparent shotgun approach. That is, the exercises are not specific to the individual's impaired balance component. The issues with generic broad-based exercise programs include being discouraging, time-consuming to perform, difficult to adhere to and costly (Baker et al., 2007; Patten, Armstrong, Martin, Sallis, & Booth, 2000). A regularly performed, efficient and effective exercise intervention with optimal outcomes for older adults is essential to improve balance and reduce fall risk.

Exercise adherence.

Exercise interventions can only improve physical function when they are adhered to and performed. Logically, an exercise program that consists of a smaller number of exercise and a more focused intervention would be easier to comply with than a large, broad-based program. Patten et al. (2000) evaluated the exercise adherence of a single-focused exercise modality versus an exercise program with a variety of exercises. Fortytwo adults age from 50 to 74 years old were randomly assigned to groups that either received a single-focused exercise modality or a variety of exercise modalities. The authors reported a significantly lower drop-out rate in the single-focused exercise group (19% drop-out rate) compared to the exercise variety group (43% drop-out rate). The results of this study suggest that prescribing a focused exercise programs may potentially improve the adherence compared to prescribing a less-focused exercise program.

Baker and coworkers (2007) conducted a randomized controlled trial to test the feasibility and efficacy of current guidelines for multi-modal exercise programs in older adults. Thirty-eight subjects with mean age of 77 years old (14 men and 24 women) participated the study. The authors pointed out that although multiple exercise modalities were sufficient to result in significant balance improvement, the exercises appeared difficult to prescribe and adhere to for older adults.

Henry and colleagues (1998) studied the effect of different numbers of exercises on compliance and performance in older adults. The authors randomly prescribed two, five, or eight home exercises. After 7-10 days, the subjects who were prescribed two exercises performed and complied better compared to the subjects who were prescribed eight exercises. Although the number of exercises to achieve optimal compliance was not determined, this study, nevertheless, supports that prescribing fewer number of exercises improves adherence.

I expect my proposed and supervised impairment-specific exercise programs to enhance motivation and adherence because they are impairment-specific and focused.

The BESTest Model.

Horak and colleagues (Horak, Wrisley, & Frank, 2009) recently developed a clinical balance measure, the Balance Evaluation Systems Test (BESTest, Figure 1; Table 1), that categorizes physical balance deficits into six different systems (or components) underlying control of balance: Biomechanical Constraints (BC), Stability Limits/Verticality (SLV), Anticipatory Postural Adjustments (APA), Postural Responses (PR), Sensory Orientation (SR), and Stability in Gait (SG). Each of these six components is scored individually and collectively comprise a summative total score. The BESTest has not yet been validated for use with community-dwelling older adults with fall risk. The BESTest has been tested mostly with patients post stroke, Parkinson's disease and other neurological conditions (Horak et al., 2009, Leddy, Crowner, & Earhart, 2011). Nevertheless, this model of balance components may enable clinicians to identify the specific nature of the balance deficits based on the individual component scores. Potentially this model may be useful as a guide to developing exercise interventions that are specific to identified (diagnosed) impairment in one or more of the components of balance. In other words, the BESTest model may provide evidence that will guide clinicians in prescribing an exercise intervention for fall prevention that is impairment-specific and individualized.

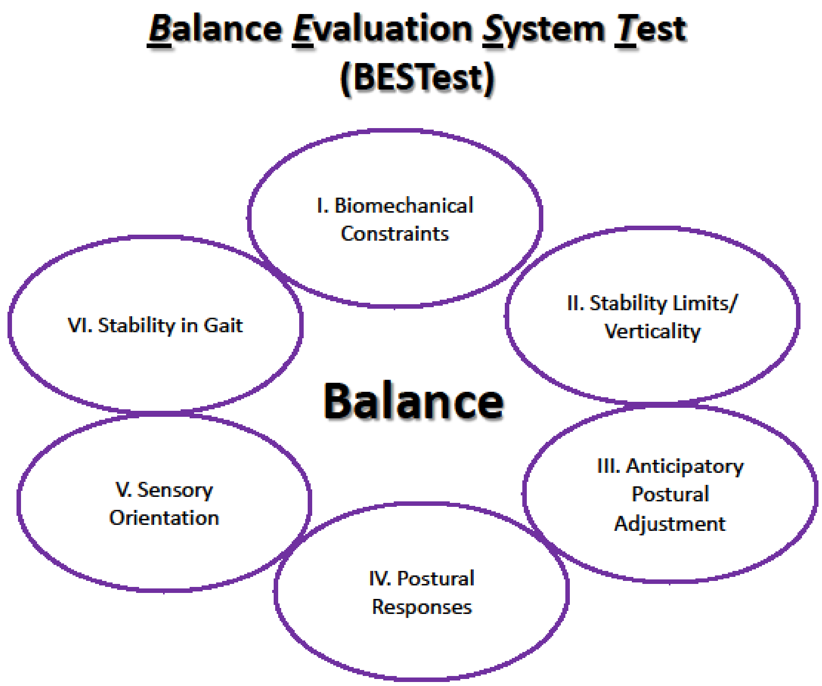

Figure 1. Diagram of the BESTest Model (adapted from Horak et al., 2009, p. 486 with permission). Balance is categorized into six components: Biomechanical Constraints (BC), Stability Limits/Verticality (SLV), Anticipatory Postural Adjustments (APA), Postural Responses (PR), Sensory Orientation (SR), and Stability in Gait (SG).

Table 1. Specific Items Comprising the Balance Evaluation System Test (BESTest) Categorized by the Components of Balance (I. – VI.) Identified in the Test

I. Biomechanical Constraints	II. Stability Limits/Verticality	III. Anticipatory Postural Adjustments	IV. Postural Responses	V. Sensory Orientation	VI. Stability in Gait
1. Base of support	6. Sitting vertically (left and right) and lateral lean (left and right)	9. Sit to stand	14. In-place response, forward	19. Sensory integration for balance (modified CTSIB) Stance on firm surface, EO Stance on firm surface, EC Stance on foam, EO Stance on foam, EC	21. Gait, level surface
2. CoM Alignment	7. Functional reach forward	10. Rise to toes	15. In-place response, backward		22. Change in gait speed
3. Ankle strength and ROM	8. Functional reach lateral	11. Stand on one leg (left and right)	16. Compensatory stepping correction, forward		23. Walk with head turns, horizontal
4. Hip/trunk lateral strength		12. Alternate stair toughing	17. Compensatory stepping correction, backward	20. Incline, EC	24. Walk with pivot turns
5. Sit on floor and get up		13. Standing arm raise	18. Compensatory stepping correction, lateral (left and right)		25. Step over obstacles
					26. Timed "Get Up & Go" test
					27. Timed "Get Up & Go" test with dual task

Note: CoM = center of mass, ROM = range of motion, CTSIB = Clinical Test of Sensory Integration for Balance, EO = eyes open, EC = eyes closed. This table is re-produced from Horak et al., 2009, p. 487 with permission.

The six components of balance of the BESTest are clearly synergistic and not mutually exclusive. Therefore, considering the sample size and logistical constraints, I propose to test exercises designed to improve impairments in only two of the six components: the components of Biomechanical Constraints (BC) and Anticipatory Postural Adjustment (APA). I have used the BESTest in my clinical practice with older adults. I informally observed that the BC and APA seem to be the least confounding with each other amongst the six components. Therefore, I selected to study these two components of balance impairment because the proposed interventions for each of these two components involve the least amount of overlap. The Biomechanical Constraints (BC) component consists of limitation or weakness of ankles or hips, or faulty postural alignment that impairs an individual's use of ankle or hip strategies or the placement of center of mass during activities. The Anticipatory Postural Adjustment (APA) component involves central initiation with the intention to move and controls the body shift to a new position during the execution of a voluntary movement (Horak et al., 2009). Therefore, older adults who are identified with BC component impairment will be prescribed mainly strengthening and flexibility exercises with emphasis on power and speed. Whereas, older adults with impairment in the component of APA will receive primarily dynamic standing postural control exercises that challenge the center of gravity out of base of support.

Operational definitions.

The terms used in this proposal will be operationally defined as follows:

1. Balance Impairment: Balance impairment will be determined by the BESTest component scores. A balance impairment in Biomechanical Constraints (BC) will be determined arbitrarily by a raw score equal to, or less than, 10 of an optimal 15 points, or the converted component score equal to, or less than, 70%. A balance impairment in Anticipatory Postural Adjustment (APA) will be determined arbitrarily by a raw score of equal to, or less than, 12 of an optimal 18 points, or the converted component score equal to, or less than 70%.

2. Adherence: Adherence to the exercise programs will be defined by three level as follows:

Adherence to the entire exercise program will be determined by completion of 80% of intervention sessions over 6 weeks of time (3 x per week x 6 weeks, or 3 x 6 = 18, 18 x 80% = 14.4 ≈ 15), i.e., completion of 15 sessions out of total of 18 sessions will be considered adherence to the entire program.

Adherence to an exercise session will be defined by 80% completion of the overall assigned exercises. For example, if there are 10 exercises to be performed then completing 8 or more of the exercises will be considered a completed session.

Adherence to each individual exercise will be defined by 80% performance of the repetitions or resistance performed during the previous performance of each exercise. For example, I will consider an individual exercise completed if the participant performs 10 repetitions of this exercise at the previous session but can only perform 8 repetitions at the subsequent session; conversely, I will *NOT* consider an exercise completed if the participant who performed 10 repetitions of an exercise can only perform 6 repetitions at the subsequent session for any given reason.

3. Fall: Any event in which a person inadvertently or unintentionally comes to rest on the ground or another lower level such as a chair, toilet or bed (Tideiksaar, 2002) with or without injury.

4. Fall risk: The scores on the Berg Balance Scale (BBS) and University of Illinois in Chicago Fear of Falling Measurement (UIC FFM) (Velozo & Peterson, 2001) will be used to determine fall risk. A reduction of fall risk will be determined by improvement in both BBS and UIC FFM scores that exceeds the minimal detectable changes (in Aim 1), and also demonstrates statistical and clinical significance (in Aim 2). Although the Berg Balance Scale (BBS) is the assessment tool used most commonly to identify people with fall risk, results of a recent systematic review (Neuls et al., 2011) recommended that BBS be used in conjunction with other test(s) to more accurately predict fall risk. I will use scores from both a physical performance test (as measured by Berg Balance Scale) and a psychological limiting factor, fear of falling (as measured by the UIC FFM), to better predict fall risk rather than the traditional practice of using only the BBS to identify fall risk. An older adult with elevated fall risk will be defined with both a BBS score equal or lower than 49 of an optimal 56 points (Shumway-Cook et al., 1997) and a UIC FFM score equal to or lower than 29 of an optimal 48 points (Smith et al., 2012).

5. Fear of falling: Fear of falling will be determined by the score of the University of Illinois in Chicago Fear of Falling Measure (UIC FFM) score equal to or lower than 29 of an optimal 48 points (Smith et al., 2012).

6. Fracture risk: Fracture risk will be defined by a score calculated using the World Health Organization’s (WHO) Fracture Risk Assessment Tool (FRAX, see “instrument” section). A 10-year probability of a hip fracture ≥ 3% or a 10-year probability of a major osteoporosis-related fracture ≥ 20% is considered a high fracture risk.

7. Older adults: Older adults will be defined as adults who are aged 65 years or older.

8. Quality of life: Quality of life will be determined by the short form 12-item quality of life questionnaire (SF-12 version-2).

9*. *Community-Dwelling: Adults who live independently in their own apartments within a senior retirement living center.

PRELIMINARY WORK

Five preliminary studies, described below, provide evidence to support the aims of the proposed work. The results of the first three preliminary studies provide justification for using both the Berg Balance Scale (BBS) and the University of Illinois at Chicago Fear of Falling Measure (UIC FFM) as assessment tools to identify older adults with a risk of falling. The results from the fourth study demonstrate the test-retest reliability and other psychometric properties of BESTest. The results of the fifth study provide preliminary evidence that both the total and component scores of BESTest can be improved with specific exercise interventions.

1. Relationship of fear of falling to fall risk and physical measures of balance, lower extremity strength and fitness in persons with low bone mass.

In this study (Wang-Hsu et al., 2012), data were analyzed from a consecutive sample of clients (N = 13; 2 men, 11 women; mean age = 63.9 yrs; SD = 13.3) with low bone mass (LBM = dual energy X-ray absortiometry [DXA] T-score < -1) referred to the *pro bono* Osteoporosis Education & Exercise Program (OEEP) at Drexel University. All clients completed questionnaires including their personal and medical information and the UIC FFM prior to their initial visit. Clients were tested during their visit with clinical assessments including the Berg Balance Scale (as an indicator of fall risk), % medial-lateral single leg stance stability on a force plate (as a measure of balance), 30-second Sit-to-Stand Test (as a functional measure of lower extremity strength), and brisk 10-m gait speed in m/s (as a measure of fitness). A Pearson correlation (r) matrix was used to determine the relationship among variables. The results showed that the UIC FFM score significantly ($p < 0.01$) and strongly correlated with the Berg Balance Scale score ($r =$

.89), % medial-lateral single leg stance stability (*r* = 1.0), completed number of Sit-to-Stands in 30 seconds (*r* = .89) and brisk 10-m gait speed (*r* =.80).

Relevance to proposed study: The findings of this study indicate that individuals' fear of falling is consistent with a decline in Berg Balance Scale, single leg medial-lateral standing balance, functional lower extremity strength and gait speed. In other words, the self-perceived fear of falling (UIC FFM score) strongly correlates with increased fall risk (as measured by the Berg Balance Scale) and physical indicators of functional decline. Therefore, the UIC FFM will be considered a useful tool to help identify older adults with fall risk in my proposed studies.

2. Diagnostic accuracy of the University of Illinois at Chicago Fear of Falling Measure (UIC FFM) to identify fallers in community-dwelling older adults.

In this study (Smith et al., 2012), 40 community dwelling older adults (8 men, 32 women, aged 69-97 years, mean = 86.9 yrs) were included. All participants completed a demographic and fall history questionnaire (number of falls in past 12 months) and the UIC FFM as part of a larger one-time falls-screening event. Diagnostic accuracy statistics were used to calculate the sensitivity, specificity and likelihood ratios to predict people with fall history (fallers). The results indicated that the overall diagnostic accuracy of UIC FFM at a derived cut-off score of 29 of an optimal 48 points was 80%, with a sensitivity of 67% and a specificity of 86%. The positive and negative likelihood ratios were 4.67 and 0.39, respectively.

Relevance to proposed study: The results of the study provide evidence that the UIC FFM is useful in identifying fallers in community-dwelling older adults with high specificity and a positive likelihood (+LH) ratio close to 5. The high ratio indicates that an individual with a positive fear of falling (UIC FFM less than 29) is almost 5 times more likely to be a faller. Therefore, the UIC FFM is a useful tool to identify people with risk of falling. However, the minimum detectable changes (MDC) and other psychometric properties of UIC FFM were not determined. I will concurrently measure the test-retest reliability and determine the MDC of the UIC FFM during the studies with my population for use in analyzing my results (Note: This substudy is separate from the Aims of this dissertation proposal).

3. Combining the University of Illinois at Chicago Fear of Falling Measure (UIC FFM) with the Berg Balance Scale improves the prediction of fallers in community dwelling older adults.

In this study (Wang-Hsu, Meiers, Bilaloglu, Gavina & Smith, 2012), 40 community dwelling older adults (8 men, 32 women, aged 69-97, mean = 86.9 yrs) participated. All participants completed a demographic and fall history (number of falls in the last 12 months) questionnaire and the UIC FFM as part of a larger screening project. The Berg Balance Scale (BBS) was administered by physical therapists and physical therapy students. Descriptive statistics were used to calculate demographic and variable (BBS and UIC FFM scores) characteristics. Logistic regression was used to predict the probability of falling based on fall history. Alpha was set at $< .05$. The overall model using the BBS and UIC FFM scores significantly predicted fall history ($\chi2 = 9.65$, $df = 2$, $N = 40$, $p = 0.008$) with an overall diagnostic accuracy of 80% versus the 75% accuracy obtained using the BBS score alone.

Relevance to proposed study: The results of the study suggest that the addition of a psychological fear of falling measure (UIC FFM) improved the predictability of the

BBS to identify fallers in community dwelling older adults. Therefore using this quick and simple self-report indicator of the fear of falling (UIC FFM) along with the BBS score improved the ability to identify fallers in community dwelling older adults. The results of the study justify the use of UIC FFM and BBS to identify community-dwelling older adults with fall risk in these proposed studies.

4. Test-retest reliability and minimal detectable change of the BESTest in postmenopausal women.

In this study (Chen, H., Meiers, J., Wang-Hsu, E., Strazzullo, T., Adjei, B., Smith, S., 2013), data from ten community-dwelling postmenopausal women (53-70 yrs of age; mean = 60, SD = 5.6) who participated in the *pro bono* Osteoporosis Education & Exercise Program (OEEP) at Drexel University were extracted from the health records. Testers were faculty members and graduate physical therapy students trained in use of the Balance Evaluation Systems Test (BESTest) measures. Testers were blinded to the results of previous measurements. The women were tested using standardized instructions and procedures. The same procedures were repeated 7-14 days later. Data were analyzed to determine test-retest reliability using an Intraclass Correlation Coefficient [$ICC_{(2,1)}$], and the Minimal Detectable Change [$MDC_{(90 \& 95)}$], as well as Coefficient of Variation of Method Error (CV_{ME}). The $ICC_{(2,1)}$ for the test-retest was .93, which was defined as excellent test-retest reliability. The MDCs for the total BESTest raw score at 90% CI and 95% CI were 5 and 6, respectively. CV_{ME} = 2.3% variation between test and retest. This study indicated that the test-retest reliability of BESTest obtained with community-dwelling postmenopausal women was excellent. We also calculated CV_{ME} to show the response stability in terms of %age variation from test to retest because, unlike correlation coefficients, method error is not affected by a lack of variation in raw scores that typically occurs with small sample sizes.

Relevance to proposed study: The results of this study provide preliminary evidence for test-retest reliability and other psychometric properties of BESTest in community-dwelling postmenopausal women. The results also suggest that an MDC score of 5 or 6 indicates a meaningful change in balance deficits over time. However, the test-retest reliability, CV and MDC in population of community-dwelling adults with a mean age of at least 65 were not determined. I will obtain the population-specific values during the course of my proposed studies and also ensure that there is no decline in reliability throughout my data collection period (Domholdt, 2005).

5. Using BESTest scores as a balance measure to determine the effectiveness of an individualized exercise intervention for older adults with fracture risk.

In this preliminary case report, the de-identified health records from one client in the Osteoporosis Education and Exercise Program (OEEP) at Drexel University were analyzed. The client was a 70 year-old, community-dwelling Caucasian woman. She was referred to the OEEP at Drexel University with a diagnosis of low bone mass. Her chief complaints were unsteady balance, faulty posture, and leg weakness. At initial evaluation visit, the participant scored 78 out of an optimal 108 points in her BESTest total raw score. Her individual component scores were low in Stability Limits/Verticality (71%), Postural Responses (50%), and Stability in Gait (71%). We adopted an arbitrary score of 75% to identify impairment in each individual component score. An individually-tailored, progressive exercise home program was prescribed for the client to improve her performance in the identified impaired components of balance. The client returned four times for regular upgrades to her home program. The client was re-evaluated four months later. Her total BESTest raw score improved from 78 to 94 out of an optimal 108 points. The improvement in her total BESTest raw score exceeded the minimum detectable change (MDC) of 5 to 6 points determined from the aforementioned study. The component scores for Stability Limits/Verticality improved from 71% to 86%; Postural Responses improved from 50% to 83%; and Stability in Gait improved from 71% to 76%. However, we were unable to determine whether these improvements were true changes because the MDC values of component scores were not available. Also, this client was older than the population upon which the MDCs were calculated. Subjectively, she reported feeling much “steadier” and “more confident”.

Relevance to proposed study: The results of this preliminary case report suggest that both the total and component scores of BESTest can be improved with exercises. However, the exercise protocol and progression was not standardized for this client. In addition, we used an arbitrary score of 75% or lower to identify impairment in total score and in each individual component score because the participant had relatively high baseline scores. I will adopt a cut-off score of 70% or lower in my proposed studies to identify balance impairment for my older adult population. My proposed cut-off score is similar to the suggested cut-off score of 68% by previous authors (Leddy et al., 2011). Further, the participant’s impaired components were not the target of my proposed studies. I will conduct small two-phased randomized controlled studies with standardized exercise programs and progressions to evaluate the effectiveness of the proposed impairment-specific exercise programs for community-dwelling older adults with fall risk.

RESEARCH DESIGN AND METHODS

Aim 1. Determine whether impairments in components of balance are modifiable with specific exercises and reduce fall risk.

Working hypotheses:

1. The identified impairments in components of balance can be modified with specific matched exercises.
2. The specific matched exercise program will reduce fall risk.

Approach: I will conduct two case series studies (n=3 each). One study will consist of specific exercises designed to reduce impairments in the BC component and the other study will be designed to reduce impairments in the APA component of balance.

Research Design: Case series.

Subjects/Participants: The population of interest will be community-dwelling older adults with elevated fracture and fall risk (see operational definitions listed previously). The inclusion and exclusion criteria are listed in Appendix 2. The participants will be recruited from an independent living, senior retirement community (Keystone Villa at Douglassville, PA). Three participants each will be needed with deficits in either the BC component or the APA component of balance. Therefore, a total of six participants are needed for this study. A separate Institutional Review Board (IRB) review for this case series will be submitted for approval.

Instrumentation, Tests and Measures:

1. ***The Mini Mental State Exam (MMSE)*****:** The MMSE (Rovner & Folstein, 1987) is a brief 30-point questionnaire test that is used to screen for cognitive impairment. The questions sample an individual's cognitive functions including arithmetic, memory and orientation. The time required to administer the questionnaire is approximately 3-5 minutes (see Appendix 3 for the entire exam).

2. ***The Balance Evaluation System Test (BESTest):*** The BESTest (Horak et al., 2009) is a dynamic balance performance assessment tool consisting of a 27-item scale (scored on an ordinal scale from 0-3) with "0" indicating the lowest level of function and "3" the highest level of function. The total possible raw score is 81 points (highest level of function). The raw score is converted to 100% [(81/81) x100% = 100%]. The BESTest is divided into six components of balance: Biomechanical Constraints (BC), Stability Limits/Verticality (SLV), Anticipatory Postural Adjustments (APA), Postural Responses (PR), Sensory Orientation (SR), and Stability in Gait (SG). Each component also yields a score that is converted to 100%. This test is used to evaluate mobility tasks of daily living. The total time required to complete the test is 15-20 minutes (see Appendix 4 for a copy of the test).

3. ***The University of Illinois at Chicago Fear of Falling Measurement (UIC FFM):*** The UIC FFM is a 16-item self-administered questionnaire (Velozo & Peterson, 2001). The participant is asked to rate his or her fear of falling for each of the 16 activities on a scale of 1 to 3. The rating of "1" equals being "very worried" and "3" equals "not worried". The activities included in the questionnaire are daily activities

progressed from easier tasks to more difficult tasks. The time required to administer the test is 30 seconds to 1 minute (see Appendix 5 for a copy of the questionnaire).

4. ***The Fracture Risk Assessment (FRAX):*** The FRAX is a fracture risk assessment web tool developed by the World Health Organization (WHO, 2007) that can be used to calculate an individual's 10-year absolute fracture risk and 10-year hip absolute fracture risk based on selected demographic and health information i.e., age, race, sex, past history of fracture, smoking, alcohol use, etc. (see Appendix 6 for details). A 10-year probability of a hip fracture of ≥ 3% or a 10-year probability of a major osteoporosis-related fracture ≥ 20% is considered high fracture risk.

5. ***Heath History questionnaire:*** The health history questionnaire is a standard, general self-report about the participant including sex, age, fall history, and health history (see Appendix 7 for the copy of the standard health history questionnaire).

6. ***Berg Balance Scale (BBS):*** The BBS is a 14-item scale, scored on an ordinal scale from 0-4, that is used to measure balance in older adults (Berg et al., 1992). A "0" indicates the lowest level of function and "4" the highest level of function. The total possible score is 56 points (highest level of function). The test evaluates tasks of daily living, progressing from easy to difficult. The total time required to complete the test is 10-15 minutes (see Appendix 8 for a copy of the scale).

7. ***The Short Form Health Survey (SF-12, Version 2):*** The SF-12 (QualityMetric Incorporated, www.qualitymetric.com) is a self-administered quality of life evaluation questionnaire. The questionnaire, consisting 12 questions and is scored on an ordinal scale. The questions request information about the participant's self-perceived quality of life in psychological and physical domains. Licensed software is required to

calculate the final score. The time required to administer the questionnaire is approximately 3-5 minutes. Permission to use the SF-12(V_2) is being sought (see Appendix 9 for a copy of the survey).

8. ***Key Exercise and Test Equipment:***

a. Standardized exercise mat (4'x8' Aeromat®, Fitness ProductsAeromat, Fremont, CA 94539)

b. Cuff weights (1 lb, 1.5-lb, 2-lb, 2.5-lb, 3-lb, 4-lb, 5-lb)

c. Theraband® (Green, 3 ft long; loop length 12 inches, The Hygenic Corporation, Akron, OH 44310)

d. Step stool (9-inch height),

e. Metronome.

f. 5-lb dumbbell

g. Stop watch

h. Measuring tape and yardstick

i. 60x60 cm block of 4-inch, medium-density, Tempur® foam

j. 10 degree (2x2 ft) incline ramp

k. Two stacked shoe boxes

l. Grip sock roll

m. Two standard chairs: one with and one without arms

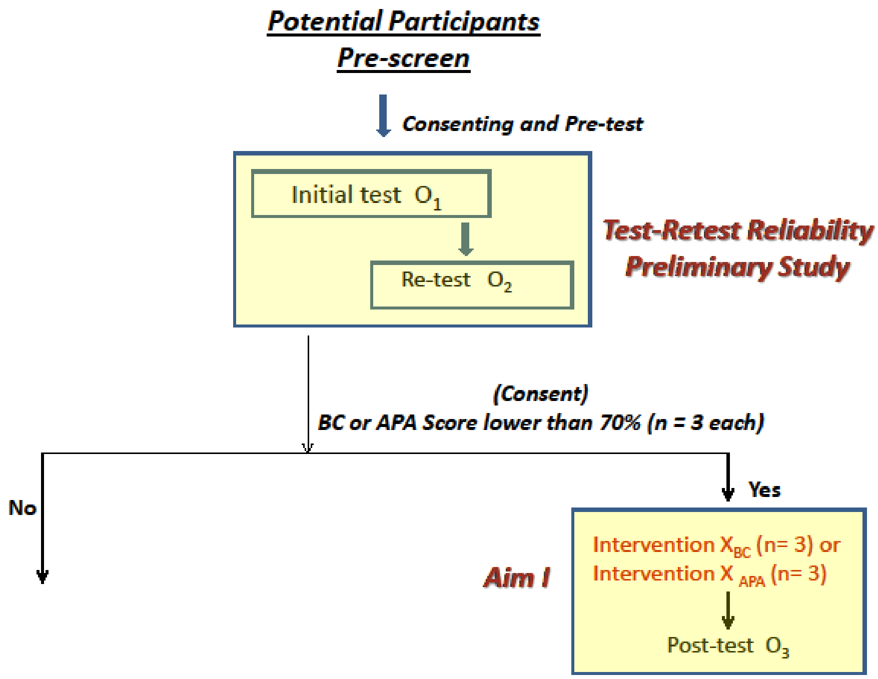

Figure 2. Diagram of Test-Retest Reliability and Aim 1.

Potential participants will be screened and consented. Qualified participants will be tested twice 7-14 days apart to determine test-retest reliability as part of a preliminary study (O_1 and O_2) and to identify participants for Aim 1 and obtain their baseline data. The first 3 older adults who score low (≤ 70%) in either the Biomechanical Constraints (BC) or Anticipatory Postural Adjustment (APA) component of balance will receive specific intervention based on their balance impairment (3 participants in each component; 6 participants total).

Note: O_1 = Observation #1; O_2 = Observation #2; O_3 = Observation #3;

X_{BC} = Specific exercise intervention for older adults with impairments in BC component of balance;

X_{APA} = Specific exercise intervention for older adults with impairments in BC component of balance.

Procedures:

The following is a list of study procedures:

1. I will perform all the tests and exercises in either the participants' own apartment or the hallway of the building where the participants live (with permission from the building administrators).

2. All potential participants will be pre-screened using a simple nameless yes/no pre-screen questionnaire to exclude people with progressive/unstable medical or other conditions that would prevent them from participating exercise programs (see Appendix 1 for the pre-screen questionnaire).

3. All potential participants will also complete the Mini Mental State Exam questionnaire (MMSE) to exclude people with cognitive impairments (Appendix 3 for MMSE).

4. Participants who meet the criteria after the pre-screen process (see Appendix 2 for inclusion and exclusion criteria) will be consented and pre-tested with health history, height, weight, FRAX score, UIC FFM, SF-12, BBS, and BESTest for baseline status.

5. All potential participants will be re-tested with the UIC FFM and BESTest 7-14 days later for concurrent test-retest reliability, regardless whether they are enrolled into Aim 1 and 2 studies or not. This ensures that the data of test-retest reliability includes older adults with all components of balance impairment rather than only the targeted two components. The test-retest reliability will continue throughout both the Aim 1 & 2 studies to ensure that there is no decline in reliability throughout the course of the studies (Domholdt, 2005).

6. A convenient consecutive sample will be selected for Aim 1 study. The first six older adults who fit the following criteria will be enrolled for Aim 1 study: a) elevated fall risk: BBS equals or lower than 49 of an optimal 56 points, and UIC FFM score equals or lower than 29 of an optimal 48 points; b) elevated fracture risk based on FRAX score (described previously); and c) balance impairments (score lower than 70%) in either BC or APA components, three with BC impairment and three with APA component impairment, but with no more than two impairments (scores lower than 70%) in other components. However, those who score low in both BC and APA components will be excluded from the study because they cannot be assigned to a particular group.

7. Older adults identified with BC impairment will be provided with primarily stretching and strengthening exercises. Older adults identified with APA impairment will be provided with exercises that improve standing postural control (see Appendices 11 and 12 for details of the exercises and progression). The progressive exercise program will be administered under my direct supervision as a physical therapist. Instruction will consist of 3 sessions per week within 6 weeks or a maximum of 18 total sessions. A recent systematic review on balance training (DiStefano, Clark, & Padua, 2009) for older adults indicated that programs performed at least 10 minutes per day, 3 days per week for 4 weeks or longer showed the potential to improve balance and to reduce fall risk. In addition, at the beginning of each exercise session, I will inquire about and record whether the participants having report fallen since the last session. A log will be kept as a record of exercise adherence, exercise progression, and reports of falls or other adverse events (see Appendix 10 for the log).

8. A post-test consisting of the UIC FFM, SF-12, BBS, and BESTest will be administered at the end of the 6-week intervention.

Data analysis:

Descriptive data on participants' characteristics and demographic information will be calculated and reported. The means and standard deviations of pre- and post- UIC FFM, SF-12, BBS, and BESTest components (BC and APA) and total scores will be calculated and reported. Qualitative information of participants' performance/adherence/feedback will also be reported from Aim 1 study. An improvement will be defined as a mean increase of more than minimum detectable change (MDC) from the baseline value for the total score. The primary outcome of Aim 1 study will be the BESTest components (BC and APA) and total scores, BBS and UIC FFM. The changes in quality of life will also be investigated using SF-12 as a secondary outcome.

Impact: The expected results of this case series will provide evidence that the score of the BC and of the APA components of BESTest are modifiable with specific exercise intervention. In addition, based on informal feedback from the participants, the exercises, or exercise instructions may be modified for clarity and realistic performance.

Time line for Aim 1: 3 months.

Aim 2. Determine the effectiveness of impairment-specific exercises in improving balance and reducing fall risk for older adults.

The second aim of this proposal will be accomplished with a two-phase small clinical randomized controlled trial (RCT).

Working Hypotheses:

Phase 1: Older adults who receive exercises specific to their targeted balance impairment will demonstrate improved balance and a reduced fall risk compared to older adults who receive no intervention.

Phase 2: Exercises that are matched to the specific balance impairment will be more effective than exercises that are mismatched to the targeted impairment for improving balance and reducing fall risk for older adults.

Approach: I will conduct a two-phase small, clinical randomized control trial (RCT) to determine the effectiveness of specific exercise interventions. Phase 1 will consist comparing the outcomes between the group that receives six weeks of impairment-matched exercises with a control group (delayed intervention group) that receives no treatment. In phase 2, the delayed intervention group will receive a six-week exercise program opposite to the participants' targeted balance impairment (impairment-mismatched intervention). The results of the mismatched intervention group from phase 2 will be compared to the results of the intervention group (matched intervention) from phase 1. An Institutional Review Board (IRB) for this two-phased study will be submitted for approval.

Research Design: two-phase, small randomized clinical trial.

In Phase 1, I will compare the effectiveness of an impairment-specific exercise intervention to no intervention. In Phase 2, I will compare the effectiveness of a matched versus a mismatched program of exercises.

Subjects/Participants: The population of interest is community-dwelling older adults with elevated fracture and fall risk because they are susceptible to fracture when they fall, as mentioned in the background session. Nine participants are needed in each group based on *a priori* power analysis (power = .80; G – Power analysis, 2009). This required number of subjects was obtained with an estimated large effect size [(≥ .6) Cohen, 1988] on the variables of UIC FFM, BBS, and BESTest total scores. The evidence for using a large effect size is supported by previous literature. A systematic review article (DiStefano et al., 2009) included eight RCTs that examined the effectiveness of balance exercises. The authors reported a large effect size (0.6-4.0) in seven of the studies. One showed no change before and after the exercise interventions. However, I will recruit 12 participants in each group with either a balance impairment in BC or APA to account for potential attrition. In other words, I will need total of 24 participants with BC impairment and 24 participants with APA impairments to be further randomly allocated into two groups. Participants will be recruited from a senior retirement community (Keystone Villa at Douglassville, PA) where they live independently.

Instrumentation, Tests and Measures (see descriptions given previously): MMSE, BESTest, UIC FFM, FRAX, Health History, BBS, SF-12 and Key Exercise and Test Equipment.

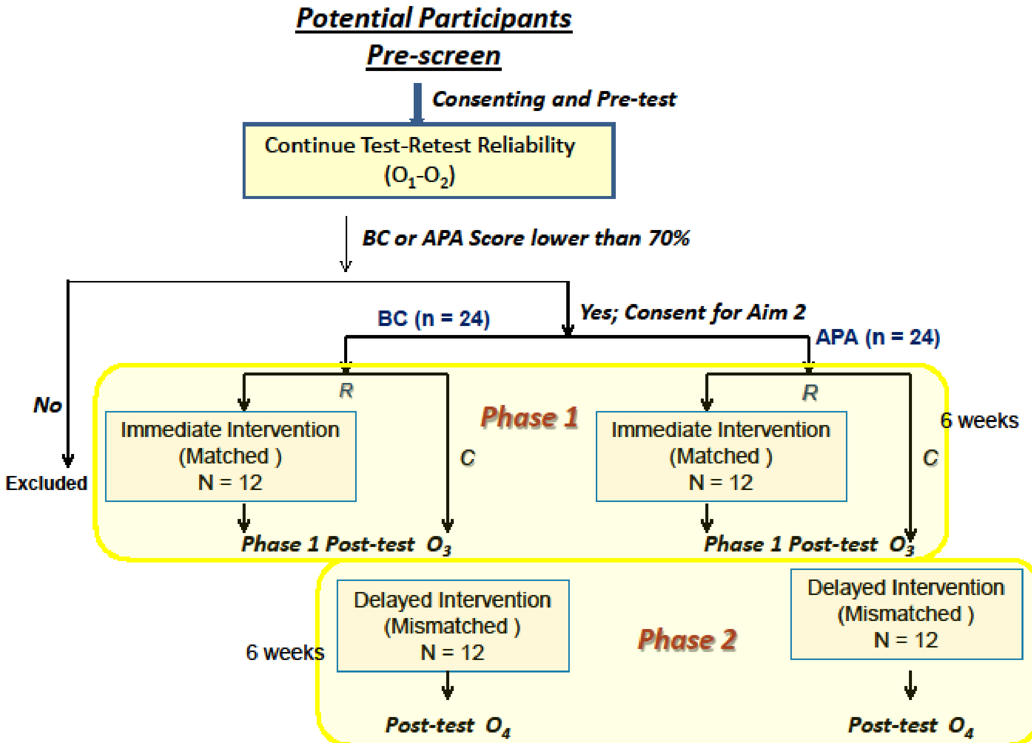

Figure 3. Diagram of Aim 2.

Aim 2 will consist of a two-phase small clinical randomized control trial (RCT). The entire Aim 2 study will proceed for 12 weeks, six weeks in each phase.

Phase 1. Specific intervention vs. control: Older adults who scored low in either Biomechanical Constraints (BC, n=24) or Anticipatory Postural Adjustment (APA, n=24) components will be randomly assigned to either a group that receives immediate intervention specific to their balance impairment (n=12 in each component of impairment), or a group that receives no intervention initially to serve as the control group in phase 1 (i.e., the delayed mismatched intervention group of phase 2, n = 12 in each component of impairment),with total of 48 participants.

Phase 2. Matched vs. mismatched intervention: Older adults in the delayed intervention group will receive a mismatched exercise intervention opposite to their identified component of balance impairment (12 participants with each component of impairment) in the second phase of the study.

Note: O_1 = Observation #1; O_2 = Observation #2; O_3 = Observation #3; O_4 = Observation #4; R = randomization; C = Control.

Procedures:

The second aim of this proposal will be accomplished with a two-phase, small clinical randomized controlled trials (RCT) described below. The following is a list of study procedures:

Phase 1: six weeks

1. As mentioned previously, I will perform all the tests and exercises in either the participants' own apartment or the hallway of the building where the participants live.

2. Similar to Study Aim 1, all potential participants will undergo the same screening and process of consenting for continuous test-retest reliability (see Figure 3 for details).

3. Participants will be tested initially with Health History form, FRAX score, UIC FFM, SF-12, BBS, and BESTest, and will be re-tested 7-14 days later for reliability.

4. The inclusion criteria for Aim 2 studies are the same as Aim 1 study: a) elevated fall risk based on UIC FFM and BBS scores; b) elevated fracture risk based on FRAX score;c) balance impairments (score lower than 70%) in either BC or APA components. A convenient consecutive sample will be selected for the two-phase Aim 2 study. The first 24 participants who score lower than 70% in the component of BC, but with no more than two other impairments in other components that score lower than 70%, will be recruited and consented. Similarly, the first 24 participants who score lower than 70% in the component of APA, but with no more than two impairments in other components that scores lower than 70% will also be recruited and consented. However, those who score low in both BC and APA components will be excluded from the study because they cannot be assigned to a particular group.

5. Qualified participants from each cohort (those with impairments in either BC or APA component) will be randomly allocated into one of two groups by the drawing without replacement method until the desired number in each cohort is met (12 in each group). This randomization will be executed consecutively as participants are admitted to the study. For example, an older adult with a BC impairment who consents to participate in my Aim 2 study and draws “delayed group” out of a hat will be assigned to the delayed (mismatched) group. That is, the participant will wait for 6 weeks in the phase one study and serve in the no treatment control group. After 6 weeks, the participant will receive the mismatched intervention in phase 2. Likewise, participants with a BC impairment who draw “treatment” out of the hat will immediately receive the matched intervention. This process will be the same for individuals with APA impairments. The entire process will continue until all 48 participants are recruited.

6. One group will receive immediate intervention based on their identified targeted balance impairment (intervention group), the other group will receive no intervention in the first 6 weeks during phase one of the study to serve as the control group (i.e., the delayed mismatched intervention group). As described previously, the immediate intervention group will consist of 12 participants with impairment in BC component and 12 participants with impairment in APA component. The other group (the delayed mismatched intervention group) will also consist of 24 participants, 12 with impairment in either BC or APA component.

7. Older adults who are assigned to the immediate intervention group identified with the BC impairment will immediately start performing primarily stretching and strengthening exercises; those identified with APA impairment will immediately be given

exercises to improve standing postural control (see Appendix 11 and 12 for exercise descriptions and diagrams). Older adults assigned to the other treatment group (control group of phase one, i.e., the delayed mismatched intervention group) will be instructed to continue their daily routine and not to change their activities while waiting for their delayed intervention. The progressive exercise program will be administered with my direct supervision. The program will consist of 3 sessions per week for 6 weeks or maximum of 18 total sessions. An exercise log will be kept as a record of exercise performance adherence and progression, and incidence of falls (see Appendix 10).

8. A post-test consisting of the UIC FFM, SF-12, BBS, and BESTest will be administered to participants in both groups at the end of 6 weeks of exercise. This will conclude phase one of the Aim 2 study.

Phase two: six weeks

1. As the phase two of Aim 2 begins, the older adults who were assigned to the delayed intervention group (i.e. the group that was originally served as the control group) will be given an exercise intervention opposite to their identified impairment of balance component. The exercise interventions will be the same described previously except for being opposite to the identified impairment (Appendix 11 and 12). In other words, those who are identified with APA impairment will perform primarily stretching and strengthening exercises; the ones identified with BC impairment will perform exercises that improve standing postural control. The progressive exercise program will also be performed with my direct supervision and instruction for 3 sessions per week over 6 weeks or maximum of 18 total sessions. An exercise log will be kept as a record of exercise adherence, progression and incidence of falls (see Appendix 10).

b. A post-test battery consisting of UIC FFM, SF-12, BBS, and BESTest will be administered at the end of the 6 weeks of exercise. This will conclude the phase two as well as the entire Aim 2 study. The results of the mismatched group will be compared to the results from the immediate intervention group (matched intervention) from phase one.

Data analysis:

Descriptive data (mean, standard deviation, standard error of measurement, confidence intervals) of participants' demographic information and characteristics will be calculated and reported.

The primary outcomes of the Aim 2 study will be the BESTest component (BC and APA) and total scores, BBS and UIC FFM. The changes in quality of life will also be investigated using SF-12 as the secondary outcome. All outcome variables including fall risk (BBS and UIC FFM), balance impairment (BESTest total and component scores) and quality of life (SF-12 scores) of both groups will be calculated and pretreatment scores compared to assess the homogeneity between the two groups.

Four within and between subjects mixed, two-way repeated measures analyses of variance (ANOVA) will be used for data analysis for each of the four primary variables (UIC FFM, BBS, and BESTest total and component scores) at the end of phase one to compare the intervention versus control groups. The same four analyses will be conducted at the end of phase two to compare matched versus mismatched intervention groups. The advantage of using repeated measures ANOVA is that each individual is compared to himself/herself; therefore, individual difference is controlled and the size of the error term in analysis of variance is reduced and resulting in a larger F-ratio. This analysis makes the test more powerful than independent sample designs (Portney &

Watkins, 2009; Tabachnick & Fidell, 2007). The assumptions of repeated measures ANOVA are independence, normality and homogeneity of variances (Leech et al., 2005; Portney & Watkins, 2009; Tabachnick & Fidell, 2007). I chose to use the repeated measure ANOVA despite of the small sample size because of the robustness of the statistical tool. However, I will check all assumptions. In addition, the alpha level will be adjusted to 0.013 (0.05/4 = 0.013) for each study phase because the same statistical analysis will be performed four times in each study, once with each primary outcome variable. In addition, participants' quality of life will also be compared between and within groups using repeated measures ANOVA as secondary outcome variable. Post hoc tests including polynominal contrast and Tukey's honestly significant difference (HSD) will be used to further examine within and between group differences.

In addition to statistical significance, improvement will be interpreted in two ways: 1) a true change, that is, a mean increase of more than the minimum detectable change (MDC) from the baseline value; and 2) a clinical significant difference, that is, a mean of at least 15% difference from the control group value (Philadelphia Panel, 2001).

All participants' data, including that of those participants who did not complete the intervention will be analyzed using intent-to-treat. A separate analysis, including only those who have successfully completed the exercises, will also be conducted and reported. In addition, I will report the participants' exercise adherence and incidence of falls.

Impact: The expected results of this two-phased small RCT will provide evidence for whether the exercise interventions are effective in reducing fall risk and improving quality of life. The results are also expected to provide evidence for the construct validity of the effectiveness of impairment-specific exercise interventions in improving balance and quality of life and reducing fall risk.

Time line for Aim 2 studies: 12 months.

Expected Outcomes: I expect the results from these studies from the two Aims will provide evidence for a treatment-based intervention for clinicians to prescribe an impairment-specific and individualized exercise intervention that will improve balance and quality of life and reduce fall risk for older adults with an elevated fracture and fall risk. The exercises will be specific to the individual's impairment in contrast to the current generic broad-based intervention. Targeted exercise interventions will enable older adults to live independently within their community and reduce the individual and societal cost of fall-related fractures.

Feasibility:

I work as a physical therapist at the onsite Manorcare Outpatient Rehabilitation Clinic located within the independent living community (Keystone Villa, PA) where I will primarily recruit the participants. The Villa is a senior retirement community where approximately 250 older adults live independently in their own apartments. The residents have their choice of driving or taking shuttles provided by the community for shopping and errands. They can also cook on their own or dine from a buffet for meals. Recruiting participants from this community will be facilitated because I am a familiar to most of the residents. I have given educational talks on the topic of fall risks and fall prevention on multiple occasions. In addition, I have obtained verbal permission to conduct these studies from the executive director of the community, Keystone Villa. I will obtain written consent from the director for Internal Review Board prior to initiating the studies.

Potential Limitations:

A list of potential limitations in the proposed studies is as follows:

1. ***The BESTest model***: The construct for the model may not be adequately comprehensive or definitive enough to differentiate (or diagnose) specific impairments in the BC or APA components of balance. My studies are expected to contribute to the extent of construct validity for these two components of balance.

2. ***Participants:*** The participants who will be included in my studies are likely to have impairments in multiple components of balance. As discussed previously, the six component of balance in the BESTest model are synergistic and not mutually exclusive; therefore, it may be difficult to single out an impairment in one component of balance. This may result in interactive and overlapping effects of exercise intervention and indistinguishable differences between the matched and mismatched groups. However, I plan to minimize this potential limitation with my inclusion and exclusion criteria.

3. ***Sampling method and sample size:*** A limitation of convenient sampling is the bias of "self-selection" (Portney & Watkins, 2009). Those who voluntarily participate in studies may not be representative of the target population. In addition, a relatively small sample size may not be normally distributed and may not reflect the true population of interest. I plan to minimize the effect of a sample that is not normally distributed by checking all the assumptions and making appropriate adjustments

4. ***Bias and blindness:*** I will administer all the tests. In addition, I will be the therapist who administers the exercises; therefore, I will not be blinded to the test results and group assignment. The inability to blind may create a potential observation bias when evaluating the outcome improvement because of my expectations (Portney & Watkins,

2009). However, to minimize this, I will place the results of the previous tests in a separate location and will not review them prior to each test.

5. ***Adherence and attrition:*** The participants may not adhere to the program or regimen. However, adherence issues will be minimized because I will directly supervise performance of the entire exercise routine. Data will be analyzed using intent-to-treat analysis. The data will also be analyzed by excluding those who dropped out. Result of both conditions will be presented. To address potential attrition, I will recruit a greater number of participants than estimated as required with the power analysis.

6. ***Exercise intensity:*** Recent literature recommends using the Borg Scale (Borg, 1970) to determine exercise intensity and the number of repetitions of each exercise when prescribing exercises for older adults (McDermott et al., 2006). This is because the Borg Scale indicates an individual's self-perceived level of exertion and fatigue with activities. However, I plan to use the conventional method of sets and repetitions with standardized progression criteria as the indicators of intensity of the exercises in my study. Standardizing the exercise program and progression criteria using individual Borg Scale scores would be difficult.

7. ***Fall history recall bias and interpretation of a fall:*** Despite my efforts to operationally define a fall, participants may still interpret the incidence of a fall differently. Also, the participants may not remember falling or be reluctant to report falling. Therefore, recall bias remains a potential bias. I will ask each participant about falling at the initiation of the study and at the beginning of each exercise session. I will re-emphasize the definition of a fall each time in order to minimize misinterpretation of what constitutes a fall.

8. ***Limitation of using the Fracture Risk Assessment tool (FRAX) to identify fracture risk:*** I plan to use FRAX scores as the indicator of each participant's fracture risk. However, the stance of the International Society for Clinical Densitometry (ISCD, 2009) is that FRAX scores may not be valid with adults who are receiving treatments such as bisphosphonate or calcitonin for osteoporosis. I will record and report all medications, vitamins, minerals and herbals related by each participant in order to determine the extensiveness of this potential limitation.

9. ***Issues with treat-to-task (or test):*** Older adults who are identified as having impairment in a targeted component of balance will receive exercises designed to improve that particular component of balance. Although I have attempted to avoid prescribing exercises that directly resemble the BESTest items, the prescribed exercises are, nevertheless, still similar to the items in BESTest attributed to the particular component of balance that I will be treating. This may be a limitation because improvements in the component of balance being treated may not represent a true improvement, but rather may result from the participants training to the task, or test.

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TIMELINE

The Table Illustrates the Anticipated Timeline to Execute the Proposed Studies.

	Submit IRB for Aim 1 and 2	Submit Grant Appli-cation (Adopt-a-Doc)	Recruit and exercises (data collection)	Submit Grant Appli-cation (PODS II)	Data Ana-lysis	Write Aim 1 Manu-script #1/ submit	Write Aim 2 Manu-script #2/ submit	Write Aim 2 Manu-script #3/ submit	Defend
Oct., 2012	X								
Nov., 2012		X	↑						
Dec., 2012			│						
Jan., 2013			│	X					
Feb., 2013			│						
March 2013			│		↑				
April, 2013			│		│	↑			
May, 2013			│		│	│			
June, 2013			│		│	│			
July, 2013			│		│	│			
Aug., 2013			│		│	↓	↑		
Sept., 2013			│		│		│		
Oct., 2013			│		│		│		
Nov., 2013			│		│		│		
Dec., 2013			│		│		↓	↑	
Jan., 2014			│		│			│	
Feb., 2014			│		│			│	
March 2014			↓		│			│	
April 2014					↓			↓	X

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CHAPTER II

INTERRATER AND TEST-RETEST RELIABILITY AND MINIMAL DETECTABLE CHANGE OF THE BALANCE EVALUATION SYSTEMS TEST (BESTEST) AND SUBSYSTEMS WITH COMMUNITY-DWELLING OLDER ADULTS

Authors:

Elizabeth Wang-Hsu, PT, MS, PhD Candidate

Department of Physical Therapy and Rehabilitation Sciences, Drexel University, Philadelphia, PA. (TEL) 610 592-6212

cw322@drexel.edu

Susan S. Smith, PT, PhD

Associate Dean for Research & Health Professions Graduate Education, College of Nursing & Health Professions

Associate Professor, Department of Physical Therapy and Rehabilitation Sciences, Drexel University, Philadelphia, PA. (TEL) 215 762-1758; (FAX) 215 762-3886

sue.smith@drexel.edu

The authors declare no conflict of interest.

Address correspondence to: Susan S. Smith, PT, PhD, College of Nursing and Health Professions, Drexel University, 245 N. 15th Street, MS 501, Philadelphia, PA 19102 (sue.smith@drexel.edu)

ABSTRACT

Background and Purpose: Falls are a common cause of injuries and hospital admissions in older adults. Impaired balance is a potentially modifiable factor contributing to falls. The Balance Evaluation Test System (BESTest), a recently developed clinical balance measure, categorizes balance impairments into six underlying subsystems. Each of the subsystems is scored individually and collectively they constitute a total score. The reliability of the BESTest and its individual subsystems has been reported in patients with various neurological disorders and cancer survivors. However, the reliability and minimal detectable change (MDC) of the BESTest with community-dwelling older adults has not been reported. The purposes of our study were to: (1) determine the interrater and test-retest reliability of the BESTest total and subsystem scores; and (2) estimate the MDC of the BESTest and its individual subsystem scores with community-dwelling older adults.

Methods: This was a prospective cohort methodological study. Community-dwelling older adults (n = 70; aged 70-94; mean = 85.0 ± 5.5) were recruited from an independent living senior community. Three trained testers administered the BESTest. All participants were tested with the BESTest by the same tester initially and then re-tested 7-14 days later. A second tester concurrently scored the re-test (n = 32). Testers were blinded to each other's scores. Intraclass correlation coefficients [$ICC_{(2, 1)}$] were used to determine the interrater and test-retest reliability. MDC was calculated using standard error of measurement (SEM).

Results: Interrater reliability (n = 32) of the BESTest total score was $ICC_{(2, 1)}$ = 0.97 (95% CI, 0.94-0.99) The ICCs for the individual subsystem scores ranged from 0.85-0.94. Test-retest reliability (n = 70) of the BESTest total score was $ICC_{(2, 1)}$ = 0.93 (95%

CI, 0.89-0.96). ICCs for the individual subsystem scores ranged from 0.72-0.89. Minimal detectable change (n = 70) for the BESTest total score at the 95% CIs was 7.6% or 8.2 points. MDC at the 95% CI for subsystem scores ranged from 11.7%-19.0% (2.1-3.4 points).

Discussion: Results demonstrated generally good to excellent interrater and test-retest reliability in both the BESTest total and subsystem scores with community-dwelling older adults.

Conclusion: The BESTest total and individual subsystem scores demonstrate good to excellent interrater and test-retest reliability with community-dwelling older adults. A change of 7.6% (8.2 points) or more in the BESTest total and a percentage change ranged from 11.7%-19.0% (2.1-3.4 points) in the subsystem scores are suggested for clinicians to be 95% confident of true change when evaluating change in this population.

Key Words: Interrater reliability, Test-retest reliability, Minimal detectable change, Balance, Geriatrics.

INTRODUCTION

Falls are one of the most common cause of injuries and hospital admissions in older adults.[1] Experts estimate that the annual direct and indirect cost of fall injuries will reach $54.9 billion by 2020.[2] Impaired balance is a potentially modifiable factor known to contribute to falls. Clinicians need to be able to identify individuals who have balance impairments and the underlying causes in order to decide on the most effective treatment approach. Dynamic balance is a complex skill based on the interactions of postural control and sensory-motor processes;[3] therefore, choosing the optimal test to assess the entire spectrum of balance and to identify specific balance impairments is a challenging task. Current standardized balance assessments are typically used to identify balance impairments and risk of falls; however, the tests are not designed to inform treatment decisions.

A recently developed clinical balance measure, the Balance Evaluation Test Systems (BESTest),[4] was developed using selected items from existing clinical balance tests including the Functional Reach Test,[5] Berg Balance Scale,[6] Dynamic Gait Index,[7] and Timed Up and Go.[8] The BESTest categorizes balance impairments into six underlying subsystems of balance control (Table 1). Each of these six subsystems is scored individually, and collectively, they comprise a summative total score. The conceptual framework of the BESTest model, organized with these subsystems of balance, may enable clinicians to identify the specific balance impairments based on the individual subsystem scores. Potentially this model may be useful as a guide to determining interventions specific to identified impairments in one or more of the subsystems of balance.[4] The BESTest is lengthy and it may take up to 45 minutes to complete for someone with moderate to severe movement dysfunction.[4,9] An abbreviated version, the Mini-BESTest,[9] was created using psychometric analysis. The Mini-BESTest is shorter in length and therefore takes less time to complete. However, the Mini-BESTest no longer retains the conceptual framework of underlying subsystems of balance that the original BESTest offered. An alternative shorter version, the Brief-BESTest,[10] was suggested using one item selected from each subsystem. Although the Brief-BESTest intended to preserve the construct of the BESTest, further studies are needed to determine whether a single item adequately represents the subsystem construct. The original BESTest provides the opportunity to evaluate, and possibly identify, the specific subsystems of balance impairments.

Table 1. Items Comprising the Balance Evaluation System Test (BESTest) Categorized by the Subsystems of Balance

Biomechanical Constraints	**Stability Limits/Verticality**	**Anticipatory Postural Adjustments**	**Postural Responses**	**Sensory Orientation**	**Stability in Gait**
1. Base of support	6. Sitting vertically (left and right) and lateral lean (left and right)	9. Sit to stand	14. In-place response, forward	19. Sensory integration for balance (modified CTSIB) Stance on firm surface, EO Stance on firm surface, EC Stance on foam, EO Stance on foam, EC	21. Gait, level surface
2. CoM Alignment	7. Functional reach forward	10. Rise to toes	15. In-place response, backward		22. Change in gait speed
3. Ankle strength and ROM	8. Functional reach lateral	11. Stand on one leg (left and right)	16. Compensatory stepping correction, forward		23. Walk with head turns, horizontal
4. Hip/trunk lateral strength		12. Alternate stair toughing	17. Compensatory stepping correction, backward	20. Incline, EC	24. Walk with pivot turns
5. Sit on floor and get up		13. Standing arm raise	18. Compensatory stepping correction, lateral (left and right)		25. Step over obstacles
					26. Timed "Get Up & Go" test
					27. Timed "Get Up & Go" test with dual task

Abbreviations: CoM = center of mass, ROM = range of motion, CTSIB = Clinical Test of Sensory Integration for Balance, EO = eyes open, EC = eyes closed.
This table is re-produced from Horak et al., 2009, p. 487 (*permission will be requested*).

The reliability[4,11-15] and concurrent validity[4,11,13-15] of the BESTest and the individual subsystems have been reported for adults with Parkinson's disease,[11,12] stroke,[13,14] other neurological conditions[4] and cancer survivors.[15] The BESTest has been validated against the Berg Balance Scale (BBS),[11,13,14] and the Activity-Specific Balance Confidence Scale (ABC)[4,14,15] in these populations. The interrater and test-retest reliability of the BESTest total score has been reported as good to excellent with ICC values ranging from 0.87 to 0.94;[4,11-15] the reliability of individual subsystem scores has also been reported from adequate to excellent with ICC values ranged from 0.63-0.96 in adults with the above-mentioned populations.[12,14] The minimal detectable change (MDC) for the BESTest total score was reported for only the sample (N = 28) of cancer survivors.[15] However, interrater and test-retest reliability and the MDC for the BESTest total and subsystem scores have not been reported for community-dwelling older adults aged 65 or above. Reliability and MDC for the BESTest and its subsystems with community-dwelling older adults will be useful to generalize the use of the BESTest. More importantly, the MDC of BESTest total and subsystem scores may provide an estimate of whether changes in the total BESTest score and the targeted subsystem scores reflect measurement variation or "true changes."

The purposes of the study were to: (1) determine the interrater and test-retest reliability of the BESTest and its individual subsystems; and (2) estimate the MDC of the BESTest total and individual subsystem scores for use with community-dwelling older adults.

METHODS

We used a prospective cohort methodological design. We also followed the "Guidelines for Reporting Reliability and Agreement Studies (GRRAS)"[16] and included relevant elements of Evaluation Database to Guide Effectiveness (EDGE) Task Force Outcome Measure Criteria.[17] Institutional Review Board approval was obtained for this study. All participants consented to participate.

Participants

Ninety-eight consecutive community-dwelling older adults were pre-screened over a 21-month period from April 2013 to December 2014. Participants were recruited as a sample of convenience from a senior independent living community located in suburban Pennsylvania via posted flyers and word-of-mouth. Inclusion criteria were: (1) apparently healthy, (2) aged 65 years or older, (3) community-dwelling, and (4) able to walk with or without assistive device independently for 100 feet. Individuals with unstable medical conditions, moderate to severe cognitive impairments, legal blindness, or currently receiving structured exercise interventions were excluded from the study.

Testers

Three testers administered the tests. Tester 1 (EWH) was a physical therapist with authorization for direct access and more than 20 years clinical experience. Tester 2 (HC) was a physician with 11 years clinical experience. Tester 3 (JB) was a physical therapist assistant with certified indirect supervision and over 20 years clinical experience. All three testers were trained by watching the BESTest DVD provided by the developer, studying instruction materials,[4] and practicing with each other.

Instruments

The BESTest[4] (Table 1) consists of 36-items scored on an ordinal scale from 0-3, with "0" indicating the lowest level of function and "3", the highest level of function. The total possible raw points is 108 (highest level of function). Total points are converted to a percentage score [(total point/108) × 100%]. Higher percentages indicate better balance.[4] The BESTest items are categorized into six subsystems of balance: (1) Biomechanical Constraints (BC; 15 points); (2) Stability Limits/Verticality (SLV; 21 points); (3) Anticipatory Postural Adjustments (APA; 18 points); (4) Postural Responses (PR; 18 points); (5) Sensory Orientation (SR; 15 points); and (6) Stability in Gait (SG; 21 points). Subsystem points are also converted to a percentage score. For example, 12 points in the BC subsystem would be converted to a score of 80% (12/15 × 100%), and 12 points in the APA subsystem would be converted to a score of 67% (12/18 × 100%). Higher scores indicate better performance. The total time required to complete the test once it is setup can be up to 45 minutes. Materials used for BESTest are: a half-inch thick floor mat, 9-inches step stool, stop watch, measuring tape and yardstick, 5" × 5" block of 4-inches thick (medium-density) Tempur® foam, 10-degree (2 × 2 ft) incline ramp, two stacked standard shoe boxes, an exercise mat table, and a standard chair with arms.[4]

Procedures

A flow diagram illustrated the study process (Figure). Potential participants were pre-screened for eligibility using a simple nameless yes/no pre-screen questionnaire. The Mini Mental State Examination with a cutoff score 17 or below[18] was used (permission obtained from PAR, Inc., Lutz, FL) to exclude individuals with moderate to severe cognitive impairment that would prevent their consenting and participation. In addition, we took participants' pulse (beats per minute; BPM) and blood pressure (BP, mmHg) prior to and after being tested. The testing therapist stopped all activities if any of the following signs were identified: (1) resting systolic blood pressure (SBP) ≥ 180 mmHg, (2) resting SBP ≤ 90 mmHg, (3) resting diastolic blood pressure (DBP) ≥ 110 mmHg, (4) resting heart rate < 40, or > 100 bpm, or (5) irregular pulse.[19]

Participants who met the criteria following the pre-screening were consented. An intake form was used to record participants' sex, age, weight, height, calculated body mass index (BMI), blood pressure (BP), heart rate (beats/min), and fall history in the past 12 months. Falls were defined as "any event in which a person inadvertently or unintentionally comes to rest on the ground or another lower level such as a chair, toilet or bed[20] whether the fall resulted in injury or not."[21] Seventy participants were initially tested by Tester 1. The participants' characteristics are shown in Table 2. All participants were re-tested 7-14 days later by Tester 1 to determine the test-retest reliability (n = 70, aged 70-94 yrs; mean = 85.0 ± 5.5). In 32 of the re-test sessions, one of the other two testers (Tester 2 or 3) observed concurrently and independently scored the participants to determine interrater reliability. Use of Tester 2 or 3 was based on the availability of the second tester. Testers did not discuss the participants' performance, and they were blinded to each other's scores. In order to minimize the variability of participants' energy level and performance at different time of the day, efforts were made to schedule the re-test sessions at the same time as the initial test. A flow diagram illustrates the testing procedure (Figure) No adverse events occurred during the course of the study.

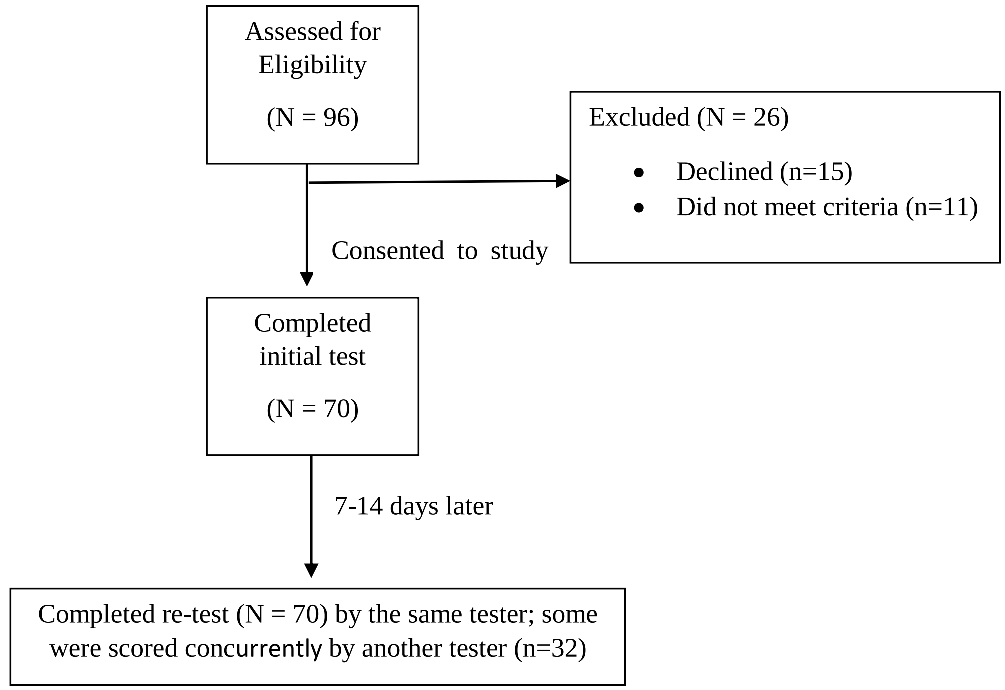

Figure. Flow diagram of participants for test-retest and interrater reliability study.

Data Analysis

Data were extracted, de-identified, and entered electronically into a spreadsheet. Data were analyzed using SPSS V.22 (IBM Inc., Chicago, IL, USA). Participants' demographic data were calculated (Table 2). Intraclass correlation coefficients [$ICC_{(2, 1)}$] were used to determine the interrater and test-retest reliability. Acceptable reliability was considered an ICC of 0.7 and above.[22] MDC at 90% and 95% confident interval (CI) was calculated using standard error of measurement (SEM)[22,23] using the following formula:

$SEM = ½ (SD_1 + SD_2) * \sqrt{(1\text{-}ICC)}$

$MCD_{90} = 1.65 * SEM * \sqrt{2}$

$MCD_{95} = 1.96 * SEM * \sqrt{2}$

Table 2. Characteristics of Participants

	Interrater Reliability N = 32 (11 men, 21 women)				**Test-retest Reliability N = 70 (27 men, 43 women)**			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Age, y	85.5	5.6	70.0	94.0	85.0	5.5	70.0	94.0
Height, cm	163.9	10.1	147.3	180.3	167.0	11.2	147.3	188.0
Weight, kg	72.0	15.4	46.7	122.0	73.5	15.4	40.4	122.0
BMI	26.6	5.2	20.7	44.9	26.2	5.1	16.8	44.9
BESTest total %	67.8	8.7	44.4	85.2	68.3	9.9	24.1	85.2
Biomechanical Constraints %	68.5	16.2	33.3	93.3	68.9	16.1	33.3	100.0
Stability Limits /Verticality %	79.6	7.7	52.4	90.0	79.5	7.8	52.4	90.0
Anticipatory Postural Adjustment %	59.4	13.0	38.9	100	61.6	14.6	16.7	100
Postural Response %	63.7	17.4	0.0	94.4	62.8	17.3	0.0	94.4
Sensory Orientation %	69.8	14.5	33.3	100	67.1	13.9	20.0	100.0
Stability Gait %	65.5	11.5	42.9	85.7	68.2	13.4	14.3	90.5
Abbreviation: BMI = Body mass index								

RESULTS

Test-retest reliability

The $ICC_{(2, 1)}$ for test-retest reliability (Table 3) of the BESTest total score was 0.93 (95% CI, 0.89-0.96), and the ICC values of the test-retest reliability for the individual subsystem scores ranged from 0.72-0.89. The Stability Limits/Verticality (SLV) subsystem demonstrated the lowest reliability with ICC value at 0.72 (95% CI = 0.59-0.82).

Interrater reliability

The $ICC_{(2, 1)}$ value foe the interrater reliability (Table 3) of the BESTest total score was 0.97 (95% CI = 0.94-0.99). The ICCs for interrater reliability of the individual subsystem scores ranged from 0.85-0.94. The SLV subsystem had the lowest ICC value at 0.85 (95% CI = 0.71-0.92).

Minimal Detectable Change (MDC)

The MDC scores for the BESTest total and individual subsystem scores are shown in Table 4. The MDC at the 90% and 95% CIs for the BESTest total scores were 6.4% and 7.6%, or 6.9 and 8.2 points, respectively. The MDC 90% CI values for the individual subsystems ranged from 9.9% to 16.0%, or 2.1 to 2.9 points. The MDC 95% CI values for the individual subsystems ranged from 11.7% to 19.0%, or 2.1 to 3.4 points.

Table 3. Interrater and Test-retest Reliability

	Interrater Reliability N = 32		Test-retest Reliability N = 70	
	ICC $_{(2, 1)}$	95% CI	ICC $_{(2, 1)}$	95% CI
BESTest total, %	0.97	0.94-0.99	0.93	0.89-0.96
BC subsystem, %	0.92	0.85-0.96	0.89	0.82-0.94
SLV subsystem, %	0.85	0.71-0.92	0.72	0.59-0.82
APA subsystem, %	0.94	0.88-0.97	0.84	0.76-0.90
PR subsystem, %	0.94	0.89-0.97	0.86	0.78-0.92
SO subsystem, %	0.91	0.79-0.96	0.79	0.69-0.87
SG subsystem, %	0.88	0.77-0.94	0.86	0.78-0.91

Abbreviations:
BC = BESTest Biomechanical subsystem.
SLV = BESTest Stability Limits/Verticality subsystem.
APA = BESTest Anticipatory Postural Adjustment subsystem.
PR = BESTest Postural Response subsystem.
SO = BESTest Sensory Orientation subsystem.
SG = BESTest Stability in Gait subsystem.

Table 4. Minimal Detectable Change for the BESTest Total and Subsystem Scores (N = 70)

Variable	SEM		MDC (95% CI)		MDC (90% CI)	
	Converted Score %	Points	Converted Score %	Points	Converted Score %	Points
BESTest total	2.74%	2.96	7.6%	8.2	6.4%	6.9
BC	5.37%	0.81	14.9%	2.1	12.5%	1.9
SLV	4.23%	0.89	11.7%	2.4	9.9%	2.1
APA	5.74%	1.03	15.9%	2.8	13.4%	2.4
PR	6.90%	1.24	19.0%	3.4	16.0%	2.9
SO	6.03%	0.90	16.7%	2.5	14.1%	2.1
SG	4.98%	1.05	13.8%	2.9	11.6%	2.4

Abbreviations:
SEM = Standard Error of Measurement
BC = BESTest Biomechanical subsystem.
SLV = BESTest Stability Limits/Verticality subsystem.
APA = BESTest Anticipatory Postural Adjustment subsystem.
PR = BESTest Postural Response subsystem.
SO = BESTest Sensory Orientation subsystem.
SG = BESTest Stability in Gait subsystem.

DISCUSSION

The purposes of this study were to determine the interrater and test-retest reliability and MDC for the BESTest total and its individual subsystems scores for community-dwelling older adults. We chose to test the original BESTest because we believe that the BESTest model using subsystems of balance may enable clinicians to identify the specific nature of the balance impairments based on the individual subsystem scores. Our results suggest that the BESTest demonstrates generally good to excellent interrater and test-retest reliability with community-dwelling older adults.

Reliability of the BESTest and individual subsystem have been reported for individuals with a variety of conditions.[4,12,14,15] Horak and colleagues[4] developed the original BESTest and tested 22 participants with neurological disorders to determine interrater reliability. They reported interrater reliability of the BESTest total scores as ICC = 0.91 with the individual subsystem ICCs ranging from 0.79-0.96. Leddy et al.[11] reported interrater reliability (n = 15) of the BESTest total score as $ICC_{(2, 1)} = 0.96$ and test-retest reliability as $ICC_{(2, 1)} = 0.88$ in 24 participants with Parkinson's disease. The same authors[12] also reported the reliability of the subsystem scores ranging from [$ICC_{(2, 1)}$] = 0.63-0.96. These authors did not report MDC values. Rodrigues and coworkers[14] tested 16 people with hemiplegia to determine the intrarater and test-retest reliability of the BESTest total and individual subsystems. They reported good to excellent intrarater reliability for the BESTest (ICC = .98) and its subsystems ranging between ICC = 0.85-0.96; and test-retest reliability for the BESTest (ICC = 0.93) and subsystems ranging between ICC = 0.71-0.94. Chinsongkram et al.[13] tested 12 adults with subacute stroke and reported excellent interrater and test-retest reliability [$ICC_{(3, 1)} = 0.99$ and $ICC_{(2, 1)}$ =

0.96, respectively). However, they did not report the reliability of the individual BESTest subsystems scores. Huang and coworkers[15] used the BESTest to evaluate 28 cancer survivors. They reported interrater reliability as $ICC_{(2,1)} = 0.96$, and test-retest reliability as $ICC_{(2,1)} = 0.92$ for the total BESTest score. In addition, these authors reported a MDC value of 6.9% for the BESTest total score. These authors did not report information about the individual subsystem scores.

In summary, our results are comparable to the previous studies, therefore providing evidence that the BESTest is reliable for a variety of populations, including community-dwelling older adults. The test-retest reliability ($ICC_{(2,1)} = 0.93$) and interrater reliability ($ICC_{(2,1)} = 0.97$) with our population of community-dwelling older adults was consistent with the test-retest reliability (ICC = 0.88 to 0.98) and the interrater reliability (ICC = 0.91 to 0.99) reported in the literature with other populations. Our test-retest and interrater reliability of the individual subsystem scores are also similar to that reported in the literature.

Our results showed good to excellent[22] interrater and test-retest reliability in both the BESTest total and subsystem scores in community-dwelling older adults with the exception of the test-retest reliability of SLV subsystem. However, similar to the results from Leddy et al.,[12] we noticed that amongst the reliability for the subsystem scores, the SLV subsystem had the lowest test-retest reliability [ICC = .72 (95% CI .59-.82)]. Typically, the two main reasons for finding lower ICC values are rating disagreement and limited variability among participants' scores.[22] To investigate our rating agreement, we investigated the interactions between ratings and participants' scores. We found no interaction between ratings and participant scores from the repeated measures analysis of variance (ANOVA). In addition, a paired t test indicated no difference between the means of test and retest scores. Therefore we concluded that ratings of the initial and retest scores were in agreement. We then investigated the variability among participants' SLV subsystem scores. We compared the variance for all variables including BESTest total and subsystem scores with their raw points and converted percentage scores. We found that the participants' scores in the SLV subsystem had a limited range of scores from 52.4 to 90.0% (equivalent to 11-19 point from a possible 21 points) with variance of 13.3% which equates to only 2.8 points. Reliability is defined as true variance divided by total variance. Thus, the variance decreases, the reliability coefficient also decreases. The lower variance in the SLV subsystem may contribute to the lower ICC value. Our findings are similar to those of Leddy et al.,[12] who reported that the SLV subsystem scores were not normally distributed and had an unequal variance. These findings suggest that either our population showed a more consistent performance in SLV subsystem, or the test items in the SLV subsystem maybe too broad to distinguish performance differences.

Several researchers recommend that statistical significance alone is not sufficient when evaluating outcomes of interventions.[22,23,26] Stratford et al. [23] suggested calculating MDC as an indication of absolute reliability. MDC is the amount of change in a given measure that must be obtained to determine whether true change has occurred between two testing occasions. The MDC is expressed as a confidence interval around the SEM, indicating the values that are within the range of variability (error) attributed to the testing instrument. MDC can provide clinicians useful and easy-to-understand criteria to assess change (improvement or decline) in an individual's performance. Our results indicated that the MDC of BESTest total score at 95 % CI was 7.6% (8.2 points), which was similar to the results from Huang et al.,[15] who reported a MDC of 6.2% (6.86 points) for cancer survivors. Our results at the 95% CI for MDC of the individual subsystem scores ranged from 11.6% to 19.0% (2.1-3.4 points). Thus a larger change in the individual subsystem scores is needed for clinicians to be 95% confident of a true change. No other authors reported MDCs for the individual subsystem scores.

Our results fill an essential gap and may facilitate the use of BESTest with community-dwelling older adults. Our sample size is large compared to previous similar studies. Further, the age of our participants (mean = 85.0 years; 70-94 years of age) is older than the participants in the similar studies. As previous literature indicates, balance and physical performance gradually decline with age.[1,24]

Our results also suggest a potential "norm value" of BESTest in community-dwelling adults who are older, 70 to 94 years of age. Interestingly, we compared our mean value for the BESTest total scores (68.3%) to the normative data suggested by O'Hoski et al.[25] We found our mean value was lower than the suggested normative value for the equivalent age group. O'Hoski et al. reported a normative value for BESTest total score of 85.4% for aged 70-79 years (n = 20) and 79.4% for aged 80-89 years (n = 20)[25] compared to our BESTest total score mean value at 68.3% for individuals aged 70-94 years. A possible explanation is that the sample from our study and the sample tested by O'Hoski and co-workers[25] represented samples with different activity or fitness levels, although both investigating groups recruited "community-dwelling adults." The term "community-dwelling" has been widely used, but is not well defined. Older adults who live in senior independent living communities, older adults who live with caregivers, and older adults who live alone may have different activity and fitness levels, therefore, yielding differing BESTest scores. For future studies we suggest use of an activity level scale rather than relying simply on living environment to better define "community-dwelling."

As stated previously, our findings may be limited by the ambiguous term "community-dwelling older adults." Additionally, all our participants were Caucasian and volunteers. Participants may have "learned the tasks" when they were tested more than once which may have contributed to the test-retest reliability results. Further studies are needed to include "community-dwelling older adults" from various living environments and racial and ethnic groups, and better define the fitness or activity levels of the participants.

CONCLUSION

Our results indicate that the BESTest total and the individual subsystem scores generally demonstrate good to excellent interrater and test-retest reliability in community-dwelling older adults. A change of 7.6% (8.2 points) or more in the total BESTest scores and a change more than 11.7-19.0% (2.1-3.4 points) in the various subsystem scores are needed for clinicians to be 95% confident of a true change when using the BESTest to evaluate changes in balance for community-dwelling older adults.

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CHAPTER III

USING A MODEL TO PRESCRIBE IMPAIRMENT-SPECIFIC EXERCISES TO REDUCE FALL RISK IN COMMUNITY-DWELLING OLDER ADULTS WITH FALL AND FRACTURE RISKS: A PROOF-OF-CONCEPT CASE SERIES

Authors:

Elizabeth Wang-Hsu, PT, MS, PhD Candidate

Department of Physical Therapy and Rehabilitation Sciences, Drexel University, Philadelphia, PA. (TEL) 610-592-6212

cw322@drexel.edu

Fay B. Horak, PT, PhD

Professor, Department of Neurology, Adjunct Professor of Physiology and Pharmacology, Adjunct Professor of Biomedical Engineering, Neuroscience and Behavioral Neuroscience Graduate Faculty, Oregon Health & Sciences University

Director, Balance Disorders Laboratory and Fall Prevention Laboratory,

Parkinson’s Center of Oregon, 181 SW Sam Jackson Park Road, Sam Jackson Hall Rm 2251, Portland, OR 97239-3098. (TEL) 503-346-0842, (FAX) 503-494-9059

horakf@ohsu.edu

Sheri P. Silfies, PT, PhD

Associate Professor, Department of Physical Therapy & Rehabilitation Sciences, Drexel University, Philadelphia, PA. (TEL) 215-762-1758; (FAX) 215-762-3886

sps26@drexel.edu

Susan S. Smith, PT, PhD

Associate Dean for Research & Health Professions Graduate Education, College of Nursing & Health Professions

Associate Professor, Department of Physical Therapy and Rehabilitation Sciences, Drexel University, Philadelphia, PA. (TEL) 215-762-1758; (FAX) 215-762-3886

sue.smith@drexel.edu

The authors declare no conflict of interest.

Address correspondence to: Susan S. Smith, PT, PhD, College of Nursing and Health Professions, Drexel University, 245 N. 15th Street, MS 501, Philadelphia, PA 19102 (sue.smith@drexel.edu)

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ABSTRACT

Background and Purpose. Balance involves complex interacting subsystems. Several conceptual models of balance have been proposed; however, no model has been universally accepted. Clinical tests of balance frequently assess only selected subsystems of balance, and do not guide in prescribing impairment-specific exercises. Consequently, current balance exercises tend be broad-based and generic. Our purpose was to determine whether using a theoretical model to prescribe exercises for identified impairments in selected subsystems of balance could reduce impairment and fall risk. This is a prospective, test-retest, proof-of-concept, case series.

Case Description. Community-living healthy older adults (n = 6) with fall and fracture risk and an identified balance impairment in either biomechanical (BC; n = 3) or anticipatory postural adjustment (APA; n = 3) subsystems, as identified using the BESTest, participated the case series. Participants completed a 6-week (total of 18 sessions) progressive exercises targeted to their identified balance subsystem impairment.

Outcomes. All 6 participants demonstrated reduced impairment in the targeted subsystem of balance and reduced fall risk post-treatment. Additionally, follow-up tests were administered with 3 participants 9 to 15 months post program. Participants' subsystem scores remained similar to their post-test scores and all participants reported continuing the exercise program.

Discussion. We used a theoretical model to identify selected balance subsystem impairments and prescribed exercises specific to those impairments. Our results suggested that using a model to more precisely identify balance impairments in selected subsystems and implementing a targeted exercise interventions may be conceptually valid

and worthy of study. We recommend randomized controlled trials with larger sample sizes to determine effectiveness of interventions.

BACKGROUND AND PURPOSE

Fall-related fractures in older adults are a significant cause of morbidity and decreased quality of life.[1] Impaired balance is a potentially modifiable factor known to contribute to falls.[1-4] Bernstein and others have proposed theories that postural control results from a number of interacting systems.[2-5] Several conceptual models have been suggested to represent postural control, or balance.[3-5] For example, Shumway-Cook and Woollacott[4] proposed a system framework, or model that involves 7 subsystems: musculoskeletal, neuromuscular synergies, individual sensory systems, sensory strategies, anticipatory mechanisms, adaptive mechanisms, and internal representation. Horak et al.[3] categorized balance into 6 subsystems: biomechanical constraints (BC), stability limits/verticality (SLV), anticipatory postural adjustments (APA), postural responses (PR), sensory orientation (SO) and stability in gait (SG). Recently, a systematic scoping review was used to identify yet another framework for balance, consisting of 6 subsystems: biomechanical constraints, orientation in space, movement strategies, control of dynamics, sensory strategies and cognitive processing.[5] To date, no theoretical model of balance has been universally accepted. In addition, the test items in each subsystem are not uniformly defined. For example, the ability to move center of mass out of base of support (reaching forward and sideways) was included in in the biomechanical (BC) subsystem in the framework proposed by Sibley et al.[5] Conversely, reaching forward and sideways is categorized in the anticipatory postural adjustment (APA) subsystem in some other models because it represents initiation a voluntary movement.[3,4]

Because of the complexity, balance is a challenge not only to model but also to evaluate. Clinical balance assessments are primarily designed to identify balance impairments and to determine fall risk. Further, several of these tests assess only selected aspects of balance. For example, the Berg Balance Scale (BBS)[6] has been considered the gold standard to evaluate balance and to identify fall risk.[7] However, the BBS does not categorize performance items by subsystems, nor is it comprehensive. For example, the BBS does not include tests of gait or response to perturbation.[5] Further, the BBS is not designed to guide clinicians in prescribing specific interventions. A recent meta-analysis[5] summarized 66 standardized measures for balance, and concluded that the Balance Evaluation Systems Test (BESTest, Table 1),[3] was a more comprehensive test that also categorized balance assessment by subsystems. Horak et al. suggested that the BESTest might be used to diagnose balance impairments and to direct specific interventions.

Exercise is an evidence-based intervention demonstrated to improve balance and to prevent falls.[1,8-11] A Cochrane systematic review presented evidence for the effectiveness of exercises to improve balance.[10] Outcomes from 34 studies with total of 2,883 participants were reviewed. The authors concluded that exercises are effective in improving balance and reducing fall risk. However, the overall strength of the evidence was limited by a failure across the studies: the lack of a standardized exercise prescription.[10] Current balance exercises programs are typically multi-dimensional.[9,10,12] Consequently, balance exercise programs typically consist of a large number of broad-based exercises that are time-consuming to perform, discouraging, and difficult for individuals to adhere to.[11,13]

Conceptually, rather than implementing a generalized approach, clinicians may be able to prescribe exercises specific to identified impairments in a particular balance subsystem or subsystems. This more directed approach may require fewer exercises and facilitate adherence as well as assuring the clients' impairments are, in fact, being addressed. To our knowledge, the effectiveness of using a theoretical model to identify specific balance impairments and then to direct exercises targeted to improve balance and reduce fall risk has not been determined.

The purpose of our prospective, test-retest, proof-of-concept, case series was to determine whether selected impairments in a subsystem of balance identified with a model are modifiable with specific exercises and will reduce fall risk for community-dwelling older adults with both fall and fracture risks. We chose to use the BESTest model to identify the specific balance subsystem impairments and then provided exercises designed to reduce these impairments in 2 subsystems: the BC (musculoskeletal)[3-5] and APA[3,4] subsystems. This case series followed the Case Report (CARE) guideline.[14]

Table 1. Test Items Comprising the Balance Evaluation System Test (BESTest) by the Subsystems of Balance.

Subsystem	**Biomechanical Constraints**	**Stability Limits/ Verticality**	**Anticipatory Postural Adjustments**	**Postural Responses**	**Sensory Orientation**	**Stability in Gait**
Construct	Postural alignment and lower extremities strength	How far the Body's CoM can be moved over its BOS	Initiation of a voluntary movement	Automatic responses to external forces/ perturbations	Spatial responses with changes in the supporting surface or visual feedback	Changes in gait at various circumstances and distractions
Test Items included in Subsystem	**1.** BOS	**6.** Sitting vertically (left and right) and lateral lean (left and right)	**9.** Sit to stand	**14.** In-place response, forward	**19.** Sensory integration for balance (modified CTSIB) Stance on firm surface, EO Stance on firm surface, EC Stance on foam, EO Stance on foam, EC	**21.** Gait, level surface
	2. CoM Alignment	**7.** Functional reach forward	**10.** Rise to toes	**15.** In-place response, backward		**22.** Change in gait speed
	3. Ankle strength and ROM	**8.** Functional reach lateral (left & right)	**11.** Stand on one leg (left and right)	**16.** Compensatory stepping correction, forward		**23.** Walk with head turns, horizontal
	4. Hip/trunk lateral strength		**12.** Alternate stair toughing	**17.** Compensatory stepping correction, backward	**20.** Incline, EC	**24.** Walk with pivot turns
	5. Sit on floor and get up		**13.** Standing arm raise	**18.** Compensatory stepping correction, lateral (left and right)		**25.** Step over obstacles
						26. Timed "Get Up & Go" test
						27. Timed "Get Up & Go" test with dual task

Abbreviations: BOS = base of support, CoM = center of mass, ROM = range of motion, CTSIB = Clinical Test of Sensory Integration for Balance, EO = eyes open, EC = eyes closed.
This table is modified from Horak et al., 2009, p. 487; permission will be sought if accepted for publication.

CASE DESCRIPTIONS

As a part of a concurrent reliability study, community-dwelling older adults were pre-screened between May 2013 and December 2014, as a sample of convenience from a senior independent living facility located in suburban Pennsylvania. The pre-screen consisted of administering a nameless yes/no questionnaire and the 30-point Mini Mental State Exam questionnaire (MMSE).[15] The inclusion criteria were: (1) community-dwelling, (2) 65 years of age or older, (3) apparently healthy, (4) able to walk with or without an assistive device independently for 100 feet. Exclusive criteria were individuals with progressive/unstable medical conditions and cognitive impairments. We used a cutoff score of 17 or less to exclude individuals with moderate to severe cognitive impairment.[16] This concurrent reliability study was approved by Drexel Internal Review Board (IRB). All potential participants gave their consents to be tested for this concurrent reliability study.

CLINICAL IMPRESSION #1

Participants' characteristics consisting of sex, age, weight, height, calculated body mass index (BMI), pre-test blood pressure (BP) and heart rate (beats/min), and 12-month fall history were collected. Falls were defined as "any event in which a person inadvertently or unintentionally comes to rest on the ground or another lower level such as a chair, toilet or bed[17] whether injured or not."[18]

EXAMINATION

Two testers conducted the examination. Tester 1 was a physical therapist (EWH) with over 20 years clinical experience. Tester 2 was a physical therapist assistant with over 20 years clinical experience. Interrater reliability between the 2 testers, test-retest reliability and the minimal detectable changes (MDC) for the outcome variables were previously determined as reported in Chapter II (also see Table 2). Tester 1 administered the initial test battery and consented all participants.

Table 2. Reliability and Minimal Detectable Changes Data from the Concurrent Methodological Study.

Variable	**Interrater Reliability (N = 32)**		**Test-retest Reliability (N = 70)**		**MDC (95% CI)**
	ICC $_{(2, 1)}$	**95% CI**	**95% CI**	**ICC $_{(2, 1)}$**	
UIC FFM	0.99	(.98-.99)	0.98	(.96-.99)	2.6 (points)
BBS	0.97	(.94-.98)	0.97	(.94-.98)	3.0 (points)
BESTest Total	0.97	(.94-.99)	0.93	(.89-.96)	7.6 (%)
BC Subsystem	0.92	(.85-.96)	0.89	(.81-.94)	14.9 (%)
APA Subsystem	0.94	(.88-.97)	0.84	(.76-.90)	15.9 (%)

Abbreviations: UIC FFM = University of Illinois in Chicago Fear of Falling Measurement; BBS = Berg Balance Scale; BESTest = the Balance Evaluation Systems Test; BC = Biomechanical Constraints; APA = Anticipatory Postural Adjustments; ICC = Intraclass Correlation Coefficient; CI = Confident Interval; MDC = minimal detectable change.

The test battery of the concurrent reliability study consisted of determination of fracture risk, fall risk, balance and quality of life. Details of outcome variables and their operational definitions are described as follows:

Fracture Risk

We used the Fracture Risk Assessment (FRAX)[19] scores to identify individuals with fracture risk for this study. The FRAX is a simple tool used to calculate adult fracture risk that can be used with or without Dual Energy X-ray Absorptiometry (DXA) results. The FRAX model estimates fracture risk using a formula that includes risk factors based on demographic and health information, i.e., age, race, sex, past history of fracture, smoking, alcohol use, etc.[19] The FRAX yields an "absolute 10-year fracture risk" score and "10-year hip fracture risk" score.[19] A person with a 10-year probability of a hip fracture ≥ 3% or a 10-year probability of a major fracture ≥ 20% is considered to have a high fracture risk.[19] Individuals who met either of the criteria for hip fracture or a major fracture qualified as having a fracture risk.

Fall risk

We used the Berg Balance Scale (BBS)[6] and the University of Illinois at Chicago Fear of Falling Measurement (UIC FFM)[20] to identify fall risk. The BBS[6] is a 14-item scale, scored on an ordinal scale from 0-4. A "0" indicates the lowest level of function and "4" the highest level of function. The total possible score is 56 points (highest level of function). The BBS evaluates balance during tasks of daily living, progressing from easy to difficult. Although the BBS[6] is commonly used to identify fall risk in older adults, results of a recent systematic review recommended that BBS be used in conjunction with other test(s) to more accurately predict fall risk.[21]

To supplement the physical performance assessment (BBS), and more accurately identify fall risk, we also used a psychological measure of fear of falling, the University of Illinois at Chicago Fear of Falling Measurement (UIC FFM).[20] Older adults who have fallen may develop a fear of falling even if they were not injured from the fall.[20,22-24] Fear of falling can cause individuals to limit their activities leading to reduced mobility and loss of physical fitness, which, in turn, further increases the risk of falling, and experiencing a poorer quality of life.[22-24] The UIC FFM[20] is a 16-item self-administered questionnaire. Individuals are asked to rate their fear of falling for each of the 16 activities on a scale of 1 to 3. The rating of "1" equals being "very worried" and "3" equals "not worried" about falling. The questionnaire consists of typical daily activities progressed from easier tasks to more difficult tasks. Higher UIC FFM scores indicate lower fear of falling.[20] Our preliminary work demonstrated that UIC FFM is an independent predictor for falls;[25] and using UIC FFM in conjunction with BBS improved the predictability of fall risk.[26] An individual had a BBS score equal or lower than 49 of an optimal 56 points[18] and a UIC FFM score equal to or lower than 29 of an optimal 48 points[25] is defined to have a fall risk.

Balance Evaluation

As noted, we used the BESTest (Table 1)[3] to evaluate individuals' balance because the BESTest consists of identified subsystems. The BESTest is a dynamic balance performance assessment tool consisting of a 36-item scale (scored on an ordinal scale from 0-3) with "0" indicating the lowest level of function and "3" the highest level of function. The total possible raw score is 108 points (highest level of function). Raw scores are then converted to percentage [(108/108) x100% = 100%]. The BESTest categorizes test items into 6 subsystems (Table 1). Each of these subsystems also yields a score that is converted to percentage.[3] We arbitrarily defined that an individual who scored 70% or less in a subsystem as having a balance impairment in that subsystem.

Quality of Life

As a secondary outcome, we assessed quality of life (QoL) using the self-administer Short Form Health Survey (SF-12, Version 2; QualityMetric Inc.) questionnaire. The survey consists of 12 questions scored on an ordinal scale that requires 3-5 minutes to complete. The questions request information about self-perceived quality of life in mental and physical domains. Licensed software was used to calculate the scores in physical and mental health. Scores on the SF-12 are based on z-scores of general US population.[27] A score of 50 represents the average point within the population. Scores greater than 50 indicate above-average QoL, and scores less than 50 indicate below-average QoL.

CLINICAL IMPRESSION #2

We reviewed the results from the concurrent reliability study to identify eligible participants for this case series. The first 6 participants (aged 82-94 years) met the fracture and fall risk criteria as well as the BESTest criterion of a score ≤ 70% in either BC or APA subsystems qualified for the exercises program targeted to address balance impairments in these subsystems. Three participants with BC subsystem impairment and with impairments in no more than 2 other subsystem, were identified and invited to participate this case series. Three participants with APA subsystem impairment and with impairments in no more than 2 other subsystem, were also invited to participate. All 6 participants gave their consents for this case series. The 6 participants were all Caucasian, and ambulated without assistive devices. Characteristics, demographic information, fracture risk (FRAX), fall risk (BBS and UIC FFM), balance (BESTest total and subsystems), and QoL (SF-12) of the 6 participants for this case series are shown in Table 3.

Table 3. Participants' Characteristics and Demographic Information.

	Participants with BC Balance Impairment			**Participants with APA Balance Impairment**		
Participants #	**BC1**	**BC2**	**BC3**	**APA1**	**APA2**	**APA3**
Sex	Man	Man	Woman	Woman	Woman	Woman
Age (yr)	90	87	94	82	87	92
Height (cm)	178	185	155	150	156	158
Weight (kg)	73	98	66	47	43	73
Body Mass Index (BMI)	23.0	27.4	28.4	20.8	17.4	29.3
Cognition (MMSE)	29	27	29	29	30	29
Educational level	HS	PhD	HS	HS	BS	HS
Self-reported health	Good	Good	Good	Good	Good	Fair
Fall history (past 12 mo.)	Yes	Yes	Yes	Yes	Yes	Yes
Fracture Risk (FRAX)						
Major fracture (%)	15	29	28	47	25	17
Hip fracture (%)	10	20	12	30	17	7
Fall Risk						
BBS (point)	47	41	42	46	45	42
UIC FFM (point)	28	29	24	28	29	29
BESTest Total (%)	85.0	72.2	71.3	62.0	67.6	60.1
BC subsystem (%)	66.7	60.0	46.7	73.3	93.3	73.3
APA subsystem (%)	72.2	77.8	88.9	38.9	50.0	44.4
QoL Score (SF-12)						
Physical	52	44	43	57	49	52
Mental	58	46	44	52	64	60

Abbreviations: MMSE = Mini Mental State Exam; HS = High School; FRAX = Fracture Risk Assessment; BBS = Berg Balance Scale; UIC FFM = University of Illinois in Chicago Fear of Falling Measurement; BESTest = the Balance Evaluation Systems Test; BC = Biomechanical Constraints; APA = Anticipatory Postural Adjustments; QoL = Quality of Life; SF-12 = Short Form Health Survey (used with permission).

APPROACH

A systematic review on balance training[8] for older adults indicated that programs performed at least 10 minutes per day, 3 days per week for minimum of 4 weeks or longer showed the potential to improve balance and to reduce fall risk. Adapting these guidelines, each participant completed a 6-week, 18-session progressive exercise program, supervised by Tester 1. Participants with a BC impairment completed the exercises targeted to improve the BC subsystem, i.e., exercises primarily aimed at strengthening and flexibility exercises with emphasis on power and speed. Cuff weights and therabands were used for resistance. Participants identified with APA impairment performed a specific exercise program targeted to improve the APA subsystem of balance, primarily consisting of dynamic standing postural control exercises that challenged the center of gravity moving out of the base of support in various directions. Both programs consisted of 9 exercises (see Appendix for detailed exercise descriptions), and required 25-40 minutes to complete.

At the beginning of each exercise session, the therapist inquired whether the participant had fallen since the last session. An exercise log was kept as a record of exercise adherence, exercise progression, report of falls or other adverse events. Each exercise was progressed through 3 steps, or levels, of difficulty. Level I was the easiest and Level III the most challenging. Progress was determined by the participants' ability to complete 2 sets of 10 repetitions of an exercise without substitutions or discomfort. Generally individuals progressed to the next level in 2 weeks. All participants reached Level III for each exercise by completion of the 18 sessions.

A post-test, consisting of the BBS, UIC FFM, BESTest and SF-12, was administered at the end of the 6-week intervention by Tester 2, who was blinded to the participants' balance impairments, initial test results, or the exercise program allocation. Tester 1 performed follow-up testing of the BESTest 9-15 months after completion of the supervised exercise program. A flow chart (Figure) illustrated the entire process of this case series.

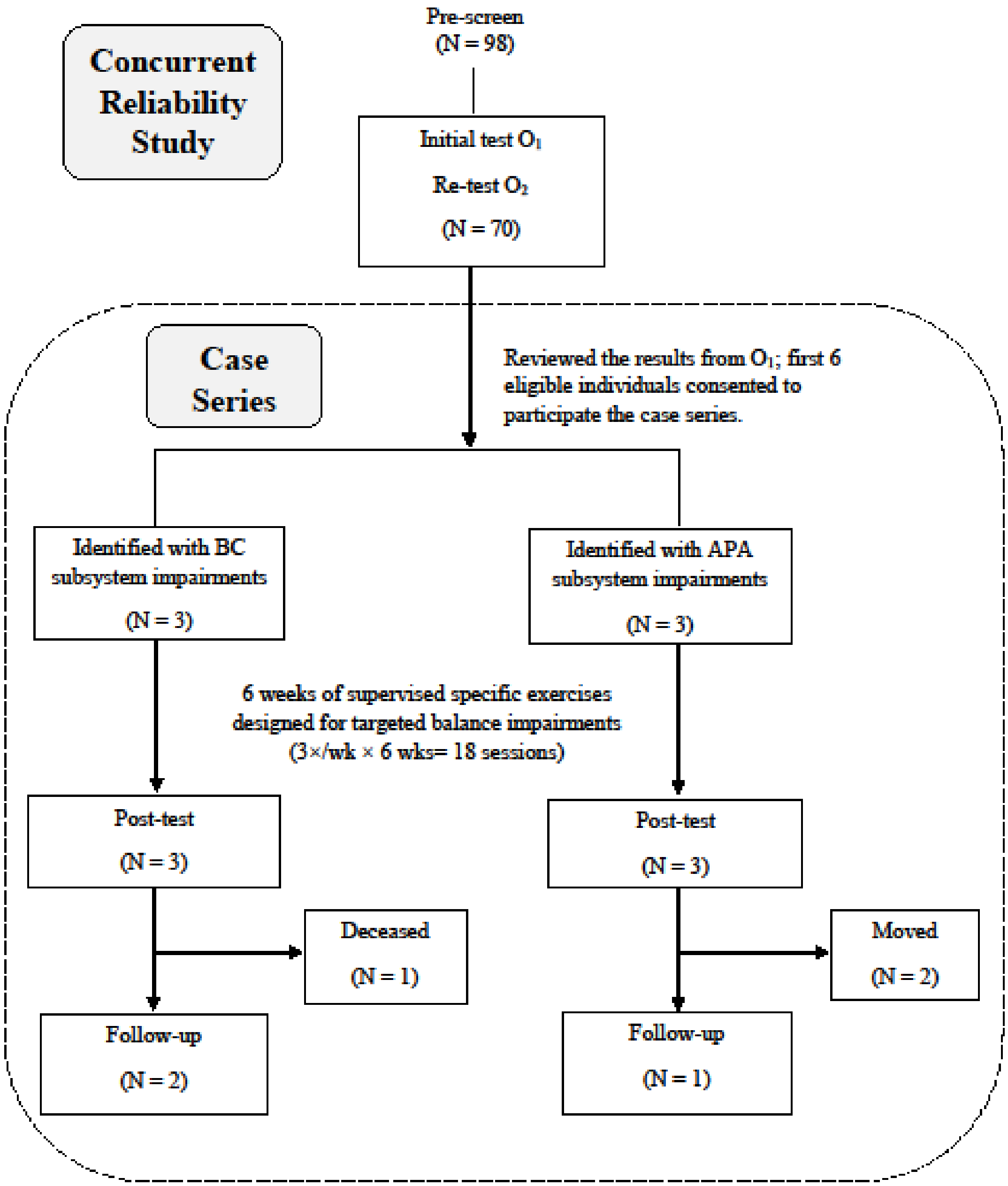

Figure: Flowchart of Enrollment for the Case Series.

Abbreviations: O1 = Initial test; O2 = re-test; BC = Biomechanical Constraints subsystem of balance; APA = Anticipatory Postural Adjustment subsystem of balance

OUTCOMES

Primary outcomes were changes in the targeted balance impairments (BC or APA, using BESTest) and fall risk (using BBS and UIC FFM). Improvements were defined as increases greater than the reported MDC from the initial test. Change in quality of life (SF-12) was a secondary outcome. No adverse events or incidence of falling occurred during the testing, exercise sessions, or during the course of the 6-week intervention.

Participants with BC impairment

Results for the participants with impairment in the BC subsystem of balance are displayed in Table 4. All 3 participants improved their BC subsystem and overall BESTest scores after receiving the specific progressive exercises. The BC subsystem scores increased 20-33.3% compared to the original subsystem scores, and exceeded the MDC at 95% CI. Improvement in other subsystem ranged from 0 to 13.3%. For fall risk, the physical performance scores (BBS) and psychological fear of falling scores (UIC FFM) at post-test exceeded the MDCs at 95% CI. In addition, quality of life (SF-12) also improved. No MDC was available for SF-12.

Participants with APA impairment

Results for the participants with impairments in the APA subsystem of balance are displayed in Table 5. All 3 participants improved their APA subsystem and overall scores on the BESTest after receiving their targeted exercise program. The targeted APA subsystem scores improved 27.8-39.1% compared to before exercises. Improvement exceeded the MDC at 95% CI. Increases in other subsystems ranged from 6.6 to 23.8%. Fall risk was reduced because both BBS and UIC FFM scores increased and exceeded the

MDCs at 95% CI. However, quality of life (SF-12) showed small to no improvement after exercises.

Table 4. Outcomes for Participants with Impairments in the BC Subsystem of Balance.

	MDC (95% CI)[a]	BC1			BC2			BC3		
		Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Fall Risk										
BBS	3.0 (points)	47	53	↑ 6[b]	41	49	↑ 8[b]	42	50	↑ 8[b]
UIC FFM	2.6 (points)	28	38	↑10[b]	29	40	↑ 11[b]	24	34	↑ 10[b]
BESTest Total (%)	7.6%	85.0	90.7	↑ 5.7	72.2	80.6	↑ 8.4[b]	60.0	93.3	↑ 33.3[b]
BC (%)	14.9 %	66.7	86.7	↑ 20[b]	60.0	93.3	↑ 33.3[b]	46.7	80.0	↑ 33.3[b]
SLV (%)		85.7	85.7	NC	85.7	85.7	NC	80.1	85.7	↑ 4.6
APA (%)	15.9 %	72.2	77.8	↑ 5.6	77.8	77.8	NC	88.9	94.4	↑ 5.5
PR (%)		94.4	100	↑ 5.6	55.6	61.1	↑ 5.5	61.1	66.7	↑ 5.6
SO (%)		100	100	NC	66.7	80.0	↑ 13.3	66.7	80.0	↑ 13.3
SG (%)		85.7	95.2	↑ 9.5	81.0	85.7	↑ 4.7	76.2	81.0	↑ 4.8
QoL (SF-12)										
Physical		52	56	↑ 4	44	53	↑ 9	43	45	↑ 2
Mental		58	60	↑ 2	46	59	↑ 13	44	63	↑ 19

Abbreviations: MDC (95% CI) = Minimal Detectable Change at 95% confident interval; BBS = Berg Balance Scale; UIC FFM = University of Illinois in Chicago Fear of Falling Measurement; BESTest = Balance Evaluation Systems Test; BC = Biomechanical Constraints; SLV = Stability Limits/Verticality; APA = Anticipatory Postural Adjustments; PR = Postural Responses; SO = Sensory Orientation; SG = Stability in Gait; SF-12 = Short Form Health Survey; NC = no change.

Note:
a. MDC 95% CI of all variables were from a previous descriptive study (E Wang-Hsu & SS Smith, 2015).
b. Indicated changes exceeded the MDC value of the variable.

Table 5. Outcomes for Participants with Impairments in the APA Subsystem of Balance.

	MDC (95% CI)[a]	APA1			APA2			APA3		
		Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Fall Risk										
BBS	3 (points)	46	52	↑ 6[b]	45	53	↑ 8[b]	42	52	↑ 10[b]
UIC FFM	2.5 (points)	28	44	↑16[b]	29	44	↑ 15[b]	29	43	↑ 14[b]
BESTest Total (%)	7.5%	62.0	77.8	↑ 15.8[b]	76.6	85.0	↑ 17.4[b]	50.0	77.8	↑ 27.8[b]
BC (%)	14.7 %	73.3	87.7	↑ 14.4[b]	93.3	93.3	NC	73.3	80.0	↑ 6.7
SLV (%)		71.4	86.0	↑ 14.6	76.2	95.2	↑ 19.0	71.4	85.7	↑ 14.3
APA (%)	15.8%	38.9	78.0	↑ 39.1[b]	50.0	77.8	↑ 27.8[b]	44.4	72.2	↑ 27.8[b]
PR (%)		55.6	67.0	↑ 11.4	55.6	77.8	↑ 22.2	55.6	88.9	↑ 33.3
SO (%)		60.0	80.0	↑ 20.0	80.0	80.0	NC	73.3	66.7	↓ 6.6
SG (%)		71.0	71.0	NC	57.1	85.7	↑ 28.6	61.9	85.7	↑ 23.8
QoL (SF-12)										
Physical		57	58	↑ 1	49	58	↑ 9	52	53	↑ 1
Mental		52	55	↑ 3	64	64	NC	60	62	↑ 2

Abbreviations: MDC (95% CI) = Minimal Detectable Change at 95% confident interval; BBS = Berg Balance Scale; UIC FFM = University of Illinois in Chicago Fear of Falling Measurement; BESTest = Balance Evaluation Systems Test; BC = Biomechanical Constraints; SLV = Stability Limits/Verticality; APA = Anticipatory Postural Adjustments; PR = Postural Responses; SO = Sensory Orientation; SG = Stability in Gait; SF-12 = Short Form Health Survey; NC = no change.

Note:
a. MDC 95% CI of the variables were from a previous descriptive study (E Wang-Hsu & SS Smith, 2015).
b. Indicated changes exceeded the MDC value of the variable.

Qualitative feedback

All 6 participants reported feeling "much more confident walking," and they felt "steadier on their feet" following the exercise program. The participants also stated that they felt the exercises instructions were clear, and they were willing to continue to perform them as part of their weekly routine.

Follow-up

As noted previously, Tester 1 re-tested participants on the BESTest 9-15 months after completion of their supervised exercise programs. One of the participants (BC2) was deceased, 2 participants (BC3 and APA2) had moved from the facility with no further contact information available. The remaining 3 participants consented per IRB to be re-tested with the BESTest.

BC1 was tested 9 months following completion of his exercises. His follow-up BESTest total score was 84.3% compared to post-test 90.7%, and his BC subsystem score was 86.7%, which was the same as his post-test score. BC1 stated that he was still performing the exercise program with the instructions and diagrams provided. He reported no incidence of falling.

APA1 was tested 15 months after completing her exercises. Her follow-up BESTest total score was 78.7% compared to her post-test score of 77.8%. The APA subsystem score was 83.3% compared to the post-test, 78.0%. She stated that she was still performing the exercise program periodically, but not as faithfully as she "should." She reported no incidence of falling.

APA3 was tested 14 months after completion of her exercises. Her follow-up BESTest total score was 79.6% compared to her post-test score of 80.6%. Her APA subsystem score was 72.2%, which was the same as her post-test score. She stated that she was still performing the exercise program faithfully. She also reported no incidence of falling.

DISCUSSION

To our knowledge, we are the first to specifically use a balance model as a guide to identify an individual's balance subsystem impairment in order to prescribe specific exercises targeted to improve the impaired subsystem. Our preliminary findings demonstrated promising outcomes for improving the subsystem impairment and overall balance, and reducing fall risk.

Despite the fact that exercises are widely recommended to improve balance and reduce fall risk, current exercises used to improve balance and to reduce fall risk tend to be multidimensional and use a broad-based approach that addresses several potential impairments but are not necessarily specific to the individual's balance impairment(s).[9,10,12,28] This practice is analogous to prescribing treatment without an accurate diagnosis. A tenet in healthcare is that effective treatment depends on an accurate diagnosis. Diagnosis is the basis for achieving effective patient outcomes, and in physical therapy that diagnosis is analogue to determining the specific impairments that are contributing to fall risk or falls.

Our case series is innovative because: (1) we used a balance model to clinically identify (i.e., diagnose) impairments in selected subsystems of balance. This approach differs from the current practice of using clinical tests or measures of fall risk that are not designed to identify specific impairments in balance; (2) we prescribed a progressive set of specific exercises based on the balance impairment identified from the model. The specific exercises were under the therapist's direct supervision in order to achieve optimal performance compliance and accuracy. Our outcomes suggested that the specific balance impairments, identified with a balance model, can be modified with targeted exercises for community-dwelling older adults at risk for falls and fracture. These findings demonstrated that specific exercises can improve not only the impaired subsystem, but also resulted in improvement in various other subsystems which resulted in an overall balance improvement and reduce in fall risk. Further, impairment-specific and progressive exercises may ultimately be used to guide clinicians in prescribing specific, individualized balance exercises.

A number of limitations and issues should be considered. We recruited participants using a convenience sampling, which has the inherent bias of "self-selection.[29] We used the FRAX score to identify individuals with fracture risk. However, we did not record the medications of individual participants. The FRAX scores are not considerd valid for adults who are receiving medications for osteoporosis.[30]

We chose to use the BESTest to identify balance subsystem impairments because the BESTest is one of the few standardized tests that includes, and categorizes, test items into subsystems. However, we agree with Horak et al.[3] that the construct for the BESTest model may not be adequately comprehensive or definitive enough to differentiate (or diagnose) specific impairments in the subsystems, which are clearly synergistic and not mutually exclusive. This potential issue could explain why all 6 participants had at least one subsystem, in addition to their targeted balance subsystem, that scored less than 70%. We attempted to use exercises targeted to 1 subsystem of balance impairments. Outcomes demonstrated an “overflow” improvement in some other subsystem and the overall BESTest scores, which supported the interacting subsystems of balance.

From our clinical experience using the BESTest, the BC and APA seem to be share less commonality with each other amongst the 6 categorized subsystems. We selected the exercises developed to improve each of these 2 subsystem impairments because our exercise interventions for each of these 2 subsystems presumably involved the least amount of overlap. This leads to the issue of “treat to task.” Participants who were identified as having impairment in a subsystem of balance received exercises designed to improve that particular subsystem of balance. Although we attempted to avoid prescribing exercises that directly resembled the test items, the prescribed exercises were, nevertheless, similar to the items in BESTest attributed to the particular subsystem we treated.

Additionally, some of the test items in BC subsystem may not be modifiable with exercises, such as postural alignment deformation including scoliosis or excessive thoracic kyphosis. In addition, test items in a subsystem may not truly reflect the intended subsystem of balance. For example, “sit on the floor and stand up” was a test item in BC subsystem of BESTest model as an indication of strength and joint limitation for lower extremities,[3] one may argue that this test item represents the initiation of a voluntary movement therefore it should have been categorized in the APA subsystem.

In summary, we conducted a proof-of-concept case series by using a theoretical balance model to identify balance impairment in BC and APA subsystems, and provided exercises targeted to improve these subsystems. Our preliminary outcomes demonstrated that the impairments in BC and APA subsystems were modifiable by our specific, progressive exercises. We believe that our case series provide the first step toward conducting a randomized controlled trial to determine the effectiveness of specific exercises for community-dwelling older adults with fall and fracture risks.

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CHAPTER IV

EFFECTIVENESS OF EXERCISES TO REDUCE SPECIFIC BALANCE IMPAIRMENTS AND FALL RISK IN COMMUNITY-DWELLING OLDER ADULTS: A RANDOMIZED CONTROLLED TRIAL

Authors:

Elizabeth Wang-Hsu, PT, MS, PhD Candidate

Department of Physical Therapy and Rehabilitation Sciences, Drexel University, Philadelphia, PA. (TEL) 610-592-6212

cw322@drexel.edu

Robert J. Palisano, PT, ScD, FAPTA

Distinguished Professor, Department of Physical Therapy and Rehabilitation Sciences, Drexel University, Philadelphia, PA. (TEL) 267-359-5533; (FAX) 267-359-5576

robert.j.palisano@drexel.edu

Sheri P. Silfies, PT, PhD

Associate Professor, Research Lab Coordinator, Department of Physical Therapy & Rehabilitation Sciences, Drexel University, Philadelphia, PA. (TEL) 267-359-5580; (FAX) 267-359-5576

silfies@drexel.edu

Fay B. Horak, PT, PhD

Professor, Department of Neurology, Adjunct Professor of Physiology and Pharmacology, Adjunct Professor of Biomedical Engineering, Neuroscience and Behavioral Neuroscience Graduate Faculty, Oregon Health & Sciences University

Director, Balance Disorders Laboratory and Fall Prevention Laboratory, Parkinson's Center of Oregon, 181 SW Sam Jackson Park Road, Sam Jackson Hall Rm 2251, Portland, OR 97239-3098. (TEL) 503-346-0842, (FAX) 503-494-9059

horakf@ohsu.edu

Edward J. Gracely, Ph.D.

Associate Professor, Department of Family, Community, and Preventive Medicine, College of Medicine, Drexel University. 2900 Queen Lane, Philadelphia, (TEL) 215-991-8466, (FAX) 215-843-6028

Edward.Gracely@drexelmed.edu

Susan S. Smith, PT, PhD

Associate Dean for Research & Health Professions Graduate Education, College of Nursing & Health Professions

Associate Professor, Department of Physical Therapy and Rehabilitation Sciences, Drexel University, Philadelphia, PA. (TEL) 215-762-1758; (FAX) 215-762-3886

sue.smith@drexel.edu

The authors declare no conflict of interest.

Address correspondence to: Susan S. Smith, PT, PhD, Associated Dean, College of Nursing and Health Professions, Drexel University, 245 N. 15th Street, MS 501, Philadelphia, PA 19102 (sue.smith@drexel.edu)

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ABSTRACT

Background Balance impairment is a key factor contributing to falls in older adults. Conceptually, clinicians may be able to prescribe targeted exercises if specific impairments can be identified. **Objective** Our objective was to use a model of balance subsystems to identify balance impairments and demonstrate the effectiveness of targeted (matched) exercises to improve balance and reduce fall risk in community-dwelling older adults. We used the Balance Evaluation System Test (BESTest) as the model because it categorizes balance into 6 subsystems. **Design** Randomized, partially blinded, pretest-post-test clinical trial consisting of 2 Phases: 1. A comparison between impairment-matched exercises and a control, and 2. A comparison between impairment-matched and mismatched exercises. **Setting** Senior independent living community. **Participants** Adult volunteers (n = 40; aged 74-94) recruited as sample of convenience who met the criteria. Participants (n = 20) identified with impairment in the biomechanical (BC) constraints subsystem and participants (n = 20) with impairment in anticipatory postural adjustment (APA) subsystem were enrolled and randomized into 2 subgroups (matched and control/delayed mismatched; n = 10 each subgroup). **Intervention** Phase 1: Participants in the matched subgroup received a 6-week exercise program matched to their impaired subsystem while the mismatched subgroup served as control. Phase 2: Following the delay, participants in the mismatched group received a 6-week exercise program mismatched to their impairment. **Measurements** Primary outcome variables were scores on the targeted subsystem (BC, APA), BESTest total, Berg Balance Scale, and fear of falling measure. Quality of life was a secondary outcome. Outcome data were collected by the tester blind to pretest scores and group allocation. **Results** The matched exercise subgroups demonstrated both statistical and clinical improvement in all outcome variables compared to the control; and showed greater improvement in balance impairments compared to the mismatched subgroup, but not in fall risk reduction. **Limitations** The therapist who administered the pretest knew the subgroup assignment and implemented the exercises. **Conclusions** Results provide preliminary evidence that using a balance assessment model to identify impairments in the BC and APA subsystems and prescribing targeted exercises reduces these balance impairments for older adults and may warrant future studies.

INTRODUCTION

One in 3 older adults in the US fall every year.[1] Falls are costly to the individual and to society. In 2013, direct medical costs of falls totaled over $34 billion. Experts estimate that the annual direct and indirect cost of fall injuries will reach $54.9 billion by 2020.[1]

Balance impairment is one of the key factors contributing to falls in older adults.[1-3] Balance is a complex skill based on the interactions of a number of underlying subsystems.[2,4,5] Several conceptual models have been suggested to represent postural control, or balance.[2,4,5] However, to date, no universally accepted theoretical model of balance has emerged.

Because of the complexity, balance is a challenge not only to model but also to evaluate. Clinical balance tests are primarily designed to identify balance impairments and to determine fall risk. Several of these tests assess only selected aspects of balance. For example, the Berg Balance Scale (BBS)[6] has been considered the gold standard to evaluate balance and to identify fall risk.[7] However, the BBS does not categorize performance items by subsystems, nor is it comprehensive. The BBS does not include tests of stability in gait or response to perturbation.[4] Further, the BBS is not designed to guide clinicians in prescribing impairment specific interventions.

Exercise is an evidence-based intervention demonstrated to improve balance and to prevent falls. Current balance exercise programs are typically multidimensional with a broad-based approach in attempt to address most aspects of balance control.[3,8,9] A Cochrane systematic review[3] presented evidence for the effectiveness of exercises to improve balance for older adults. Outcomes from 94 studies with total of 9,917 participants were reviewed. The authors concluded that exercises are effective in improving balance and reducing fall risk. Nine different types of exercises programs were cited for improving balance. Most of these programs were conducted 3 times a week for over 3 months. However, the overall strength of the evidence was limited by the general lack of participant blinding, core outcome measures and a standardized exercise prescription.[3]

Clinical prediction rule and treatment-based classification systems have been developed to assist healthcare providers in decision making in variety of areas,[10] including for individuals with low back pain.[11] Conceptually, if an individual's specific balance impairment can be identified, clinicians may be able to prescribe exercises specific to the identified impairments. An exercise program that consists of a focused intervention and a smaller number of exercises might optimize adherence.[12] However, limited evidence is available for using a model of balance to identify the specific balance impairments and the effectiveness of exercises targeted to significant impairments.

A recent meta-analysis[4] summarized 66 current standardized measures for balance, and concluded that the Balance Evaluation System Test (BESTest) was a comprehensive test that categorized balance assessment by subsystems. Horak et al.[2] developed the BESTest which categorize balance into 6 subsystems (Figure 1): biomechanical constraints (BC), stability limits/verticality (SLV), anticipatory postural adjustments (APA), postural responses (PR), sensory orientation (SO) and stability in gait (SG). The BESTest adapted and extracted test items from existing standardized balance assessments and grouped them into these 6 subsystems accordingly. These authors suggested that the BESTest might be used to diagnose balance impairments and direct specific interventions.[2]

In a proof-of-concept case series,[13] we investigated the outcomes of specific progressive exercises for older adults with balance impairments in 1 of 2 subsystems, BC or APA, identified with the BESTest (Figure 1). Our preliminary outcomes demonstrated that impairment-specific exercises reduced impairments in the selected subsystems and improved overall balance. These findings support the concept of impairment-specific exercises.[13] Based on those findings we conducted this small randomized controlled trial (RCT) to determine the effectiveness of prescribing impairment-specific exercises.

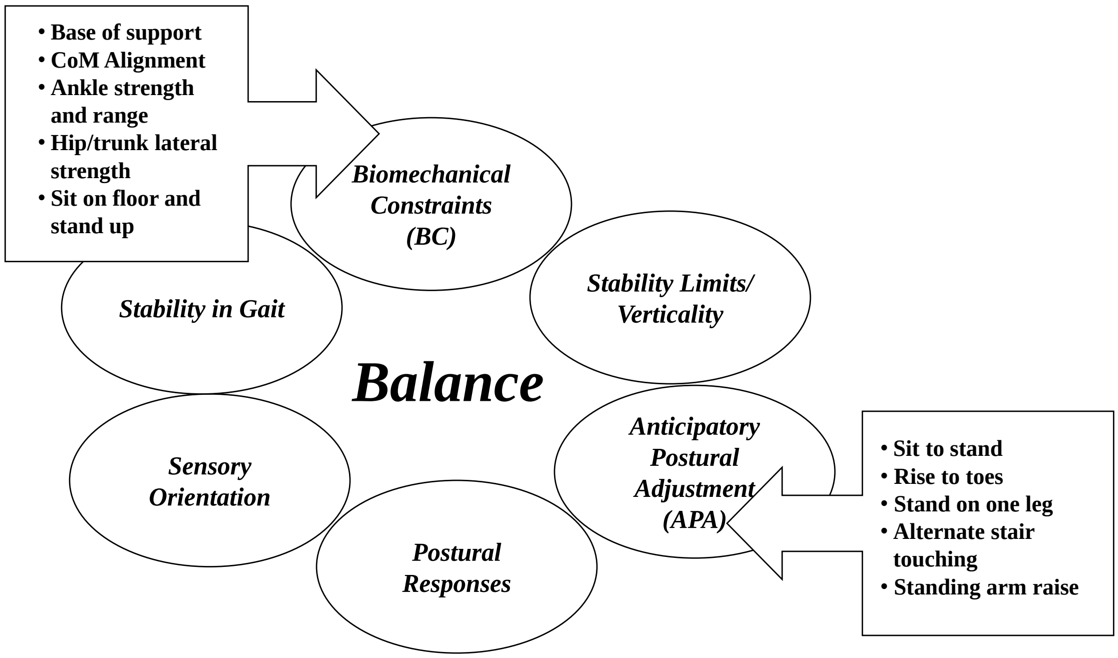

Figure 1. The BESTest model categorized by the subsystems of balance, and the test Items in BC and APA subsystems.

In contrast to the current practice of broad-based balance exercises, the long term objective of our study is to improve balance and reduce fall risk in older adults using impairment-specific exercises that are efficient, effective and easy to adhere to. We conducted this small RCT to test the following hypotheses: (1) older adults who received exercises specific to their balance impairment will demonstrate improved balance and reduced fall risk compared to older adults who received no intervention; and (2) exercises that are matched to a specific balance impairment will be more effective than exercises that are mismatched to a specific impairment in improving balance and reducing fall risk for older adults. As able, we used the requirements from the Consolidated Standards of Reporting Trials (CONSORT).[14]

METHODS

Design Overview

This study was a randomized, partially blinded, pretest-post-test clinical trial that consisted of 2 phases: Phase 1 was comparison between an impairment-specific exercise group and a control (delayed treatment) group. Phase 2 was a comparison between participants who received impairment-matched and those who received mismatched exercises. Participants were blinded to their subgroup assignment; and the post-tester was blinded to participants' group allocation and pre-test scores.

Setting and Participants

This study was conducted between August 2014 and February 2015. The population was community-dwelling older adults with a high fracture and fall risk. Participants were recruited as a sample of convenience from a senior independent living facility located in suburban Pennsylvania. Potential participants for this RCT study were identified and recruited based on the test results from a psychometric study conducted concurrently by the same investigators (with separate IRB approval). For the psychometric study, we tested 70 older adults aged 65 years and older, cognitively able to understand and follow simple instructions (Mini Mental State Exam (MMSE) score > 17/30),[15] and able to walk independently with or without an assistive device for more than 100 ft. Participants' demographic information, cognitive status, health history, fracture risk, fall risk, balance, and quality of life were measured. Potentially eligible adults were invited to participate in this RCT. Inclusion criteria for the RCT study were: (1) individuals who met the criteria for the psychometric study; and demonstrated (2) elevated fracture risk; (3) elevated fall risk; and (4) impaired balance in either the BC or APA subsystem of balance as identified with BESTest. Exclusion criteria were individuals who had: (1) a progressive diseases or unstable medical conditions, (2) major surgery in the past 3 months, (3) physician's orders not to participate in an exercise program for any reason, (4) impairment in both BC and APA subsystems, (5) impairments in more than a total of 3 subsystems; and (6) who were currently receiving treatment for balance or fall prevention. Participation was voluntary and all participants signed a written informed consent. Participants' demographic information and characteristics are reported in Table 1.

Table 1. Participant Characteristics and Descriptive Statistics for Outcome Measures.

	Participants with BC Balance Impairment (N = 20)		**Participants with APA Balance Impairment (N = 20)**	
Allocation	**Matched Exercises (n = 10)**	**Delayed (Mismatched) (n = 10)**	**Matched Exercises (n = 10)**	**Delayed (Mismatched) (n = 10)**
Sex (men and women)	7 M, 3 W	6 M, 4 W	2 M, 8 W	2 M, 8 W
Age (yr)	85.0 (6.4)	86.0 (3.1)	83.3 (5.3)	86.2 (5.5)
Height (cm)	176.0 (11.1)	173.0 (11.0)	160.4 (8.8)	163.6 (9.4)
Weight (kg)	79.2 (11.2)	70.6 (9.7)	66.7 (13.0)	69.8 (9.6)
Body Mass Index (BMI)	25.5 (2.4)	23.6 (2.9)	26.0 (4.9)	25.2 (1.5)
Cognition (MMSE)	27.5 (1.8)	27.8 (1.0)	29.2 (0.9)	27.9 (1.2)
Fall history (past 12 mo.)	6 Yes, 4 No	7 Yes, 3 No	7 Yes, 3 No	8 Yes, 2 No
Fracture Risk (FRAX)				
Major fracture (%)	19.6 (8.1)	24.0 (13.9)	27.1 (10.4)	29.3 (11.0)
Hip fracture (%)	10.0 (4.3)	15.1 (13.7)	14.1 (8.9)	14.5 (8.8)
Fall Risk				
BBS (point)	43.5 (2.6)	43.3 (3.0)	44.0 (3.7)	45.6 (2.5)
UIC FFM (point)	26.2 (2.6)	27.3 (2.0)	27.1 (1.9)	27.2 (1.6)
BESTest Total (%)	72.8 (5.2)	69.7 (2.1)	68.1 (5.4)	72.3 (3.4)
BC subsystem (%)	59.4 (8.0)	54.7 (9.3)	79.3 (8.0)	80.0 (7.0)
APA subsystem (%)	76.1 (5.9)	74.4 (5.4)	47.8 (6.5)	55.6 (5.2)
QoL Score (SF-12)				
Physical	43.1 (4.3)	40.5 (3.8)	44.3 (8.9)	43.1 (6.4)
Mental	42.4 (6.4)	42.7 (3.9)	51.0 (8.2)	48.1 (7.2)

Abbreviations: M = men; W = women; MMSE = Mini Mental State Exam; HS = High School; FRAX = Fracture Risk Assessment; BBS = Berg Balance Scale; UIC FFM = University of Illinois in Chicago Fear of Falling Measurement; BESTest = the Balance Evaluation Systems Test; BC = Biomechanical Constraints; APA = Anticipatory Postural Adjustments; QoL = Quality of Life; SF-12 = Short Form Health Survey (used with permission).

Instruments

Fracture Risk

We used the Fracture Risk Assessment (FRAX)[16] scores to identify individuals with fracture risk for this study. The FRAX yields an “absolute 10-year fracture risk” score and “10-year hip fracture risk” score.[16] A person with a 10-year probability of a hip fracture ≥ 3% or a 10-year probability of a major fracture ≥ 20% is considered a high risk for fracture.[16] Individuals who met either of the criteria for hip fracture or a major fracture qualified as having a high fracture risk.

Fall Risk

We used the Berg Balance Scale (BBS)[6] and the University of Illinois at Chicago Fear of Falling Measurement (UIC FFM)[17] to identify fall risk. The BBS[6] is a 14-item scale, scored on an ordinal scale from 0-4. A “0” indicates the lowest level of function and “4” the highest level of function. The total possible score is 56 points (highest level of function). The BBS evaluates balance during tasks of daily living, progressing from easy to difficult. Although the BBS[6] is commonly used to identify fall risk in older adults, results of a 2011 systematic review recommended that BBS be used in conjunction with other test(s) to more accurately predict fall risk.[18]

To supplement the BBS and more accurately identify fall risk, we also used a psychological measure of fear of falling, the University of Illinois at Chicago Fear of Falling Measure (UIC FFM).[17] Older adults who have fallen may develop a fear of falling even if they were not injured from the fall.[17,19-21] Fear of falling can cause individuals to limit their activities leading to reduced mobility and loss of physical fitness, which, in turn, further increases the risk of falling, and reduces quality of life.[19-21] The UIC FFM[17] is a 16-item self-administered questionnaire. Individuals are asked to rate their fear of falling for each of the 16 activities on a scale of 1 to 3. The rating of "1" equals being "very worried" and "3" equals "not worried" about falling. The questionnaire consists of typical daily activities progressed from easier tasks to more difficult tasks. Higher UIC FFM scores indicate less fear of falling.[17] Our preliminary work demonstrated that UIC FFM is an independent predictor for falls;[22] and using UIC FFM in conjunction with BBS improved the predictability of fall risk.[23] We defined high fall risk as a BBS score equal or lower than 49 of an optimal 56 points[24] *and* a UIC FFM score equal to or lower than 29 of an optimal 48 points.[22]

Balance

We used the BESTest[2] to evaluate balance. The BESTest is a dynamic balance performance assessment tool consisting of a 36-item scale (scored on an ordinal scale from 0-3) with "0" indicating the lowest level of function and "3" the highest level of function. The total possible raw score is 108 points (highest level of function). Raw scores are converted to percentages [(raw score/108) × 100%]. Each of the 6 subsystems in the BESTest also yields a score that is converted to a percentage.[2] We arbitrarily defined scores of 70% or less in a subsystem as a balance impairment in that subsystem.

Quality of Life

As a secondary outcome, we assessed quality of life (QoL) using the self-administered Short Form Health Survey (SF-12, Version 2; QualityMetric Inc.) questionnaire.[25] The survey consists of 12 questions scored on an ordinal scale that requires 3-5 minutes to complete. The questions request information about self-perceived quality of life in mental and physical domains. Licensed software was used to calculate the scores separately for physical and for mental health. Scores on the SF-12 are based on z-scores from the general US population.[25] A score of 50 represents the average score within the US population. Scores greater than 50 indicate above-average QoL, and scores less than 50 indicate below-average QoL.

Testers

Two testers administered the measures. Tester 1 was a physical therapist (EWH) with over 20 years clinical experience. Tester 2 was a physical therapist assistant with over 20 years clinical experience. Tester 1 administered the initial test battery (pretest of the psychometric study) and consented all participants. Tester 2, who was blinded to the participants' pretest tests results and group allocations, administered the post-tests. Interrater reliability, test-retest reliability and minimal detectable change (MDC) of the outcome variables were determined from a concurrent psychometric study (see Table 4).

Randomization and Intervention

To test our hypotheses, we used 2 independent cohorts: a cohort with balance impairment in the BC subsystem, and a cohort with balance impairment in the APA subsystem. In Phase 1, participants in each cohort were randomly allocated to a matched exercise group and a control group who later received mismatched exercises during Phase 2. A CONSORT diagram[14] illustrates the study flow (Figure 2).

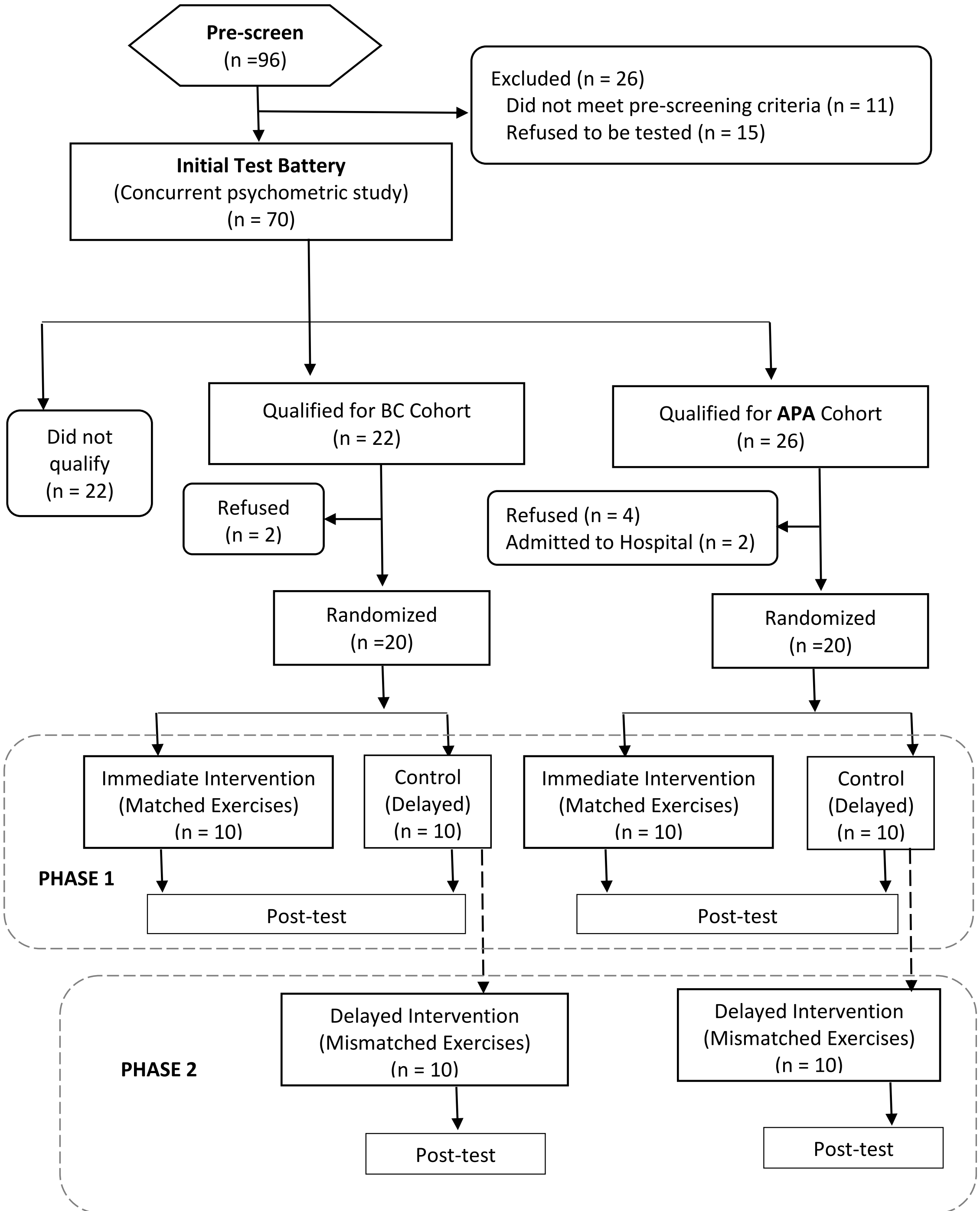

Figure 2. Diagram of participants flow.

A priori power analysis (power = 0.80; G–Power analysis)[26] indicated a minimum of 9 participants was needed in each subgroup (matched intervention and control/delayed mismatched intervention within each cohort) using an estimated large effect size (≥ 0.6)[27] on the variables of BESTest total and subsystem scores, BBS, and UIC FFM. Evidence for using a large effect size was supported by our previous case series.[13] We enrolled 10 participants in each subgroup to account for possible attrition. A total of 40 participants [BC impairment cohort (n = 20); and APA impairment cohort (n = 20)] signed a consent approved by Drexel University's Institutional Review Board.

The randomization method consisted of a drawing without replacement until the 20 participants were consented and allocated into 2 subgroups for each cohort (n = 10 each subgroup). Two containers (1 for the BC and 1 for the APA cohort), each contained 20 folded ballots, 10 marked "A" and 10 marked "B". Participants in each cohort drew a ballot from the appropriate container for their exercise allocation. Randomization was executed consecutively until all 40 participants were enrolled to the study. Participants were informed that they had "the kind of balance impairment" that interested us. The participants were blinded from whether they were allocated to the matched or mismatched exercise subgroup, that is, they were unaware of their identified subsystem balance impairments (cohort), and they were unaware the meaning of exercise "A" or "B".

The exercise programs differed based on allocation. The exercise program targeted to improve the BC subsystem impairments (B) consisted of progressive strengthening and flexibility exercises with emphasis on power and speed. Cuff weights and therabands were used for resistance. The exercise program targeted to improve the

APA subsystem of balance (A) consisted of progressive dynamic standing postural control exercises that challenged the center of gravity out of the base of support in various directions (see Appendix for detailed exercise descriptions and progression criteria).

At the beginning of each exercise session, the therapist inquired whether the participant had fallen since the last session. An exercise log was kept as a record of exercise adherence, exercise progression, report of falls and other adverse events. Each participant completed a 6-week program consisting of 18 exercise sessions that were directly and individually supervised by the therapist (Tester 1, EWH). Sessions required 25-40 minutes to complete. Each program consisted of 9 exercises with 3 levels of progression (see Appendix for detailed exercise descriptions and progression criteria).

Levels progressed from the easiest level, Level I, to the most challenging level, Level III. Exercise progress was determined by the participant’s ability to complete 2 sets of 10 repetitions of an exercise without substitution or discomfort. Generally individuals progressed to the next level in 2 weeks. All participants reached Level III at the completion of the 18 sessions.

Phase I: Matched Exercises vs. Control Programs

Participants with a balance impairment matched to their exercise intervention immediately started their exercise program. Those participants whose subsystem impairment did not match the exercises were instructed that they were to start their exercises 6 weeks later because of “scheduling issues.” The control participants were instructed to continue their daily routine while they waited for their exercise program to begin. The post-test battery consisting of balance (measured by BESTest), fall risk (measured by BBS and UIC FFM) and QoL (measured by SF-12) was administered to all participants in both subgroups at the end of 6 weeks by tester 2. Tester 2 was unaware of the pretest scores and group allocations.

Phase 2: Matched Exercises vs. Mismatched Exercises

Immediately after the post-testing, the participants who initially served as the control group started their exercises, which were not specific to their identified balance impairment (mismatched). The protocol was as described previously except that the exercises were not specific to the identified impairment, that is, those in the BS cohort performed APA exercise program and vice versa. Initial test results from the psychometric study served as their baseline scores. Another post-test, consisting of BESTest, BBS, UIC FFM and SF-12, was administered at the end of the 6-week mismatched exercise program by the blinded tester (Tester 2).

Outcome Measures

Our primary outcomes were balance subsystem scores (BC or APA), overall balance (BESTest total scores), and fall risk (BBS and UIC FFM). Our secondary outcome was quality of life. Minimal detectable change (MDC) data for the primary outcome variables were obtained during our concurrent psychometric study as described previously. Minimal detectable change scores (MDC) at the 95% confident interval (CI) were as follows: 3.0 points for BBS, 2.6 points for UIC FFM, 14.9% for the BC subsystem, 15.9% for the APA subsystem, and 7.6% for BESTest total score. To minimize bias, scores on the outcome measures were not calculated for analysis until all participants completed their exercise programs.

Statistical Analysis

Data were extracted, de-identified, and entered electronically into spreadsheet (SPSS 22, IBM Corporation; Armonk, NY) following the completion of the study. Descriptive statistics were used to calculate participants' demographic information and characteristics.

One-way ANOVA was used to investigate whether participants in each subgroup met assumptions for homogeneity and equivalency at baseline (pre-test). In the cohort with impaired BC subsystem, we found no significant difference between subgroups in age, height, weight, and FRAX scores, BBS, UIC FFM, BESTest total and BC and APA subsystem scores. However, in the cohort with APA impairment, we found significant differences in BESTest, UIC FFM, and APA subsystem scores.

To control differences between subgroups at baseline, using the pre-test scores as a covariate, we performed 4 separate within and between subjects mixed, 2-way repeated measures analyses of covariance (ANCOVA)[28] to analyze each of the 4 primary variables (BESTest total and impaired BC or APA subsystem scores, BBS, UIC FFM) to compare the respective matched intervention group versus the control subgroups. The same 4 analyses were conducted to compare results between matched and mismatched (delayed) subgroups. We met the assumptions of repeated measures ANCOVA (independence, normality, homogeneity of variances, linearity and reliability of the covariance and homogeneity of slopes).[28] The alpha level for the 4 primary outcomes was adjusted to 0.013 using the Bonferroni adjustment to accommodate a potentially inflated Type I error.[28] The alpha level was adjusted to 0.025 for the 2 secondary outcomes (QoL: Physical and Mental).

In addition to statistical significance, we interpreted whether changes exceeded measurement error. A mean increase of greater or equal to the minimal detectable change (MDC)[28] from the baseline values was used, as determined with this population in our psychometric study.[29]

RESULTS

No adverse events or incidence of falling occurred during the testing, exercise sessions, or during the course of the study. All 40 participants completed the 18 sessions of exercises. Tables 2 and 3 display the results of the mixed repeated ANCOVA using initial test scores (baseline) as the covariate.

Matched Exercises vs. Control

As shown in Table 2, in both cohorts, between-group results indicated a statistically significant difference in all 4 primary outcome variables between the matched exercises and the control subgroups. Significant differences were also found in the variables for QoL (Table 3). The partial eta square indicated large effect sizes for the differences between groups. As shown in Figure 3a and 3b, for both impairment cohorts, the within-subject change from the baseline scores for all primary variables (BESTest total and impaired BC or APA subsystem scores, BBS, UIC FFM) was significant in the matched exercise subgroup, but not in the control subgroup. Significant within-subject improvement was also found for the secondary variable (QoL: Physical and Mental) in the matched exercise subgroup but not in the control subgroup (Table 3).

Matched Exercises vs. Mismatched Exercises

Cohort with BC Impairment

As shown in Table 2, the matched exercise subgroup demonstrated significantly greater improvement compared to the mismatched exercise subgroup in the BC subsystem scores but not in fall risk (BBS and UIC FFM). The partial eta square values indicated small to moderate effect sizes for the differences between subgroups. No difference was found in the QoL between the 2 subgroups (Table 3). The within-subject results for both subgroups showed that the 4 primary outcome variables increased significantly after completing the matched or mismatched exercises compared to the baseline scores (Figure 3c).

Cohort with APA Impairment

As shown in Table 2, the matched exercise subgroup demonstrated significantly greater improvement compared to the mismatched exercise subgroup in the APA subsystem and BESTest total scores. The partial eta square values indicated small to moderate effect size for the differences between subgroups. No significant difference was found in UIC FFM and BBS or the secondary outcomes in QoL. Both subgroups with APA impairment showed significant improvement in the 4 primary outcome variables after completing their matched or mismatched exercises compared to their baseline scores (Figure 3d).

Clinical Change

Table 4 displays the MDC, the change scores from the baseline, and the percentage of change for each variable after completing the exercises for the matched and mismatched subgroups. Improvements in all 4 primary variables in the matched exercise subgroup exceeded the MDCs from the baseline values. In the mismatched subgroup, improvement of all primary variables met or exceeded the MDC except the APA subsystem scores in the APA cohort. All participants (BC and APA cohorts) who received matched exercises showed improvement that exceeded the MDCs in their targeted subsystem scores. For the participants of mismatched exercises subgroups, 5 of 10 participants in APA cohort did not exceed the MDC in the APA subsystem scores. Three of 10 participants in BC cohort did not show improvement that exceeded the MDC in their BC subsystem scores.

Table 2. Post-test Results of Mixed Repeated Measures ANCOVA for BESTest Total Score, Impaired Subsystem (BC or APA), BBS, and UIC FFM using Baseline (initial test) Scores as a Covariate

	Variable	**Allocation**				
Phase 1 Control vs Matched	**BC Impairment**	**Specific Exercise (n = 10)**	**Control (n = 10)**	**F (1, 17)**	**P**	**Partial Eta^2**
	BC subsystem%	84.7 (3.2)	58.7 (8.8)	84.45	< 0.01*	0.83
	BESTest %	84.3 (3.3)	68.9 (3.8)	126.28	< 0.01*	0.88
	BBS (point)	52.8(1.9)	44.4 (3.1)	86.89	< 0.01*	0.83
	UIC FFM (point)	41.1 (3.2)	26.7 (1.8)	152.47	< 0.01*	0.90
	APA Impairment	**Specific Exercise (n = 10)**	**Control (n = 10)**	**F (1, 17)**	**P**	**Partial Eta^2**
	APA subsystem%	78.4 (9.2)	54.5 (6.3)	49.08	< 0.01*	0.74
	BESTest %	83.6 (4.1)	71.7 (3.0)	95.35	< 0.01*	0.85
	BBS (point)	53.3 (1.6)	46.3 (2.3)	124.81	< 0.01*	0.88
	UIC FFM (point)	42.4 (2.6)	28.5 (1.5)	360.10	< 0.01*	0.96
	Variable	**Allocation**				
Phase 2 Matched vs Mismatch	**BC Impairment**	**Matched (n = 10)**	**Mismatched (n = 10)**	**F (1, 17)**	**P**	**Partial Eta^2**
	BC subsystem%	84.7 (3.2)	77.3 (4.7)	13.99	< 0.01*	0.45
	BESTest %	84.3 (3.3)	80.2 (5.0)	4.33	0.05	0.20
	BBS (point)	52.8 (1.9)	53.4 (1.4)	0.68	0.42	0.04
	UIC FFM (point)	41.1 (3.2)	41.8 (1.1)	1.27	0.61	0.02
	APA Impairment	**Matched (n = 10)**	**Mismatched (n = 10)**	**F (1, 17)**	**P**	**Partial Eta^2**
	APA subsystem%	78.4 (9.2)	70.6 (7.4)	10.26	< 0.01*	0.38
	BESTest %	83.6 (4.1)	80.8 (1.8)	9.94	< 0.01*	0.37
	BBS (point)	53.3 (1.6)	52.3 (1.2)	5.84	0.03	0.26
	UIC FFM (point)	42.4 (2.6)	41.6 (1.8)	0.72	0.41	0.04

Abbreviations: BESTest = the Balance Evaluation Systems Test; BC = Biomechanical Constraints; APA = Anticipatory Postural Adjustments; BBS = Berg Balance Scale; UIC FFM = University of Illinois in Chicago Fear of Falling Measurement.
* Indicated statistical significance (α adjusted to 0.013).

Table 3. Post-test Results of Mixed Repeated Measure ANCOVA for Quality of Life (QoL) Using Baseline (initial test) Scores as Covariate

	Variable	Allocation				
Phase 1 Control vs. Matched	**BC Impairment**	**Specific Exercise (n = 10)**	**Control (n = 10)**	**F (1, 17)**	**P**	**Partial Eta^2**
	Physical	53.8(3.8)	40.2 (2.9)	73.10	< 0.01*	0.81
	Mental	60.0 (2.1)	42.5 (3.7)	220.19	< 0.01*	0.93
	APA Impairment	**Specific Exercise (n = 10)**	**Control (n = 10)**	**F (1, 17)**	**P**	**Partial Eta^2**
	Physical	55.7 (2.7)	42.6 (5.3)	82.95	< 0.01*	0.83
	Mental	58.2 (4.1)	47.3 (5.9)	33.55	< 0.01*	0.66
Phase 2 Matched vs. Mismatch	**Variable**	**Allocation**				
	BC Impairment	**Matched (n = 10)**	**Mismatched (n = 10)**	**F (1, 17)**	**P**	**Partial Eta^2**
	Physical	53.8 (3.8)	51.7 (3.1)	2.26	0.15	0.12
	Mental	58.8 (3.4)	60.0 (2.1)	0.90	0.36	0.05
	APA Impairment	**Matched (n = 10)**	**Mismatched (n = 10)**	**F (1, 17)**	**P**	**Partial Eta^2**
	Physical	55.7 (2.7)	54.1 (2.7)	1.67	0.21	0.01
	Mental	61.1 (2.4)	58.2 (4.1)	4.53	0.05	0.21

Abbreviations: BC = Biomechanical Constraints; APA = Anticipatory Postural Adjustments.
* Indicated statistical significance (α adjusted to 0.025).

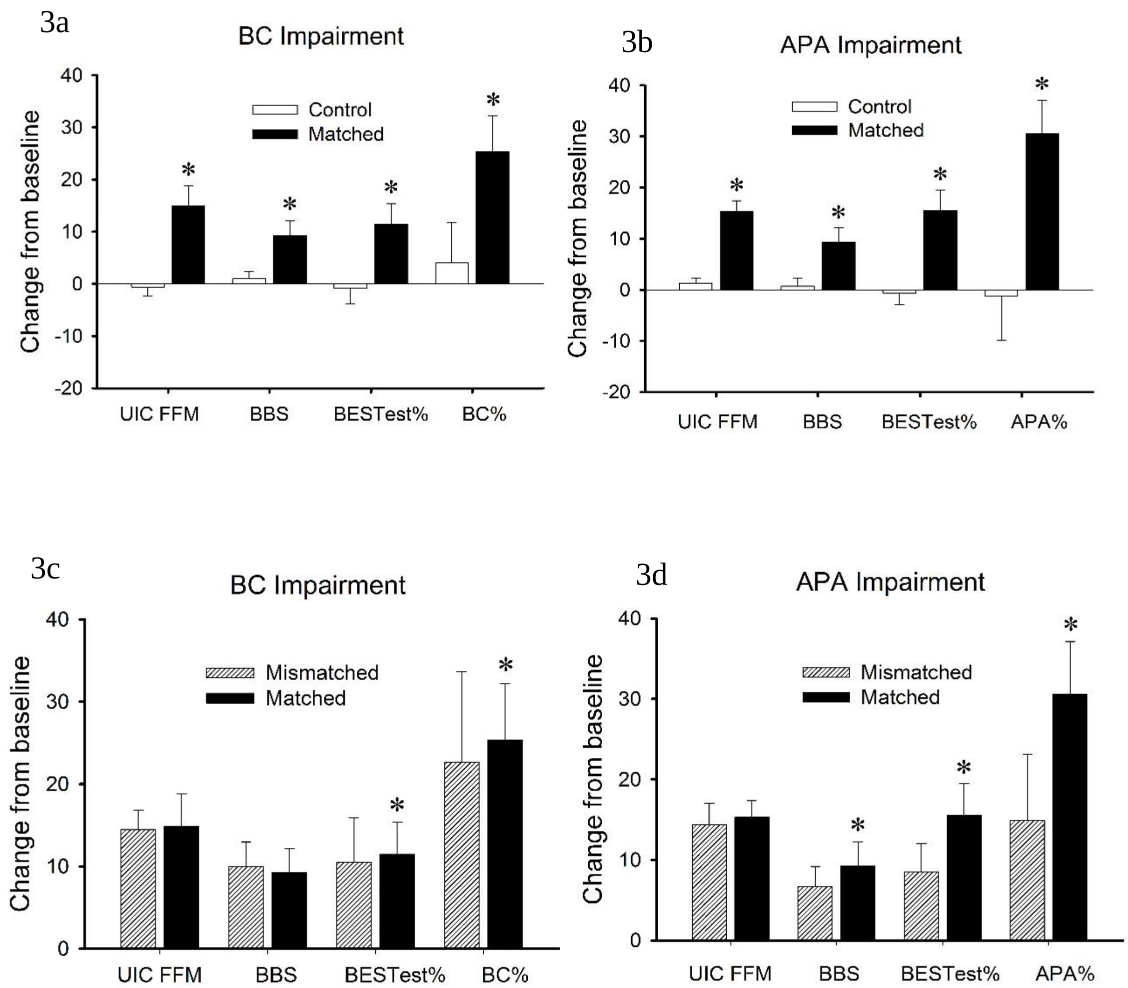

Figure 3. Changes from baseline scores for the primary variables (UIC FFM, BBS, BESTest total %, BC and APA subsystem %)

3a. Matched exercises vs. control subgroups in BC cohort

3b. Matched exercises vs. control subgroups in APA cohort

3c. Matched vs. Mismatched exercises subgroups in BC cohort

3d. Matched vs. Mismatched exercises subgroups in APA cohort

Table 4. Clinical Changes from Baseline after Exercises

Matched Exercises							
BC				**APA**			
Variable	MDC (95% CI)	Difference (post-pre)	% change	Variable	MDC (95% CI)	Difference (post-pre)	% change
BC (%)	14.9	25.2 [a]	42.6%	APA (%)	15.9	30.6 [a]	64.0%
BESTest (%)	7.6	11.5 [a]	15.8%	BESTest (%)	7.6	15.5 [a]	22.8%
BBS (points)	3.0	9.3 [a]	21.4%	BBS (points)	3.0	9.3 [a]	21.1%[b]
UIC FFM (points)	2.6	14.9 [a]	56.9%	UIC FFM (points)	2.6	15.3 [a]	56.5%[b]
Mismatched Exercises							
BC				**APA**			
Variable	MDC (95% CI)	Difference (post-pre)	% change	Variable	MDC (95% CI)	Difference (post-pre)	% change
BC (%)	14.9	22.6 [a]	41.3%	APA(%)	15.9	15	27.0%
BESTest (%)	7.6	10.5 [a]	15.1%	BESTest (%)	7.6	7.6 [a]	10.4%
BBS (points)	3.0	10.1 [a]	23.4%	BBS (points)	3.0	6.7 [a]	14.7%
UIC FFM (points)	2.6	14.5 [a]	53.1%[b]	UIC FFM (points)	2.6	14.4 [a]	52.9%

Abbreviations: BC = Biomechanical Constraints; APA = Anticipatory Postural Adjustments; BESTest = the Balance Evaluation Systems Test; BBS = Berg Balance Scale; UIC FFM = University of Illinois in Chicago Fear of Falling Measurement; MDC = minimal detectable change; CI = confident interval; % change = (post-pre)/baseline scores × 100%.
a indicated exceeded 95% CI of MDC.

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DISCUSSION

We investigated the effectiveness of exercises prescribed specifically for subsystem impairments identified using the BESTest in community-dwelling older adults with high fall and fracture risk. Our results support our first hypothesis that the subgroup who received exercises matched to their targeted balance impairment demonstrated improved balance, reduced fall risk, and improved QoL compared to the control subgroup. Our results partially supported our second hypothesis, that is, the subgroup who received matched exercises demonstrated greater improvement in their targeted subsystem and overall BESTest scores, but did not show greater reduction in fall risk (as measured by BBS and UIC FFM) compared to the mismatched subgroup.

Although fall risk was reduced in both subgroups, we expected the matched exercises would reduce fall risk more than the mismatched exercises. This did not happen. A possible explanation may be related to how we identified fall risk. Although we attempted to improve the fall risk assessment by using the BBS with the UIC FFM, this method may not have been sufficient to detect small differences. We noticed that all participants' UIC FFM improvement exceeded the MDC after exercises, either matched or mismatched. This finding suggests that exercise alone, regardless of type of exercises, reduced the individual's fear of falling. In addition, the responsiveness of the combination of BBS/UIC FFM tests to demonstrate change is unknown. Thus, not showing a significant difference in fall risk reduction using BBS and UIC FFM may not necessarily mean that one did not occur. The limitation may have been our measure of fall risk.

We chose to use the BESTest model to identify balance subsystem impairments because the BESTest is one of the few standardized tests that includes and categorizes test items into subsystems.[4] We agreed with Horak et al[2] that the construct for the BESTest model may not be adequately comprehensive or sufficiently definitive to differentiate specific impairments in the subsystems, which are clearly synergistic and not mutually exclusive.[2] For example, “sit on the floor and stand up” is a test item in the BC subsystem as an indicator of strength and joint limitation for lower extremities.[2] One could argue that this test item represents the initiation of a voluntary movement and therefore it could be categorized in the APA subsystem.[5] This potential issue could explain why all participants had at least 1 subsystem impairment (scored less than 70%) in addition to the targeted balance subsystem impairment. Singling out an impairment in only 1 subsystem was difficult. To this end, an initial step may be to better define a universally acceptable model of balance.

We attempted to provide exercises targeted to 1 subsystem, and that subsystem showed the greatest improvement; however, there was also “overflow” improvement in other subsystems that contributed to the overall improvement in BESTest total scores. However, the improvement in more than 1 subsystem is not necessarily a negative outcome. We demonstrated improvement in overall balance with fewer and more targeted exercises. For some of the participants, despite being impaired, the targeted subsystem was not the primary or “most impaired” subsystem. In the APA cohort only 2 out of the 20 participants had another subsystem that scored lower than their APA subsystem score; however, 10 of the 20 participants in BC cohort had another subsystem score lower than our targeted subsystem. Thus the subsystems that we chose to treat were not always the most impaired subsystem for the participants. Therefore the exercises we provided may not have been those most needed to improve individuals' impairments. Perhaps exercises would have been more effective had we chosen to provide exercises targeted to the most impaired subsystems. In addition, we arbitrarily defined that scores of 70% or less in a subsystem constituted an impairment in that subsystem. However, each subsystem may have a different cutoff score than the uniform score of 70% or less that we used.

Potential limitations of this study that may have affected the results. The therapist, Tester 1 (EWH), administered the pretest and randomized the participants, and instructed and supervised each individual's exercise program. Tester 1 may have been unconsciously biasing by giving differential encouragement.[28] Further, Tester 1 worked with and knew all the participants. This may have influenced adherence. Our participants were all from a senior independent living community. All participants were Caucasians, and more women participated than men. Our participants were relatively homogeneous and may not represent older adults living in other environments. Our participants are generally older (aged 74-94 old) and had a high prevalence of fall history. In addition, we recruited participants using a sample of convenience, which has the inherent bias of "self-selection."[28] Further, participants might have "learned" the tests as they were tested 3-4 times with the same outcome measures over a 12-week period of time for initial tests (2 times for reliability, and 1-2 times for the post-tests). Also, we had a small sample size and did not measure falls prospectively. Because we tested only 2 out of the 6 subsystems in BESTest, the results of this study may not be extrapolated to the other subsystems of balance in the BESTest, or to different balance models. Also, results may have been different if the participants performed the exercises as a home program.

The strengths of our small RCT were: (1) we followed CONSORT[14] requirements, as able; (2) the study design satisfied 8/11 criteria of the PEDro scale[30], and (3) all participants completed the study and were analyzed. Further, our approach was unique in 2 ways: (1) we used a clinical model to classify balance and to identify (i.e., diagnose) specific impairments in 2 selected subsystems of balance, BC and APA; and (2) we prescribed a progressive set of standardized specific exercises based on our selected balance impairment identified from the model. We compared the effectiveness of matched specific exercises to a control subgroup, then further to a mismatched (non-specific exercises) subgroup. The exercise programs were standardized, progressive and were directly supervised by a therapist in order to achieve optimal accuracy of performance and adherence.

We recommend a larger clinical trial of the effectiveness of using a balance subsystem model to compare exercises targeted to participants' actual primary impairments to a placebo of fixed, generalized balance exercises for community-dwelling older adults. We also recommend using a more definitive and responsive measure for fall risk, determining the participants' perceived clinical meaningful difference in outcome measurements, and measuring falls prospectively. Additionally, we suggest studies to determine the most effective exercises and the exercise dosage for each subsystem of balance. The concept of using the BESTest model to diagnose specific impairments and guide exercise prescription may facilitate developing a treatment-based classification model that might assist clinicians in using a diagnostic approach to standardize exercises and optimize outcomes.

In conclusion, our results provide preliminary evidence that exercises matched to specific balance impairments improve balance and reduced fall risk with community-dwelling older adults. However, compared to non-specific exercises, specific exercises are more effective in improving balance but not in reducing fall risk as we measured it. The clinical implication is that, with further studies, older adults may be more adherent with fewer exercises and that exercises targeting their primary impairments may be adequate to improve balance and to reduce fall risk.

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CHAPTER V

SUMMARY

One in 3 adults, aged 65 years or older, fall each year.[1] More than 20% of those who fall sustain injuries that affect their ability to function independently and increase their likelihood of an earlier death.[1] Balance impairment is a key factor contributing to falls.[1-5] Balance control is complex and involves multiple underlying subsystems.[2,4,6] Although several conceptual balance models have been proposed,[2,4,5] to date, there is no universally accepted model. Clinical tests typically assess only selected aspects of balance and do not categorize performance items into subsystems.[5] Therefore, clinicians are challenged to diagnose specific balance impairments, and, the results of these tests do not guide exercise prescriptions. Consequently, recommendations for exercises to improve balance tend to be multidimensional[3] with an apparent broad-based approach in order to cover all subsystems of balance control.[1,3] Conceptually, if specific balance subsystem impairments can be identified, clinicians may be able to prescribe exercises specific to the identified impairments in balance subsystems rather than use the more common broad-based approach. **My central hypothesis was "Exercises that are prescribed based upon specific impairments associated with balance control will improve balance and reduce the risk of falling in older adults greater than no exercises or non-specific exercises."**

In order to test my central hypothesis, I conducted a concurrent psychometric study to determine interrater and test-retest reliability and minimal detectable change (MDC) for the primary outcome variables; a proof-of-concept case series determine whether impairments in subsystems of balance are modifiable with specific exercises and reduce fall risk (Aim 1); and a small randomized controlled trial to determine the effectiveness of impairment-specific exercises in improving balance and reducing fall risk for older adults (Aim 2). The summary of each study follows.

CHAPTER II PSYCHOMETRIC STUDY: Psychometric Properties of the BESTest Total and Selected Subsystem Scores, Berg Balance Scale (BBS), and the University of Illinois at Chicago Fear of Falling Measure (UIC FFM) with Community-Dwelling Older Adults.

The purposes of this methodological study were to: (1) determine interrater reliability and test-retest reliability of the primary outcome variables (BESTest total and subsystem scores, BBS, and UIC FFM) to be used in the subsequent studies; (2) determine the minimal detectable change (MDC)[7] of each of the above variables to provide reference for clinically meaningful changes for each variable; and (3) serve as the qualifying process for participant recruitment for Aims 1 and 2.

The interrater reliability, test-retest reliability and MDC of the outcome variables are displayed in Tables 1 and 2. Participants (n = 70) were tested as part of this methodological study over 20 months. Results demonstrated good to excellent interrater reliability [$ICC_{(2, 1)}$ ranged from 0.92 to 0.99] with 2 testers and myself, and good to excellent test-retest reliability [$ICC_{(2, 1)}$ ranged from 0.85 to 0.98] with 2 sessions conducted 7-14 days apart. We also provided MDC values for all 4 variables at 95% and 90% CIs to be used in the subsequent studies (Aims 1 and 2). The strength of this study included having large sample size, and being the first authors to report interrater and test-retest reliability and MCD scores for the BESTest total and subsystem scores with community-dwelling older adults. Chapter II consists of a manuscript to submit to the *Journal of Geriatric Physical Therapy* disseminating the information on reliability and MDCs for BESTest total and subsystem scores. The title of the manuscript is:

"Interrater and Test-Retest Reliability and Minimal Detectable Change of the Balance Evaluation Systems Test (BESTest) and Subsystems with Community-Dwelling Older Adults."

Table 1. Interrater Reliability (n = 32; 11men, 21 women)

Variable	ICC $_{(2, 1)}$	95% CI
UIC FFM	.99	(.98 - .99)
BBS	.97	(.94 - .98)
BESTest total %	.97	(.94 - .99)
BC subsystem %	.92	(.85 - .96)
APA subsystem %	.94	(.88- .97)

Abbreviations: BBS = Berg Balance Scale; UIC FFM = University of Illinois in Chicago Fear of Falling Measurement; BESTest = the Balance Evaluation Systems Test; BC = Biomechanical Constraints; APA = Anticipatory Postural Adjustments, CI = confident interval, ICC = Intraclass correlation coefficient

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Table 2. Test-retest Reliability (n = 70)

Variable	**Test-retest Reliability(N = 70)**		**MDC (95% CI)**	**MDC (90% CI)**
	95% CI	**ICC $_{(2, 1)}$**		
UIC FFM (point)	0.98	(.96-.99)	2.6	2.1
BBS (point)	0.97	(.94-.98)	3.0	2.5
BESTest Total%	0.93	(.89-.96)	7.6	6.3
BC Subsystem (%)	0.89	(.81-.94)	14.9	12.4
APA Subsystem (%)	0.84	(.76-.90)	15.9	13.3

Abbreviations: BBS = Berg Balance Scale; UIC FFM = University of Illinois in Chicago Fear of Falling Measurement; BESTest = the Balance Evaluation Systems Test; BC = Biomechanical Constraints; APA = Anticipatory Postural Adjustments, MDC = minimal detectable change; CI = confident interval, ICC = Intraclass correlation coefficient

CHAPTER III SPECIFIC AIM 1: Determine whether impairments in subsystems of balance are modifiable with specific exercises and reduce fall risk.

My expectations were: (1) the identified impairments in subsystems of balance would be modified with specific matched exercises; and (2) the specific matched exercise program would improve overall balance and reduce fall risk.

A case series (n = 6) consisting of 3 older adults identified as having impairment in the biomechanical constraints (BC) subsystem and 3 older adults identified as having impairment in the anticipatory postural adjustment (APA) subsystem was used to determine proof-of-concept prior to the Aim 2 RCT. I developed and provided specific exercises designed to reduce impairments in the identified subsystem (BC or APA). All 6 participants demonstrated improvement in the impaired subsystem of balance, improved overall balance measured by BESTest total scores, and reduced fall risk after 18 supervised exercise sessions. Follow-up tests were administered to the available 3 participants 9 to 15 months post program. Participants' subsystem scores at follow-up remained similar to their immediate post-test scores, and all of the participants reported continuing to perform the exercise program. The results of the case series provided preliminary evidence that specific exercises could improve identified impairments in the BC and APA subsystems of balance. Thus, the results suggested that using a model to more precisely identify balance impairments in selected subsystems and implementing a targeted exercise intervention may be conceptually valid and worthy of study. The strengths of the proof-of-concept case series are that: (1) all participants completed the exercise programs within the time frame with full adherence; (2) no injuries or falls were reported during the program; (3) the tester who administered the post-test was unaware of the pretest scores or the group assignment; and (4) all exercises were performed with direct supervision to ensure optimal performance and outcomes.

Chapter III consists of a manuscript of the case series in the format ready to submit to the *Physical Therapy*:

"Using a Model to Prescribe Impairment-Specific Exercises to Reduce Fall Risk in Community-Dwelling Older Adults with Fall and Fracture Risks: A Proof-of-Concept Case Series."

CHAPTER IV SPECIFIC AIM 2. Determine the effectiveness of impairment-specific exercises in improving balance and reducing fall risk for older adults.

My working hypotheses were: (1) older adults who receive exercises specific to their targeted balance impairment will demonstrate improved balance and a reduced fall risk compared to older adults who receive no intervention, (2) exercises that are matched to the specific balance impairment will be more effective than exercises that are mismatched to the targeted impairment for improving balance and reducing fall risk for older adults.

A small randomized control trial (n = 40) consisting of 2 phases was conducted to test my hypotheses in Aim 2. Twenty older adults identified as having balance impairment in BC subsystem and 20 with impairment in APA subsystem were enrolled and randomly allocated into 2 subgroups (matched exercises and control/delayed mismatched exercises). During Phase 1, participants in the matched subgroup received a 6-week program consisting of 18 sessions of supervised, standardized and progressive exercises developed specific to their targeted impaired subsystems. The mismatched exercise subgroup waited 6 weeks and served as control group. During Phase 2, participants of the mismatched group then received a 6-week, 18-session, supervised, standardized and progressive exercise program that was opposite that of their identified balance impairment. We used within and between subjects mixed, 2-way repeated measures analyses of covariance (ANCOVA) in order to control baseline differences between the randomized subgroups by using the baseline scores as the covariate to adjust and equate the initial scores on the BC and APA cohorts.[7] Results of the matched exercise subgroup compared to the control demonstrated that all 4 outcome variables (BC or APA subsystem, BESTest, BBS and UIC FFM) increased in the matched exercise subgroup significantly and exceeded MDCs with large effect size, but not in the control subgroup. Results of the matched subgroup compared to the mismatched subgroup demonstrated that (1) all 4 outcome variables improved after exercises in both matched and mismatched subgroups; (2) the matched subgroup showed significantly greater improvement in the targeted subsystem of balance and overall balance (BESTest total scores) but not in fall risk (measured as BBS and UIC FFM). The results of this small RCT supported my first hypothesis and partially supported my second hypothesis.

The strengths of this small RCT were: (1) we followed CONSORT[8] requirements as able; (2) the study design satisfied 8/11 criteria of the PEDro scale[9] including specified eligibility criteria, randomly allocated subjects, similarity between subgroups, blinded subjects, blinded outcome tester, more than 85% of subjects completed outcome measures, reported statistical comparisons and reported point results as well as standard deviations, and (3) all participants completed the study and were analyzed.

Chapter IV consists of a manuscript of the small RCT in the format ready to submit to the *Physical Therapy*:

"Effectiveness of Exercises to Reduce Specific Balance Impairments and Fall Risk in Community-Dwelling Older Adults: A Randomized Controlled Trial."

MODIFICATIONS TO THE ORIGINAL STUDY PLAN

I made the following 4 modifications to the study plan from that described in my original dissertation proposal:

Additional tester involvement

I was able to improve the original study design by adding two additional testers for the interrater reliability, and I was able to recruit a tester for the post-testing who was blinded to the pretest scores and group assignment.

Overall modifications of terminology from the Proposal

I modified the original terminology used in the proposal. Originally, I used "component" of balance, and later changed to "subsystem" of balance because the term "subsystem" was used in the original BESTest article.[2]

Modification in recording participants' medications

I initially planned to record participants' medications, but abandoned this effort because most of the participants were unable to provide credible information.

Extension of original timeline

I modified the proposed timeline from 1 year to 2 years because of the time required to recruit, assess, treat, analyze the data and write the manuscripts.

OVERALL LIMITATIONS

Participants

I included community-dwelling older adults from a senior independent living center. Although the term "community-dwelling" has been widely used, it is poorly defined. Older adults who live in senior independent living communities, older adults who live with caregivers, and older adults who live alone may have different activity and fitness levels, thereby, yielding differing scores on each of the tests used. For future studies, to better define "community-dwelling," use of an activity-level scale maybe more discriminating than relying simply on living environment. All our participants were residents of same facility and therefore may be more homogeneous, but may limit generalizability of our findings. Further, the prevalence of fall history in my sample (70%) exceeds that of the reported US older adult population (40-60%),[10] which may be due to the choice of a retirement community as their living environment. In addition, our participants were general older (aged 85.0 ± 5.5; 70-94 years old). The prevalence of falls increases with age particularly for individuals 75 and older.[1]

Potential bias

Several forms of bias may have affected the results and generalizability. Participants were volunteers and from a sample of convenience, which introduces the potential bias of "self-selection."[7] In addition, fall history and fear of falling were collected using self-reported data, which may involve recall bias. Participants may not remember falling or be reluctant to report falling. Also, despite efforts to operationally define a fall, participants may still interpret the incidence of a fall differently. Another potential bias was "teaching to tests."[7] Participants who were identified as having an impairment in a particular subsystem of balance received exercises designed to improve that subsystem. Although attempting to avoid prescribing exercises that directly resembled the test items, the prescribed exercises were, nevertheless, unavoidably similar to the test for the particular subsystem treated.

Additional bias involves me as the primary tester and intervention provider. I instructed and supervised each individual's exercise program, and I administered the pretest and knew the randomized subgroup allocation (matched, mismatched) Therefore, I may have been unconsciously biasing by providing differentiated encouragement.[7] Furthermore, the participants knew me as the onsite supervisory physical therapist in the physical therapy practice located in the retirement community. Participants may have worked harder to try to please me and help me complete my dissertation, that is, to "please the teacher."[7]

The Fracture Risk Assessment tool (FRAX)[11]

I used FRAX scores as the indicator of each participant's fracture risk because it can be administered without Dual Energy X-ray Absorptiometry (DXA) scan results.[11] The stance of the International Society for Clinical Densitometry is that FRAX scores may not be valid with adults who are receiving medications such as bisphosphonate or calcitonin for osteoporosis.[12] I was unable to obtain information about the participants' medications, therefore, the FRAX score may not have been valid for some participants.

The BESTest model

We chose to use the BESTest model to identify balance subsystem impairments because the BESTest is one of the few standardized tests that includes and categorizes test items into subsystems.[5] However, the construct for the BESTest model may not be adequately comprehensive or sufficiently definitive to differentiate specific impairments in the subsystems, which are clearly synergistic and not mutually exclusive.[2] This issue could explain why all participants had at least 1 subsystem impairment in addition to their targeted balance subsystem impairment that scored less than 70%. As noted, the 6 subsystems of balance in the BESTest model are not mutually exclusive; therefore, singling out an impairment in 1 subsystem was difficult. I attempted to provide exercises targeted to 1 subsystem of balance impairment, however, there was also “overflow” improvement in other subsystems that contributed to the overall improvement in BESTest total scores, further supporting the interaction of the subsystems.

I chose the BC and APA subsystems to test my hypotheses because the BC and APA seem to share less commonality with each other amongst the 6 subsystems. In addition, I used the BC and APA subsystem and the BESTest total scores as primary outcome variables for both the case series and RCT studies. However, because the BC and APA subsystems were part of the BESTest, they are not independent from each other. Using retrospective reliability data ($n = 70$), I conducted a Pearson Product Correlation between all subsystems and BESTest total scores. Not surprisingly, each individual subsystem was significantly correlated to the BESTest total scores with the correlation coefficients ranging from $r = .56$-$.79$ ($p < 0.01$). Each individual subsystem also was significantly correlated with each other with the exception of between the BC and APA subsystems ($r = .01$, $p = 0.92$). Although this correlation seemed to validate my choice of using the BC and APA subsystems to test my hypotheses, the BC subsystem may not represent the same construct as the other BESTest subsystems. The BC subsystem relates more to underline pain, posture, and strength elements that may affect balance rather than direct postural control which is more evident in the other 5 subsystems. In an abbreviated version of the BESTest, the Mini-BESTest,[13] the test items of BC subsystem were eliminated. The Mini-BESTest used psychometric and Rasch analysis to eliminate 14 items deemed as not belonging to the main trait, “dynamic balance.” We arbitrarily defined scores of 70% or less in a subsystem as a balance impairment in that subsystem. Each individual subsystem may contribute to overall balance differently, thereby yielding different cutoff scores.

Exercise program

I tested exercises targeted to only 2 out of the 6 subsystems in BESTest in my dissertation studies, the results may not be inferred to the other subsystems of balance in the BESTest, or to different balance models.

The subsystems that we chose to provide specific exercises were not always the most impaired subsystem for the participants. For some of the participants, despite being impaired, the targeted subsystem was not the primary or “most impaired” subsystem. In the APA cohort only 2 out of the 20 participants had another subsystem that scored lower than their APA subsystem score; however, 10 of the 20 participants in BC cohort had another subsystem score lower than our targeted subsystem. Therefore the subsystem I targeted at may not have been those most needed to improve individuals’ impairments. Perhaps exercises would have been more effective had we chosen to provide exercises targeted to the most impaired subsystems.

Literature recommends using the Borg Scale[14] to determine exercise intensity and the number of repetitions of each exercise when prescribing exercises for older adults.[15] The Borg Scale indicates an individual’s self-perceived level of exertion and fatigue with activity.[14] However, I chose to use the conventional method of using sets and repetitions with standardized progression criteria as indicators of intensity and progression of the exercises. Standardizing the exercise program and progression criteria using individual Borg Scale scores would have been difficult. Also, results may have been different if the participants performed the exercises as a home program.

IMPLICATIONS FOR REHABILITATION

Overall, my Aim 1 and Aim 2 studies were innovative because: (1) I used a theoretical model of balance to clinically identify (i.e., diagnose) impairments in selected subsystems of balance. This approach differed from the current practice of using clinical tests or measures of fall risk that are not designed to identify specific impairments in balance; and (2) I prescribed a specific, standardized and progressive set of exercises based on the balance subsystem impairment identified using the theoretical balance model.

The results are significant because they may directly impact clinical practice in the following ways: (1) the exercise programs consisted of more focused, progressive and standardized exercises. Because the intervention was more focused, the program consisted of a smaller number of exercises that were less time-consuming to perform (25 to 40 minutes each session). Participants' feedback indicated that the program was easy to adhere to and my very limited follow-up (n = 3) indicated that some participants continued their exercises after completion of the supervised programs. The exercises were performed with the therapist's direct supervision in order to achieve optimal compliance and performance accuracy. However, ultimately we hope that balance exercises can be performed as a home program because the balance issues can be a lifelong issue for older adults. In addition, balance should be re-evaluated annually or bi-annually in order to progress and update the exercise program to reflect the changes in status because adaptation may limit continued effectiveness.

The overall results of using exercises matched to the impairment versus a control group provided evidence of (1) the effectiveness of using an impairment-specific balance model upon which to prescribe exercises for older adults at risk for falls and fracture and (2) that these specific exercises demonstrated greater improvement at targeted balance subsystem impairments and overall balance compared to the non-specific exercises, but not in reduction fall risk. Further, impairment-specific and progressive exercises demonstrated efficiency and effectiveness that may guide clinicians in prescribing specific, individualized exercises to reduce fall risk. Overall our results provided a first step toward future studies that will compare the effectiveness, efficacy, and compliance of the current practice of prescribing generic broad-based exercises and impairment-specific exercises to reduce fall risk in community-dwelling older adults.

RECOMMENDATIONS FOR FUTURE STUDIES

The results of our studies suggest that using a model to diagnose specific impairment may eventually guide clinicians in prescribing specific, individualized balance impairment exercise routines. A larger, multi-site clinical trial of the effectiveness of using a balance subsystem model to compare exercises targeted to participants' primary (worst) impairments to a placebo of fixed, broad-based balance exercises for community-dwelling older adults is recommended. Ultimately a prediction rule[16] should be developed to assist in providing evidence for a diagnostic approach to optimize treatment. To this end, an initial step may be to better validate a universally accepted model of balance and the interacting subsystems in order to categorize balance impairments. Advances made in orthopedic physical therapy with the development of the treatment-based classification of mechanical low back pain[17] have standardized care and improved outcomes. Balance assessment and treatment may need similar advancement.

SUMMARY

Overall, results from this dissertation should contribute to the body of knowledge for clinical practices to better diagnose balance with subsystems impairment and to prescribe impairment-specific exercises. Aim 1 and Aim 2 studies provide evidence that 6-week exercises, specific to 2 subsystems of balance impairments, improve targeted subsystem of balance as well as the overall balance compared to no exercises and non-specific exercises for community-dwelling older adults. Potential limitations in this dissertation were related to the construct of BESTest and how we measured fall risks. The concept of using the BESTest as a model to diagnose specific impairments of balance and guide exercise prescription may facilitate developing a treatment-based classification model that might assist clinicians in using a diagnostic approach to standardize exercises and optimize outcomes.

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APPENDICES

Appendix 1.

<u>Pre-screen Questionnaire</u>

Pre-screen Questionnaire

Part A	***Yes***	***No***
1. Are you 65 years or older?		
2. Are you able to walk with or without assistive device such as a walker or a cane independently for 30 feet?		
3. Are you able to stand by yourself without help?		
4. Are you able to sign legal documents?		
5. Are you able to follow verbal instructions and demonstrations?		
Part B		
6. Do you have medical conditions such as poor controlled diabetes or high blood pressure?		
7. Is there any reason that you cannot perform exercises for balance?		
8. Are you currently actively receiving physical therapy, occupational therapy or other forms of exercise therapy?		
9. Are you considered legally blind?		
10. Do you have diagnosis of a condition that might impair your balance or muscle strength such as Parkinson's disease, Amyotrophic lateral sclerosis (ALS), Multiple sclerosis (MS), or had a massive stroke within the past 6 months?		

Appendix 2.

Inclusion and Exclusion Criteria

Inclusion Criteria	***Rationale***
65 years or older	Defined as “older adults” in this study
Able to ambulate at indoor level surface with or without assistive device independently for 10 meters; able to stand independently without aid.	Safely complete BBS and BESTest assessment.
Experienced a fall in the past 12 months.	Defined as “at risk of falls” in this study.
FRAX score 10-year probability of a hip fracture ≥ 3% or a 10-year probability of a major osteoporosis-related fracture ≥ 20%	Defined as “at risk of fracture” in this study.
Living in community or independent retirement senior home.	Defined as “community-dwelling” in this study.
Cognitively able to provide informed consent.	Respect autonomy; safely able to complete assessment and exercise procedures.
Exclusion Criteria	***Rationale***
Unstable medical conditions including poor control of chronic medical conditions such as diabetes or hypertension.	Safety concerns as uncontrolled medical conditions could put participants at risk for injuries with exercise program.
Cognitively unable to follow exercise instructions with verbal cues and demonstration. MMSE score 17 or below (Crum, Anthony, Bassett & Folstein, 1993).	Unable to understand informed consent and to follow instructions for assessments and exercises.
Weight-bearing or exercise restrictions from physician or other healthcare providers.	Weight bearing is needed for balance trainings and BBS and BESTest assessments; restrictions in weight bearing and exercises indicate conditions that contradict balance exercises.
Excessive pain with stretching, strengthening or weight bearing exercises.	Confound test results and unable to tolerate instructed exercises.
Actively receiving physical therapy or other forms of exercise interventions.	Confounding factors to results.
Legal blindness.	Unable to participate this study.
Diagnosis of progressive neurological condition that would influence balance or muscle strength such as Parkinson’s, ALS, MS, or had a massive stroke within the past 6 months.	Confounding factors to results.

BBS = Berg Balance Scale
BESTest = Balance Evaluation Systems Test
MMSE = Mini Mental State Exam

Appendix 3.

Mini Mental State Exam (MMSE)

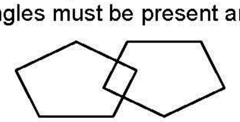
For cognitive screen

(Permission pending)

Mini-Mental State Examination (MMSE)

Patient's Name: ______________________________________ Date: ____________

Instructions: ***Ask the questions in the order listed. Score one point for each correct response within each question or activity.***

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day of the week? Month?"
5		"Where are we now: State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: ___________
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Stop after five answers. Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

(Adapted from Rovner & Folstein, 1987)

Instructions for administration and scoring of the MMSE

Orientation (10 points):

- Ask for the date. Then specifically ask for parts omitted (e.g., "Can you also tell me what season it is?"). One point for each correct answer.
- Ask in turn, "Can you tell me the name of this hospital (town, county, etc.)?" One point for each correct answer.

Registration (3 points):

- Say the names of three unrelated objects clearly and slowly, allowing approximately one second for each. After you have said all three, ask the patient to repeat them. The number of objects the patient names correctly upon the first repetition determines the score (0-3). If the patient does not repeat all three objects the first time, continue saying the names until the patient is able to repeat all three items, up to six trials. Record the number of trials it takes for the patient to learn the words. If the patient does not eventually learn all three, recall cannot be meaningfully tested.
- After completing this task, tell the patient, "Try to remember the words, as I will ask for them in a little while."

Attention and Calculation (5 points):

- Ask the patient to begin with 100 and count backward by sevens. Stop after five subtractions (93, 86, 79, 72, 65). Score the total number of correct answers.
- If the patient cannot or will not perform the subtraction task, ask the patient to spell the word "world" backwards. The score is the number of letters in correct order (e.g., dlrow=5, dlorw=3).

Recall (3 points):

- Ask the patient if he or she can recall the three words you previously asked him or her to remember. Score the total number of correct answers (0-3).

Language and Praxis (9 points):

- Naming: Show the patient a wrist watch and ask the patient what it is. Repeat with a pencil. Score one point for each correct naming (0-2).
- Repetition: Ask the patient to repeat the sentence after you ("No ifs, ands, or buts."). Allow only one trial. Score 0 or 1.
- 3-Stage Command: Give the patient a piece of blank paper and say, "Take this paper in your right hand, fold it in half, and put it on the floor." Score one point for each part of the command correctly executed.
- Reading: On a blank piece of paper print the sentence, "Close your eyes," in letters large enough for the patient to see clearly. Ask the patient to read the sentence and do what it says. Score one point only if the patient actually closes his or her eyes. This is not a test of memory, so you may prompt the patient to "do what it says" after the patient reads the sentence.
- Writing: Give the patient a blank piece of paper and ask him or her to write a sentence for you. Do not dictate a sentence; it should be written spontaneously. The sentence must contain a subject and a verb and make sense. Correct grammar and punctuation are not necessary.
- Copying: Show the patient the picture of two intersecting pentagons and ask the patient to copy the figure exactly as it is. All ten angles must be present and two must intersect to score one point. Ignore tremor and rotation.

(Folstein, Folstein & McHugh, 1975)

Appendix 4.

Balance Evaluation Test System (BESTest)

(Reproduced with permission)

eAppendix.
Balance Evaluation Systems Test (BESTest)[a]

Test Number/Subject Code ____________________ **Date** ____________

Examiner Name ______________________________

Examiner Instructions for BESTest

1. Subjects should be tested with flat-heeled shoes or with shoes and socks off.
2. If subject must use an assistive device for an item, score that item one category lower.

Tools Required

- Stopwatch
- Measuring tape mounted on wall for Functional Reach Test
- Approximately 60 × 60 cm (2 × 2 ft) block of 4-inch, medium-density, Tempur® foam[b]
- 10-degree incline ramp (at least 2 × 2 ft) to stand on
- Stair step, 15 cm (6 in) in height for alternate stair tap
- 2 stacked shoe boxes for obstacle during gait
- 2.5-kg (5-lb) free weight for rapid arm raise
- Firm chair with arms with 3 m in front marked with tape for Timed "Get Up & Go" Test
- Masking tape to mark 3-m and 6-m lengths on the floor for Timed "Get Up & Go" Test

Summary of Performance: Calculate Percent Score

Section I: ______/15 × 100 = ______ **Biomechanical Constraints**

Section II: ______/21 × 100 = ______ **Stability Limits/Verticality**

Section III: ______/18 × 100 = ______ **Anticipatory Postural Adjustments**

Section IV: ______/18 × 100 = ______ **Postural Responses**

Section V: ______/15 × 100 = ______ **Sensory Orientation**

Section VI: ______/21 × 100 = ______ **Stability in Gait**

TOTAL: ______/108 points = ______ **Percent Total Score**

(Continued)

eAppendix.
Continued

Balance Evaluation Systems Test (BESTest) Interrater Reliability

Subjects should be tested with flat-heeled shoes or shoes and socks off. If subject must use an assistive device for an item, score that item one category lower. If subject requires physical assistance to perform an item, score the lowest category (0) for that item.

I. Biomechanical Constraints — Section I: ______/15 Points

1. Base of support

(3) Normal: Both feet have normal base of support with no deformities or pain
(2) One foot has deformities and/or pain
(1) Both feet have deformities *OR* pain
(0) Both feet have deformities *AND* pain

2. CoM alignment

(3) Normal AP and ML CoM alignment and normal segmental postural alignment
(2) Abnormal AP *OR* ML CoM alignment *OR* abnormal segmental postural alignment
(1) Abnormal AP *OR* ML CoM alignment *AND* abnormal segmental postural alignment
(0) Abnormal AP *AND* ML CoM alignment

3. Ankle strength and range

(3) Normal: Able to stand on toes with maximal height and to stand on heels with front of feet up
(2) Impairment in either foot of either ankle flexors or extensors (ie, less than maximum height)
(1) Impairment in two ankle groups (eg, bilateral flexors or both ankle flexors and extensors in one foot)
(0) Both flexors and extensors in both left and right ankles impaired (ie, less than maximum height)

4. Hip/trunk lateral strength

(3) Normal: Abducts both hips to lift the foot off the floor for 10 s while keeping trunk vertical
(2) Mild: Abducts both hips to lift the foot off the floor for 10 s but without keeping trunk vertical
(1) Moderate: Abducts only one hip off the floor for 10 s with vertical trunk
(0) Severe: Cannot abduct either hip to lift a foot off the floor for 10 s with trunk vertical or without trunk vertical

5. Sit on floor and stand up — *Time ______ seconds*

(3) Normal: Independently sits on the floor and stands up
(2) Mild: Uses a chair to sit on floor *OR* to stand up
(1) Moderate: Uses a chair to sit on floor *AND* to stand up
(0) Severe: Cannot sit on floor or stand up, even with a chair, or refuses

II. Stability Limits/Verticality — Section II: ______/21 Points

6. Sitting verticality and lateral lean

Lean: Left	Lean: Right	Lean	Verticality: Left	Verticality: Right	Verticality
(3)	(3)	Maximum lean, subject moves upper shoulders beyond body midline, very stable	(3)	(3)	Realigns to vertical with very small or no overshoot
(2)	(2)	Moderate lean, subject's upper shoulder approaches body midline or some instability	(2)	(2)	Significantly overshoots or undershoots but eventually realigns to vertical
(1)	(1)	Very little lean, or significant instability	(1)	(1)	Failure to realign to vertical
(0)	(0)	No lean or falls (exceeds limits)	(0)	(0)	Falls with the eyes closed

(Continued)

eAppendix.
Continued

7. Functional reach forward *Distance reached: _______ cm OR _______ inches*
- (3) Maximum to limits: >32 cm (12.5 in)
- (2) Moderate: 16.5–32 cm (6.5–12.5 in)
- (1) Poor: <16.5 cm (6.5 in)
- (0) No measurable lean—or must be caught

8. Functional reach lateral *Distance reached:* ***Left*** _____ cm (_____ in) ***Right*** _____ *cm (_____ in)*

Left	Right	
(3)	(3)	Maximum to limit: >25.5 cm (10 in)
(2)	(2)	Moderate: 10–25.5 cm (4–10 in)
(1)	(1)	Poor: <10 cm (4 in)
(0)	(0)	No measurable lean, or must be caught

III. Anticipatory Postural Adjustments — Section III: ______/18 Points

9. Sit to stand
- (3) Normal: Comes to stand without the use of hands and stabilizes independently
- (2) Comes to stand on the first attempt with the use of hands
- (1) Comes to stand after several attempts or requires minimal assist to stand or stabilize or requires touch of back of leg or chair
- (0) Requires moderate or maximal assist to stand

10. Rise to toes
- (3) Normal: Stable for 3 s with good height
- (2) Heels up, but not full range (smaller than when holding hands so no balance requirement) *OR* slight instability and holds for 3 s
- (1) Holds for less than 3 s
- (0) Unable

11. Stand on one leg

Left *Time in seconds* _______	Right *Time in seconds* _______
(3) Normal: Stable for >20 s	(3) Normal: Stable for >20 s
(2) Trunk motion, *OR* 10–20 s	(2) Trunk motion, *OR* 10–20 s
(1) Stands 2–10 s	(1) Stands 2–10 s
(0) Unable	(0) Unable

12. Alternate stair touching *# of successful steps: _______ Time in seconds: _______*
- (3) Normal: Stands independently and safely and completes 8 steps in <10 s
- (2) Completes 8 steps in <10 seconds, but shows instability such as inconsistent foot placement, excessive trunk motion, hesitation, or arhythmical stepping
- (1) Completes <8 steps—without assistance (ie, assistive device) *OR* >10 s for 8 steps
- (0) Completes <8 steps in 10 s, even with assistive device

13. Standing arm raise
- (3) Normal: Remains stable
- (2) Visible sway
- (1) Steps to regain equilibrium/unable to move quickly without losing balance
- (0) Unable, or needs assistance for stability

(Continued)

eAppendix.
Continued

IV. Postural Responses

Section IV: ______/18 Points

14. In-place response—forward

(3) Recovers stability with ankles, no added arm or hip motion
(2) Recovers stability with arm or hip motion
(1) Takes a step to recover stability
(0) Would fall if not caught *OR* requires assist *OR* will not attempt

15. In-place response—backward

(3) Recovers stability at ankles, no added arm/hip motion
(2) Recovers stability with some arm or hip motion
(1) Takes a step to recover stability
(0) Would fall if not caught *OR* requires assistance *OR* will not attempt

16. Compensatory stepping correction—forward

(3) Recovers independently with a single, large step (second realignment step is allowed)
(2) More than one step used to recover equilibrium, but recovers stability independently *OR* one step with imbalance
(1) Takes multiple steps to recover equilibrium, or needs minimum assistance to prevent a fall
(0) No step *OR* would fall if not caught *OR* falls spontaneously

17. Compensatory stepping correction—backward

(3) Recovers independently with a single, large step
(2) More than one step used, but stable and recovers independently *OR* one step with imbalance
(1) Takes several steps to recover equilibrium or needs minimum assistance
(0) No step *OR* would fall if not caught *OR* falls spontaneously

18. Compensatory stepping correction—lateral

Left	Right
(3) Recovers independently with one step of normal length/width (crossover or lateral OK)	(3) Recovers independently with one step of normal length/width (crossover or lateral OK)
(2) Several steps used, but recovers independently	(2) Several steps used, but recovers independently
(1) Steps, but needs to be assisted to prevent a fall	(1) Steps, but needs to be assisted to prevent a fall
(0) Falls, or cannot step	(0) Falls, or cannot step

V. Sensory Orientation

Section V: ______/15 Points

19. Sensory integration for balance (modified CTSIB)

A–Eyes open, firm surface	B–Eyes closed, firm surface	C–Eyes open, foam surface	D–Eyes closed, foam surface
Trial 1 _____ s	Trial 1 _____ s	Trial 1 _____ s	Trial 1 _____ s
Trial 2 _____ s	Trial 2 _____ s	Trial 2 _____ s	Trial 2 _____ s
(3) 30 s stable	(3) 30 s stable	(3) 30 s stable	(3) 30 s stable
(2) 30 s unstable	(2) 30 s unstable	(2) 30 s unstable	(2) 30 s unstable
(1) <30 s	(1) <30 s	(1) <30 s	(1) <30 s
(0) Unable	(0) Unable	(0) Unable	(0) Unable

20. Incline–eyes closed

Toes Up

(3) Stands independently, steady without excessive sway, holds 30 s, and aligns with gravity
(2) Stands independently 30 s with greater sway than in item 19B *OR* aligns with surface
(1) Requires touch assist *OR* stands without assist for 10–20 s
(0) Unable to stand >10 s *OR* will not attempt independent stance

(Continued)

eAppendix.
Continued

VI. Stability in Gait — Section V: ______/21 points

21. Gait–level surface *Time ______ seconds*

(3) Normal: Walks 20 ft, good speed ($\leq$5.5 s), no evidence of imbalance
(2) Mild: Walks 20 ft, slower speed (>5.5 s), no evidence of imbalance
(1) Moderate: Walks 20 ft, evidence of imbalance (wide base, lateral trunk motion, inconsistent step path)—at any preferred speed
(0) Severe: Cannot walk 20 ft without assistance or severe gait deviations *OR* severe imbalance

22. Change in gait speed

(3) Normal: Significantly changes walking speed without imbalance
(2) Mild: Unable to change walking speed without imbalance
(1) Moderate: Changes walking speed but with signs of imbalance
(0) Severe: Unable to achieve significant change in speed *AND* signs of imbalance

23. Walk with head turns—horizontal

(3) Normal: Performs head turns with no change in gait speed and good balance
(2) Mild: Performs head turns smoothly with reduction in gait speed
(1) Moderate: Performs head turns with imbalance
(0) Severe: Performs head turns with reduced speed *AND* imbalance *AND/OR* will not move head within available range while walking

24. Walk with pivot turns

(3) Normal: Turns with feet close, fast ($\leq$3 steps) with good balance
(2) Mild: Turns with feet close, slow ($\geq$4 steps) with good balance
(1) Moderate: Turns with feet close at any speed with mild signs of imbalance
(0) Severe: Cannot turn with feet close at any speed and significant imbalance

25. Step over obstacles *Time ______ seconds*

(3) Normal: able to step over 2 stacked shoe boxes without changing speed and with good balance
(2) Mild: steps over 2 stacked shoe boxes but slows down, with good balance
(1) Moderate: steps over shoe boxes with imbalance or touches box.
(0) Severe: cannot step over shoe boxes *AND* slows down with imbalance or cannot perform with assistance.

26. Timed "Get Up & Go" Test *Get Up & Go: Time ______ seconds*

(3) Normal: Fast (<11 s) with good balance
(2) Mild: Slow (>11 s) with good balance
(1) Moderate: Fast (<11 s) with imbalance
(0) Severe: Slow (>11 s) *AND* imbalance

27. Timed "Get Up & Go" Test With Dual Task *Dual Task: Time ______ seconds*

(3) Normal: No noticeable change between sitting and standing in the rate or accuracy of backward counting and no change in gait speed
(2) Mild: Noticeable slowing, hesitation, or errors in counting backwards *OR* slow walking (10%) in dual task
(1) Moderate: Affects on *BOTH* the cognitive task *AND* slow walking (>10%) in dual task
(0) Severe: Cannot count backward while walking or stops walking while talking

(Continued)

eAppendix.
Continued

Instructions for BESTest

Biomechanical Constraints

1. Base of support

Examiner Instructions: Closely examine both feet to look for deformities or complaints of pain such as abnormal pronation/supination, abnormal or missing toes, pain from plantar fasciitis, bursitis, etc.

Patient: Stand up in your bare feet and tell me if you currently have any pain in your feet or ankles or legs.

2. CoM alignment

Examiner Instructions: Look at the patient from the side and imagine a vertical line through their center of body mass (CoM) to the feet. (The CoM is the imaginary point inside or outside the body about which the body would rotate if floating in outer space.) In an adult, standing erect, a vertical line through the CoM to the support surface is aligned in front of the vertebrae at the umbilicus and passes about 2 cm in front of the lateral malleolus, centered between the two feet. Abnormal segmental postural alignment such as scoliosis or kyphosis or asymmetries may or may not affect CoM alignment.

Patient: Stand relaxed, looking straight ahead.

3. Ankle strength and range

Examiner Instructions: Ask the patient to rest their fingertips in your hands for support while they stand on their toes as high as possible and then stand on their heels. Watch for height of heel and toe lift.

Patient: Rest your fingers in my hands for support while you stand on your toes. Now stand on your heels by lifting up your toes. Maintain each position for 3 s.

4. Hip/trunk lateral strength

Examiner Instructions: Ask the patient to rest their fingertips in your hands while they lift their leg to the side off the floor and hold. Count for 10 s while their foot is off the floor with a straight knee. If they must use moderate force on your hands to keep their trunk upright, score as without keeping trunk vertical.

Patient: Lightly rest your fingertips in my hands while you lift your leg out to the side and hold until I tell you to stop. Try to keep your trunk vertical while you hold your leg out.

5. Sit on floor and stand up

Examiner Instructions: Start with the patient standing near a sturdy chair. The patient can be considered to be sitting when both buttocks are on the floor. If the task takes more than 2 minutes to complete, with or without a chair, score 0. If the patient requires any physical assistance, score 0.

Patient: Are you able to sit on the floor and then stand up in less than 2 minutes? If you need to use a chair to help you go onto the floor or to stand up, go ahead, but your score will be affected. Let me know if you cannot sit on the floor or stand up without my help.

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eAppendix.
Continued

Stability Limits/Verticality

6. Verticality and lateral lean

Examiner Instructions: Patient is sitting comfortably on a firm, level, armless surface (bench or chair) with feet flat on floor. It is okay to lift ischium or feet when leaning. Watch to see if the patient returns to vertical smoothly without overshooting or undershooting. Score the worst performance to each side.

Patient: Cross your arms over your chest. Place feet shoulder width apart. I'll be asking you to close your eyes and lean to one side as far as you can. You'll keep your spine straight and lean sideways as far as you can without losing your balance *OR* using your hands. Keeping your eyes closed, return to your starting position when you've leaned as far as you can. It's okay to lift your buttocks and feet. Close your eyes. Lean now. (*REPEAT* other side)

7. Functional reach forward

Examiner Instructions: Examiner places the ruler at the end of the fingertips when the arms are out at 90 degrees. The patient may not lift heels, rotate trunk, or protract scapula excessively. Patient must keep their arms parallel to ruler and may use less-involved arm. The recorded measure is the maximum horizontal distance reached by the patient. Record best reach.

Patient: Stand normally. Please lift both arms straight in front of you, with fingertips held even. Stretch your fingers and reach forward as far as you can. Don't lift your heels. Don't touch the ruler or the wall. Once you've reached as far forward as you can, please return to a normal standing position. I will ask you to do this two times. Reach as far as you can.

8. Functional reach lateral

Examiner Instructions: Have patient align feet evenly so that the fingertips, when the arm is out at 90 degrees, are at the start of the ruler. The recorded measurement is the maximum horizontal distance reached by the patient. Record the best reach. Make sure the patient starts in neutral. The patient is allowed to lift one heel off the floor but not the entire foot.

Patient: Stand normally with feet shoulder width apart. Arms at your sides. Lift your arm out to the side. Your fingers should not touch the ruler. Stretch your fingers and reach out as far as you can. Do not lift your toes off the floor. Reach as far as you can. (*REPEAT* other side)

Anticipatory Postural Adjustments

9. Sit to stand

Examiner Instructions: Note the initiation of the movement, and the use of hands on the arms of the chair or their thighs or thrusts arms forward.

Patient: Cross arms across your chest. Try not to use your hands unless you must. Don't let your legs lean against the back of the chair when you stand. Please stand up now.

10. Rise to toes

Examiner Instructions: Allow the patient to try it twice. Record the best score. (If you suspect the patient is using less than their full height, ask them to rise up while holding the examiner's hands.) Make sure patients look at a target 4–12 ft away.

Patient: Place your feet shoulder width apart. Place your hands on your hips. Try to rise as high as you can onto your toes. I'll count out loud to 3 s. Try to hold this pose for at least 3 s. Look straight ahead. Rise now.

11. Stand on one leg

Examiner Instructions: Allow the patient two attempts and record the best. Record the seconds they can hold posture, up to a maximum of 30 s. Stop timing when patient moves their hands off hips or puts a foot down.

Patient: Look straight ahead. Keep your hands on your hips. Bend one leg behind you. Don't touch your raised leg on your other leg. Stay standing on one leg as long as you can. Look straight ahead. Lift now. (*REPEAT* other side)

(Continued)

eAppendix.
Continued

12. Alternate stair touching
Examiner Instructions: Use standard stair height of 6 in. Count the number of successful touches and the total time to complete the 8 touches. It's permissible for patients to look at their feet.

Patient: Place your hands on your hips. Touch the ball of each foot alternately on the top of the stair. Continue until each foot touches the stair four times (8 total taps). I'll be timing how quickly you can do this. Begin now.

13. Standing arm raise
Examiner Instructions: Use 2.5-kg (5-lb) weight. Have patients stand and lift weight with both hands to shoulder height. Patients should perform this as fast as they can. Lower score by 1 category if weight must be less than 2.5 kg (5 lb) and/or lifts <75 degrees.

Patient: Lift this weight with both hands from a position in front of you to shoulder level. Please do this as fast as you can. Keep your elbows straight when you lift and hold. Hold for my count of 3. Begin now.

Postural Responses

14. In-place response—forward
Examiner Instructions: Stand in front of the patient, place one hand on each shoulder and lightly push the patient backward until their anterior ankle muscles contract (and toes just start to extend), then suddenly release. Do not allow any pre-leaning by patient. Score only the best of 2 responses if the patient is unprepared or you pushed too hard.

Patient: For the next few tests, I'm going to push against you to test your balance reaction. Stand in your normal posture with your feet shoulder width apart, arms at your sides. Do not allow my hands to push you backward. When I let go, keep your balance without taking a step.

15. In-place response—backward
Examiner Instructions: Stand behind patient, place one hand on each scapula and isometrically hold against patient's backward push until heels are about to be lifted, not allowing trunk motion. Suddenly release. Do not allow any pre-leaning by patient. Score the best of 2 responses if patient is unprepared, or you pushed too hard.

Patient: Stand with your feet shoulder width apart, arms at your sides. Do not allow my hands to push you forward. When I let go, keep your balance without taking a step.

16. Compensatory stepping correction—forward
Examiner Instructions: Stand in front and to the side of patient with one hand on each shoulder and ask them to push forward. (Make sure there is room for them to step forward.) Require them to lean until their shoulders and hips are in front of their toes. Suddenly release your support when the patient is in place. The test must elicit a step. Be prepared to catch patient.

Patient: Stand with your feet shoulder width apart, arms at your sides. Lean forward against my hands beyond your forward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall.

17. Compensatory stepping correction—backward
Examiner Instructions: Stand in back and to the side of the patient with one hand on each scapula and ask them to lean backward. (Make sure there is room for them to step backward.) Require them to lean until their shoulders and hips are in back of their heels. Release your support when the patient is in place. Test must elicit a step.

Patient: Stand with your feet shoulder-width apart, arms down at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall.

NOTE: Be prepared to catch patient.

(Continued)

eAppendix.
Continued

18. Compensatory stepping correction—lateral

Examiner Instructions: Stand behind the patient, place one hand on either the right (or left) side of the pelvis, and ask them to lean their whole vertical body into your hand. Require them to lean until the midline of pelvis is over the right (or left) foot, and then suddenly release your support.

Patient: Stand with your feet together, arms down at your sides. Lean into my hand beyond your sideways limit. When I let go, step if you need to, to avoid a fall.

NOTE: Be prepared to catch patient.

Sensory Orientation

19. Sensory integration for balance (modified CTSIB)

Examiner Instructions: Do the tests in order. Record the time the patient was able to stand in each condition to a maximum of 30 s. Repeat condition if not able to stand for 30 s, and record both trials (average for category). Use medium-density Tempur® foam, 4-in thick. Assist patient in stepping onto foam. Have the patient step off the foam between trials. Include leaning or hip strategy during a trial as "instability."

Patient: For the next 4 assessments, you'll either be standing on this foam or on the normal ground, with your eyes open or closed. Place your hands on your hips. Place your feet together until almost touching. Look straight ahead. Each time, stay as stable as possible until I say "stop."

20. Incline—eyes closed

Examiner Instructions: Aid the patient onto the ramp. Once the patient closes their eyes, begin timing. Repeat condition if not able to stand for 30 s and average both trials. Note if sway is greater than when standing on level surface with eyes closed (item 15B) or if poor alignment to vertical. Assist includes use of a cane or light touch any time during the trial.

Patient: Please stand on the incline ramp with your toes toward the top. Place your feet shoulder width apart. Place your hands on your hips. I will start timing when you close your eyes.

Stability in Gait

21. Gait—level surface

Examiner Instructions: Place two markers 20 ft (6 m) apart and visible to the patient on a level walkway. Use a stopwatch to time gait duration. Have patients start with their toes on the mark. Start timing with the stopwatch when the first foot leaves the ground and stop timing when both feet stop beyond the next mark.

Patient: Walk at your normal speed from here past the next mark and stop.

22. Change in speed

Examiner Instructions: Allow the patient to take 2–3 steps at their normal speed, and then say "fast"; after 2–3 fast steps, say "slow." Allow 2–3 slow steps before they stop walking.

Patient: Begin walking at your normal speed. When I tell you "fast," walk as fast as you can. When I say "slow," walk very slowly.

23. Walk with head turns—horizontal

Examiner Instructions: Ask the patient to turn their head and hold it so they are looking over their shoulder until you tell them to look over the opposite shoulder every 2–3 steps. If the patient has cervical restrictions, allow combined head and trunk movements (en bloc).

Patient: Begin walking at your normal speed. When I say "right," turn your head and look to the right. When I say "left," turn your head and look to the left. Try to keep yourself walking in a straight line.

(Continued)

eAppendix.
Continued

24. Walk with pivot turns

Examiner Instructions: Demonstrate a pivot turn. Once the patient is walking at normal speed, say "turn and stop." Count the steps from turn until the patient is stable. Instability is indicated by wide stance width, extra stepping, or trunk and arm motion.

Patient: Begin walking at your normal speed. When I tell you to "turn and stop," turn as quickly as you can to face the opposite direction and stop. After the turn, your feet should be close together.

25. Step over obstacle

Examiner Instructions: Place the 2 stacked boxes (9-in or 22.9-cm height) 10 ft away from where the patient will begin walking. Use a stopwatch to time gait duration to calculate average velocity by dividing the number of seconds into 20 ft. Look for hesitation, short steps and touch on obstacle.

Patient: Begin walking at your normal speed. When you come to the shoe boxes, step over them, not around them, and keep walking.

26. Timed "Get Up & Go" Test

Examiner Instructions: Have the patient sit with their backs against the chair. Time the patient from the time you say "go" until they return to sitting in chair. Stop timing when the patient's buttocks hit the chair bottom. The chair should be firm with arms to push from if necessary. Tools: tape on floor 3 m from the front of the chair legs.

Patient: When I say "go," stand up from the chair, walk at your normal speed across the tape on the floor, turn around, and come back to sit in the chair. I will time how long it takes.

27. Timed "Get Up & Go" Test With Dual Task

Examiner Instructions: Before beginning, practice with the patient how to count backward from a number between 90 and 100 by 3s, to make sure they can do the cognitive task. Then ask them to count backward from a different number, and after a few numbers say "go" for the get up and go task. Time the patient from when you say "go" until they return to sitting. Stop timing when the patient's buttocks touch the chair bottom. The chair should be firm with arms to push from if necessary.

Patient: (a) Count backward by 3s starting at 100 *OR* (b) List random numbers, and when I say "go," stand up from the chair, walk at your normal speed across the tape on the floor, turn around, and come back to sit in the chair, but continue listing numbers.

 AP=anteroposterior, ML=mediolateral, CoM=center of mass, CTSIB=Clinical Test of Sensory Integration for Balance.
[b] Tempur-Pedic North America Inc, Medical Division, 1713 Jaggie Fox Way, Lexington, KY 40511.

Appendix 5.

The University of Illinois at Chicago Fear of Falling Measure (UIC FFM)

(Reproduced with permission)

Osteoporosis Education & Exercise Program

\# _____

THE UNIVERSITY OF ILLINOIS at CHICAGO
FEAR OF FALLING MEASURE
Scoring Sheet

Client: ______________________ **Date:** ________ **Circle:** Init RT P Fol Up # ____

Please read the activities listed below. Use the following scale to describe how worried about falling you would be if you were to perform those activities:

1 = Very worried
2 = Moderately worried
3 = Not at all worried

I realize that these activities may not be a part of your daily routine. You may perform the listed activities rarely, or not at all. However, I ask that you answer *all* the questions to let me know how worried about falls you would be in the different situations listed.

How worried about falling would you be if you were to: *(Circle your choices.)*

	1 Very Worried	2 Moderately Worried	3 Not at all Worried
1. Pick up something lightweight off the floor	1	2	3
2. Carry a full plate of food to the dinner table	1	2	3
3. Get in and out of a car	1	2	3
4. Take a walk	1	2	3
5. Use an escalator	1	2	3
6. Climb up well lit stairs	1	2	3
7. Walk on a crowded sidewalk	1	2	3
8. Step off a curb onto the street	1	2	3
9. Carry bundles up well lit stairs	1	2	3
10. Get in and out of the bathtub	1	2	3
11. Climb up bus stairs	1	2	3
12. Stand on a moving bus	1	2	3
13. Climb up poorly lit stairs	1	2	3
14. Use a step stool to reach something in your kitchen cabinet	1	2	3
15. Carry bundles up poorly lit stairs	1	2	3
16. Walk when icy	1	2	3

Comments:

SCORE: _____ / 48

Appendix 6.

Fracture Risk Assessment Tool (FRAX) website

Calculation Tool

Please answer the questions below to calculate the ten year probability of fracture with BMD.

Country: US (Caucasian Name/ID: About the risk factors (i)

Questionnaire:

1. Age (between 40-90 years) or Date of birth
   Age: Date of birth: Y: M: D:
2. Sex ○ Male ○ Female
3. Weight (kg)
4. Height (cm)
5. Previous fracture ⦿ No ○ Yes
6. Parent fractured hip ⦿ No ○ Yes
7. Current smoking ⦿ No ○ Yes
8. Glucocorticoids ⦿ No ○ Yes
9. Rheumatoid arthritis ⦿ No ○ Yes
10. Secondary osteoporosis ⦿ No ○ Yes
11. Alcohol 3 or more units per day ⦿ No ○ Yes
12. Femoral neck BMD (g/cm²)

Select DXA ▾

Clear Calculate

For USA use only

Consider FDA-approved medical therapies in postmenopausal women and men aged 50 years and older, based on the following:

- A hip or vertebral (clinical or morphometric) fracture
- T-score ≤ -2.5 at the femoral neck or spine after appropriate evaluation to exclude secondary causes
- Low bone mass (T-score between -1.0 and -2.5 at the femoral neck or spine) and a 10-year probability of a hip fracture ≥ 3% or a 10-year probability of a major osteoporosis-related fracture ≥ 20% based on the US-adapted WHO algorithm
- Clinicians judgment and/or patient preferences may indicate treatment for people with 10-year fracture probabilities above or below these levels

Risk factors

For the clinical risk factors a yes or no response is asked for. If the field is left blank, then a "no" response is assumed. See also notes on risk factors.

The risk factors used are the following:

Age	The model accepts ages between 40 and 90 years. If ages below or above are entered, the programme will compute probabilities at 40 and 90 year, respectively.
Sex	Male or female. Enter as appropriate.
Weight	This should be entered in kg.
Height	This should be entered in cm.
Previous fracture	A previous fracture denotes more accurately a previous fracture in adult life occurring spontaneously, or a fracture arising from trauma which, in a healthy individual, would not have resulted in a fracture. Enter yes or no (see also notes on risk factors).
Parent fractured hip	This enquires for a history of hip fracture in the patient's mother or father. Enter yes or no.
Current smoking	Enter yes or no depending on whether the patient currently smokes tobacco (see also notes on risk factors).

Glucocorticoids	Enter yes if the patient is currently exposed to oral glucocorticoids or has been exposed to oral glucocorticoids for more than 3 months at a dose of prednisolone of 5mg daily or more (or equivalent doses of other glucocorticoids) (see also notes on risk factors).
Rheumatoid arthritis	Enter yes where the patient has a confirmed diagnosis of rheumatoid arthritis. Otherwise enter no (see also notes on risk factors).
Secondary osteoporosis	Enter yes if the patient has a disorder strongly associated with osteoporosis. These include type I (insulin dependent) diabetes, osteogenesis imperfecta in adults, untreated long-standing hyperthyroidism, hypogonadism or premature menopause (<45 years), chronic malnutrition, or malabsorption and chronic liver disease
Alcohol 3 or more units/day	Enter yes if the patient takes 3 or more units of alcohol daily. A unit of alcohol varies slightly in different countries from 8-10g of alcohol. This is equivalent to a standard glass of beer (285ml), a single measure of spirits (30ml), a medium-sized glass of wine (120ml), or 1 measure of an aperitif (60ml) (see also notes on risk factors).
Bone mineral density (BMD)	(BMD) Please select the make of DXA scanning equipment used and then enter the actual femoral neck BMD (in g/cm2). Alternatively, enter the T-score based on the NHANES III female reference data. In patients without a BMD test, the field should be left blank (see also notes on risk factors) (provided by Oregon Osteoporosis Center).

Notes on risk factors

Previous fracture

A special situation pertains to a prior history of vertebral fracture. A fracture detected as a radiographic observation alone (a morphometric vertebral fracture) counts as a previous fracture. A prior clinical vertebral fracture or a hip fracture is an especially strong risk factor. The probability of fracture computed may therefore be underestimated. Fracture probability is also underestimated with multiple fractures.

Smoking, alcohol, glucocorticoids

These risk factors appear to have a dose-dependent effect, i.e. the higher the exposure, the greater the risk. This is not taken into account and the computations assume average exposure. Clinical judgment should be used for low or high exposures.

Rheumatoid arthritis (RA)

RA is a risk factor for fracture. However, osteoarthritis is, if anything, protective. For this reason reliance should not be placed on a patient's report of 'arthritis' unless there is clinical or laboratory evidence to support the diagnosis.

Bone mineral density (BMD)

The site and reference technology is DXA at the femoral neck. T-scores are based on the NHANES reference values for women aged 20-29 years. The same absolute values are used in men.

Arabic | English | Chinese Simplified | Chinese Traditional | Czech | Danish | Finnish | French | German
Italian | Japanese | Korean | Polish | Romanian | Russian | Spanish | Swedish | Turkish

Terms and Conditions

Appendix 7.

Health History Questionnaire

Health History Questionnaire
Physical Therapy &Rehabilitation Sciences

Drexel UNIVERSITY

PART I – PATIENT INFORMATION

Name: ____

Address: ____

Phone: (work) _______________ (home): ________________ (cell): __________________

Date of birth: _________________________ Age: _______ Sex: male _____ female: _____

Which hand do you write with? _______________ Height _________ Weight _________

Ethnic background (*Check all that apply*):

Asian/Pacific Islander _____ Black _____ Hispanic/Latino _____

Native American _____ White/non-Hispanic _____ Other _____

Education (*Check highest grade completed*):

1st _____ 2nd _____ 3rd _____ 4th _____ 5th _____ 6th _____ 7th _____ 8th _____

High school: 9th _____ 10th _____ 11th _____ 12th _____ High school degree ___

College: year 1 _____ year 2 _____ year 3 _____ year 4 _____

Technical school: _____ Master's degree: _____ Doctoral degree: _____

Work:

Working at a paying job full time _____
Working at a paying job part time _____
Unemployed, not looking for work _____
Volunteer work, part time _____
Volunteer work, full time _____
Laid off/unemployed _____
Retired _____
Full-time homemaker _____
Student _____
Short time disability _____
Disabled _____
In vocational rehabilitation/training _____
Other: (*please specify*): ____

General health (*check one*):

Excellent _____ Very good _____ Good _____ Fair _____ Poor _____

PART II – MEDICAL HISTORY

Below is a list of symptoms, conditions, injuries, and diseases. Please check all that apply. **If you have a symptom or condition now, and have had it in the past, check *both* boxes.**

Problem	Any time in the past?	Still bothered/ occurring/ treated for	Currently taking medication for this	Comments
	Yes	Yes	Yes	
Alcohol dependency				
Amputation				
Anemia or blood disorder				
Anxiety for more than 2 weeks				
Appetite or significant weight change				
Arthritis				
Asthma				
Autoimmune disease (MS, ALS, Lupus)				
Back pain or problems				
Bladder/urinary disorder/urine leaks				
Broken bones/fractures				
Burn (severe)				
Chronic bronchitis or lung problems				
Cancer				
Carpal tunnel syndrome				
Chronic fatigue syndrome				
Confusion				
Depressed mood/sadness				
Depression, clinically diagnosed				
Diabetes				
Dizziness or lightheadedness				
Drug dependency				
Eating disorder				
Elbow pain or problems				
Lack of energy for 2 or more weeks				
Lack of enjoyment/interest doing things				
Fatigue or tiredness for 2 or more weeks				
Fibromyalgia				
Foot/ankle pain				
Falling frequently				
Gout				
Hand pain or problems				
Headaches				
Heart attack, disease or other heart problems				
Hepatitis				
High blood pressure				

Problem	Any time in the past?	Still bothered/ occurring/ treated for	Taking medication for this	Comments
	Yes	Yes	Yes	
Hip problems				
Kidney problems				
Knee problems				
Liver disease				
Memory problems				
Neck pain/problems				
Neurological diseases				
Numbness				
Obesity				
Osteoporosis/low bone density				
Seizures/epilepsy				
Shortness of breath				
Shoulder pain or problems				
Sleeping difficulties				
Smoking (cigarettes, cigars, pipes)				
Stomach problems/ulcers				
Stroke				
Thyroid condition				
Wounds				
Other ________________				

List hospitalizations/surgeries:

Hospitalization/Surgery Date

____

____

____

____

____

____

____

PART III – FOR WOMEN ONLY

How old were you when you began your menstrual periods? ________ years

Is there any chance that you are pregnant? Yes _____ No _____

Are your menstrual periods regular? Yes _____ No _____

If your periods are irregular, please describe: ____

Please indicate number of:

Pregnancies _____ Births _____ Vaginal deliveries _____ Caesarian deliveries _____

Have you gone through menopause? Yes_____ At what age? _______ No _____

PART IV – CURRENT MEDICATIONS, DRUG THERAPY, VITAMINS, AND/OR SUPPLEMENTS *Please list:*

List	Purpose
1.	
2.	
3.	
4.	
5.	
6.	

List	Purpose
7.	
8.	
9.	
10.	
11.	
12.	

PART V – CURRENT LEVEL OF PHYSICAL ACTIVITY AND EXERCISE

Please describe your current level of exercise or physical activity. Fill in the chart below.

Type of physical activity/exercise (walking, running, gardening, weights, etc)	How long do you usually do the activity (minutes)	How often do you do this activity? (times per week)

Emergency contact: ______________________________ Number: ________________________

Reason for visit: ____

Who referred you? ____

Signature _________________________________ Date _______________________________

Rev. 5/05

Appendix 8.

Berg Balance Scale

BERG BALANCE ASSESSMENT

ID: ________ Name: ________________ Date:________ Rater: ________________

Sit-To-Stand
"Please stand up. Try not to use your hands."
- 4 Without using hands
- 3 With using hands minimally
- 2 With using hands multiple attempts
- 1 Needs min assist
- 0 Needs mod to max assist

Standing unsupported
"Please stand for 2 minutes without holding on to anything."
- 4 2 minute independent stand
- 3 2 minute supervised stand
- 2 30 sec unsupported stand
- 1 30 second supported stand
- 0 < 30 sec unsupported stand

Sitting unsupported
"Please sit with arms folded for 2 minutes."
- 4 2 minute independent sit
- 3 2 minute supervision sit
- 2 30 sec unsupported sit
- 1 10 sec unsupported sit
- 0 < 10 sec unsupported sit

Stand-To-Sit
"Please sit down."
- 4 Controlled descent with no/minimal hands
- 3 Controlled descent with hands
- 2 Controlled descent with back of legs
- 1 Uncontrolled descent without assistance
- 0 Uncontrolled descent with assistance

Transfers
"Please sit in this chair (with armrests) then get up and sit in the other chair (without armrests)."
- 4 No/min use of hands
- 3 Needs hands
- 2 Needs supervision
- 1 Needs assist of 1 person
- 0 Needs assist of ≥ 2 person

Standing with eyes closed
"Please close your eyes and stand for 10 seconds."
- 4 10 sec independent stand
- 3 10 sec supervised stand
- 2 3 sec independent stand
- 1 < 3 sec independent stand
- 0 Needs help to keep from falling

Standing with feet together
"Place your feet together and stand without holding on to anything."
- 4 1 minute independent stand
- 3 1 minute supervised stand
- 2 30 sec stand
- 1 15 sec stand, needs help to put feet together
- 0 < 15 sec stand, unable to put feet together

Forward Reach
"Raise both arms to 90° shoulder flexion. Reach forward with outstretched finger as far as you can."
- 4 Reaches 10" confidently
- 3 Reaches 5"
- 2 Reaches 2"
- 1 Reaches but needs supervision
- 0 Loses balance when reaching forward

Retrieving object from floor
"Pick up shoe/slipper in front of your foot."
- 4 Able to pick up safely and easily
- 3 Able to pick up with supervision
- 2 Unable to pick up (gets within 1-2") & keeps balance independently
- 1 Unable to pick up and needs supervision
- 0 Needs assist to keep from falling

Turning to look behind
"Turn to look directly behind right shoulder then the left shoulder."
- 4 Looks behind both shoulders with good weight shift
- 3 Looks behind one shoulder with decreased weight shift
- 2 Turns sideways only but maintains balance
- 1 Needs supervision while turning
- 0 Needs assist while turning

Turning 360 degrees
" Turn to the right in a complete circle. Now turn to the left in a complete circle."
- 4 ≤ 4 sec to turn in both circles
- 3 ≤ 4 sec to turn in one circle
- 2 > 4 sec to turn in one circle
- 1 Needs supervision or verbal cueing
- 0 Unable or needs assistance to prevent fall

Placing alternate feet on step stool
"While standing, place alternate foot on step stool 4 times (8 touches)."
- 4 ≤ 20 sec independently
- 3 > 20 sec independently
- 2 2 steps each foot with supervision
- 1 1 step each foot with min assist
- 0 Unable or needs assistance to prevent fall

Tandem Standing "Place one foot directly in front of the other. If you feel you cannot, try to place your foot far enough ahead so your heel passes your toes."
- 4 Able to place foot tandem and stand 30 sec
- 3 Able to place foot ahead of other foot and stand 30 sec
- 2 Able to take small step and stand for 30 sec
- 1 Needs assist to step but can stand for 15 sec
- 0 Loses balance while stepping or standing

One legged standing
"Standing on one leg as long as you can without holding on to anything."
- 4 > 10 seconds
- 3 5 – 10 seconds
- 2 3 – 4 seconds
- 1 < 3 seconds and retains independent standing
- 0 Unable or needs assistance to prevent fall

Appendix 9.

SF-12 Questionnaire (Version 2)

(permission pending)

SF-12v2™ Health Survey Standard Version

This survey asks for your views about your health. This information will help you keep track of how you feel and how well you are able to do your usual activities. *Thank you for completing this survey!*

For each of the following questions, please click the circle that best describes your answer.

1) In general, would you say your health is:

Excellent	Very good	Good	Fair	Poor
○	○	○	○	○

2) The following questions are about activities you might do during a typical day. Does <u>your health now limit</u> you in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
a. <u>Moderate activities</u>, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	○	○	○
b. Climbing <u>several</u> flights of stairs	○	○	○

3) During the <u>past 4 weeks</u>, how much of the time have you had any of the following problems with your work or other regular daily activities <u>as a result of your physical health</u>?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a. <u>Accomplished less</u> than you would like	○	○	○	○	○
b. Were limited in the <u>kind</u> of work or other activities	○	○	○	○	○

SF-12v2™ Health Survey Standard Version

4) During the past 4 weeks, how much of the time have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a. Accomplished less than you would like	○	○	○	○	○
b. Did work or activities less carefully than usual	○	○	○	○	○

5) During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

Not at all	A little bit	Moderately	Quite a bit	Extremely
○	○	○	○	○

6) These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks...

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a. Have you felt calm and peaceful?	○	○	○	○	○
b. Did you have a lot of energy?	○	○	○	○	○
c. Have you felt downhearted and depressed?	○	○	○	○	○

7) During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)?

All of the time	Most of the time	Some of the time	A little of the time	None of the time
○	○	○	○	○

Appendix 10.

Exercise Log

Exercise Log for BC group

Week of		*Day/Date*			*Day/Date*			*Day/Date*			*Day/Date*			*Day/Date*			*Note*
Exercise Item		W/R	Reps	Comp	W/R	Reps	Comp	W/R	Reps	Comp	W/R	Reps	Comp	W/R	Reps	Comp	
BC 1: Upper Trunk Postural Correction A	L																
	L																
	L																
BC 2: Trunk Postural Correction B	L																
	L																
	L																
BC 3: Hip Abduction Strengthening	L																
	L																
	L																
BC 4: Hip Extensor Strengthening	L																
	L																
	L																
BC 5: Knee extensor (Quads) Strengthening	L																
	L																
	L																
BC 6: Strengthening Plantar Flexors	L																
	L																
	L																
BC 7: Strengthening Dorsiflexors	L																
	L																
	L																
BC 8: Flexibility	L																
	L																
	L																
BC 9: Transitioning	L																
	L																
	L																
Time in Session																	
Fall event (Y/N)																	
Compiance (7/9 = 80%)																	

***L** = Level; **W** = weight; **R** = resistance; **Reps** = repetition; **Comp** = completion check

Exercise Log for APA group

Week of		***Day/Date***			***Day/Date***			***Day/Date***			***Day/Date***			***Day/Date***			***Note***
Exercise Item		W/R	Reps	Comp	W/R	Reps	Comp	W/R	Reps	Comp	W/R	Reps	Comp	W/R	Reps	Comp	
APA 1 Rise to toes	L																
	L																
	L																
APA 2 Stand on Heels	L																
	L																
	L																
APA 3 Stand on one leg	L																
	L																
	L																
APA 4 Stair touching	L																
	L																
	L																
APA 5 Lounge	L																
	L																
	L																
APA 6 Figure 8	L																
	L																
	L																
APA 7 Straight line Balance Forward	L																
	L																
	L																
APA 8 Straight line Balance Backward	L																
	L																
	L																
APA 9 Straight line Balance Sideways	L																
	L																
	L																
Time in Session																	
Fall event (Y/N)																	
Compliance (7/9 = 80%)																	

***L** = Level; **W** = weight; **R** = resistance; **Reps** = repetition; **Comp** = completion check

Appendix 11.

Exercise Description with Progression

Exercise Description with Progression

Exercises for impairments in BC component

(strengthening and flexibility exercises)

Exercise Item	***Purpose***	***Level***	***Progression criteria***
BC 1-I: Upper Trunk Postural Correction A (shoulder blade squeeze in sitting)	to strengthen back and shoulder blade muscles to correct upper trunk posture	1 of 3	When able to perform 2 sets of 10 easily and correctly, progress to BC 1-II
BC 1-II: Upper Trunk Postural Correction A (shoulder blade squeeze while leaning forward with elbow bending)	to strengthen shoulder, back and shoulder blade muscles to correct upper trunk posture	2 of 3	When able to perform 2 sets of 10 easily and correctly, progress to BC 1-III
BC 1-III: Upper Trunk Postural Correction A (scapular squeeze while leaning forward with elbow straight)	to strengthen shoulder, back and shoulder blade muscles to correct upper trunk posture	3 of 3	Continue with adding 5 repetitions each week.
BC 2-I: Trunk Postural Correction B	to strengthen back muscles to correct upper trunk posture	1 of 3	to BC 2-II when able to perform 2 sets of 10 easily
BC 2-II: Trunk Postural Correction B (prone isometric contraction)	to strengthen back muscle and to correct upper trunk posture	2 of 3	to BC 2-III when able to perform 2 sets of 10 easily
BC 2-III: Trunk postural correction B (prone trunk extension)	to strengthen back muscle and to correct upper trunk posture	3 of 3	Continue with adding 5 repetitions each week.
BC 3-I: Hip Abduction Strengthening (sidelying clamshell, no resistance)	to strengthen hip muscles for sideways lifting	1 of 3	to BC 3-II when able to perform 2 sets of 10 easily
BC 3-II: Hip Abduction Strengthening (sidelying clamshell, resistance)	to strengthen hip muscles for sideways lifting	2 of 3	to BC 3-III when able to perform 2 sets of 10 easily
BC 3-III Hip Abduction Strengthening (sidelying leg straight)	to strengthen hip muscles for sideways lifting	3 of 3	Continue with adding 5 repetitions each week.
BC 4-I Hip Extensor Strengthening (bridging)	to strengthen trunk and hip muscles required for standing straight	1 of 3	to BC 4-II when able to perform 2 sets of 10 easily

Exercise Item	***Purpose***	***Level***	***Progression criteria***
BC 4-II Hip Extensor Strengthening(Bridging with one foot lifting)	to strengthen trunk and hip muscles required for standing straight	2 of 3	to BC 4-III when able to perform 2 sets of 10 easily
BC 4-III Hip Extensor Strengthening (All four with leg lift)	to strengthen trunk and hip muscles required for standing straight	3 of 3	Continue with adding 5 repetitions each week.
BC 5-I Knee Extensor (Quads) Strengthening (slow motion)	to strengthen leg muscles required for walking and climbing stairs	1 of 3	to BC 5-II when able to perform 2 sets of 10 easily
BC 5-II Knee Extensor (Quads) Strengthening (fast motion)	to strengthen leg muscles required for standing, walking and climbing stairs	2 of 3	to BC 5-III when able to perform 2 sets of 10 easily
BC 5-III Knee extensor (Quads) Strengthening (wall slide)	to strengthen leg muscles required for standing, walking and climbing stairs	3 of 3	Continue with adding 5 repetitions each week.
BC 6-I Strengthening Plantar Flexors (sitting with resistance)	to strengthen calf and ankle muscles	1 of 3	to BC 6-II when able to perform 2 sets of 10 easily
BC 6-II Strengthening Plantar Flexors (stand on tiptoes 10 seconds)	to strengthen calf and ankle muscles	2 of 3	to BC 6-III when able to perform 2 sets of 10 easily
BC 6-III Strengthening Plantar Flexors (stand on tiptoes 20 seconds)	to strengthen calf and ankle muscles.	3 of 3	Continue with adding 5 repetitions each week.
BC 7-I Strengthening Dorsiflexors (sitting without resistance)	to strengthen ankle muscles	1 of 3	to BC 7-II when able to perform 2 sets of 10 easily
BC 7-II Strengthening Dorsiflexors (sitting with resistance: 2 lb)	to strengthen ankle muscles	2 of 3	to BC 7-III when able to perform 2 sets of 10 easily
BC 7-III Strengthening Dorsiflexors (sitting with resistance: 4 lb)	to strengthen ankle muscles	3 of 3	Continue with adding 5 repetitions each week.
BC 8-I Flexibility (Supine straight leg raise)	to increase the flexibility of hamstring muscles behind the thigh/knee	1 of 3	to BC 8-II when able to perform 4 times of stretch at ceiling easily
BC 8-II Flexibility (standing leaning on wall)	to increase the flexibility of calf and hamstring muscles	2 of 3	to BC 8-III when able to perform 4 times of stretch easily
BC 8-III Flexibility (supine hip and knee flexibility)	to increase the flexibility of hip and knee	3 of 3	Continue with adding time of stretching by 5 seconds each week.

Exercise Item	***Purpose***	***Level***	***Progression criteria***
BC 9-I Transitioning (sit to half-kneeling)	to achieve strength and flexibility necessary for getting up from floor	1 of 3	to BC 9-II when able to perform 5 times easily
BC 9-II Transitioning (stand to half-kneeling)	to achieve strength and flexibility necessary for getting up from floor	2 of 3	to BC 9-II when able to perform 5 times easily
BC 9-III Transitioning (stand to kneeling)	to achieve strength and flexibility necessary for getting up from floor	3 of 3	Continue with adding one repetition each week.

Exercises for impairments in APA component

(Postural control exercises)

Exercise Item	***Purpose***	***Level***	***Progression criteria***
APA 1-I: Rise on tiptoes (slow motion)	to balance stand on toes	1 of 3	to APA 1-II when able to perform 2 sets of 10 times easily
APA1-II: March-in-place on tiptoes	to balance stand on toes	2 of 3	to APA 1-III when able to perform 2 sets of 10 times easily
APA 1-III: Walk on tiptoes at progressive speed	to balance stand on toes	3 of 3	Increase speed of steps determined by a metronome.
APA 2-I: Stand on heels	to balance stand on heels	1 of 3	to APA 2-II when able to perform 2 sets of 10 times easily without losing balance or toes drop-down
APA 2-II: March-in-place on heels	to balance stand on heels	2 of 3	to APA 2-III when able to perform 2 sets of 10 times easily without losing balance or toes drop-down
APA 2-III: Walk on heels with progressive speed	to balance stand on heels	3 of 3	Increase speed of steps determined by a metronome.
APA 3-I: Stand on one leg (bilateral support)	to balance stand on one leg	1 of 3	to APA 3-II when able to perform 2 sets of 10 times easily without losing balance, knees buckling or foot drop-down
APA 3-II: Stand on one leg (unilateral support)	to balance stand on one leg	2 of 3	to APA 3-III when able to perform 2 sets of 10 times easily without losing balance, knees buckling or foot drop-down
APA 3-III: Stand on one leg (no support)	to balance stand on one leg	3 of 3	Continue with adding 5 repetitions each week

Exercise Item	***Purpose***	***Level***	***Progression***
APA 4-I: Stair touching with both hands support	to balance reaching steps	1 of 3	Gradually increase speed of touching; move to APA 4-II when able to perform 2 sets easily and quickly without losing balance, knees buckling or tip of foot kicking the stool
APA 4-II: Stair touching up and down	to balance reaching steps	2 of 3	to APA 4-III when able to perform 2 sets of 10 easily and quickly without losing balance, knees buckling or tip of foot kicking the stool
APA 4-III: Stair touching up/down backward	to balance reaching steps	3 of 3	Continue with adding 5 repetitions each week
APA 5-I: Lunge forward	to balance when shift center of gravity out of base	1 of 3	Gradually increase speed of touching; move to APA 5-II when able to perform 2 sets of 5 easily without losing balance
APA 5-II: Lunge forward with arms reaching and progressive speed	to balance when shift center of gravity out of base	2 of 3	to APA 5-III when able to perform 2 sets of 5 easily without losing balance
APA 5-III: Lunge sideway with arms reaching sideway	to balance when shift center of gravity out of base	3 of 3	Continue with adding 2 repetitions each week
APA 6-I: Figure 8 (bilateral support)	to balance on one foot with the other foot tracing on floor	1 of 3	to APA 6-II when able to perform 2 sets of 5 easily without losing balance
APA 6-II: Figure 8 (unilateral support)	to balance on one foot with the other foot tracing on floor	2 of 3	to APA 6-III when able to perform 2 sets of 5 easily without losing balance
APA 6-III: Figure 8 with progressive speed (no support)	to balance on one foot with the other foot tracing on floor	3 of 3	Continue with adding 2 repetitions each week
APA 7_I: Tandem stand forward	to balance on narrow base of support-forward	1 of 3	Move to APA 7-II when able to perform 2 sets easily with little hand support without losing balance.

Exercise Item	***Purpose***	***Level***	***Progression***
APA 7-II: Walk on a straight line forward with support	to balance on narrow base of support-forward	2 of 3	Gradually increase the speed of walking. Move to APA 7-III when able to perform 2 sets easily with no hand support without losing balance or tripping.
APA 7-III: Walk on a straight line forward without support	to balance on narrow base of support-forward	3 of 3	Increase speed of steps determined by a metronome.
APA 8-I: Tandem stand backward	to balance on narrow base of support-backward	1 of 3	Move to APA 8-II when able to perform 2 sets easily with little hand support without losing balance.
APA 8-II: Walk on a straight line backward with support	to balance on narrow base of support-backward	2 of 3	Gradually increase the speed of walking. Move to APA 8-III when able to perform 2 sets easily with little hand support without losing balance or tripping.
APA 8-III: Walk on a straight line backward without support	to balance on narrow base of support-backward	3 of 3	Increase speed of steps determined by a metronome.
APA 9-I: Sideway balance standing	to balance on narrow base of support-sideway	1 of 3	Gradually increase the speed of steps. Move to APA 9-II when able to perform 2 sets easily without losing balance.
APA 9-II: Walk on a straight line sideway with support	to balance on narrow base of support-sideway	2 of 3	Gradually increase the speed of walking. Progress to APA 9_III when able to perform 2 sets each side easily without losing support or tripping with little hands support.
APA 9-III: Walk on a straight line sideway without support	to balance on narrow base of support-sideway	3 of 3	Increase speed of steps determined by a metronome.

Appendix 12.

<u>Exercise Diagrams and Instructions</u>

<u>Exercises for older adults with Biomechanical constraints</u>

Criterion: score of biomechanical constraints < 70% (raw score $\leq$ 10/15)
Frequency: 3 times/week or maximum of 18 sessions over 6 weeks.

Before you start exercises:

Pain: If you experience "sharp pain" (not muscle aching or soreness) while doing any of the exercises, consult with your therapist before resuming the program.

Dosage: It is important to follow the repetitions as recommended in your instructions to avoid overdoing.

Stiffness: You may feel some tightness, stiffness, or soreness/aching in your movements when you first begin the program. It takes persistence and patience to work toward your goal.

Frequency: It is important that you perform the instructed exercise at least 3 times every week with me to get the best results. It would be best if we could do them at a certain time of the day as much as possible.

Breathing: It is important that you breathe normally while doing your exercises and avoid holding your breath.

Posture: Maintain good posture and proper head/neck alignment when performing the exercises.

Shoes: Please wear comfortable walking shoes (like sneakers or other sturdy shoes, not bedroom slippers) when you perform exercises involved seated, standing and walking activities. Please take off your shoes when you perform exercises involved mat or bed activities.

Exercise equipment: Standardized exercise mat (4'x8' Aeromat), Cuff weights (1 lb, 1.5 lb, 2 lb, 2.5 lb, 3 lb, 4 lb, 5 lb), Theraband (Green, 3 ft long; loop length 12 inches), Step stool (9-inch height), Metronome (for speed of measure).

BC 1-I: Upper Trunk Postural Correction A (shoulder blade squeeze in sitting)

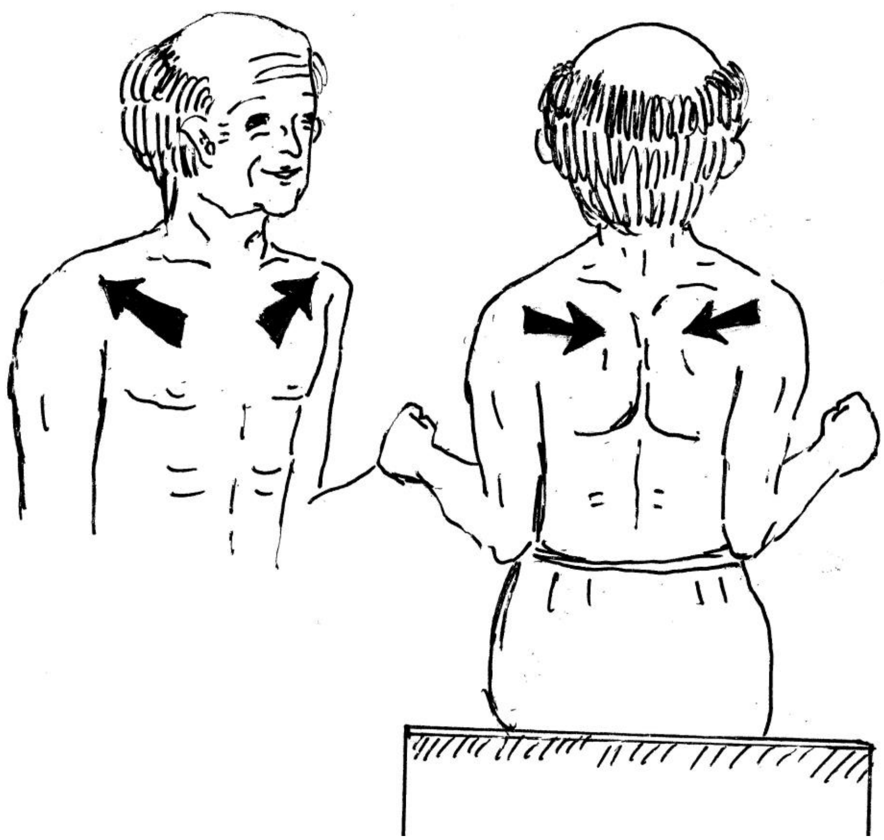
Purposes: to strengthen back and shoulder blade muscles to correct upper trunk posture.

Start position: Direct the participant to sit on a steady seat with no backrest.

Verbal Instruction: Sit up straight, look straight forward, tuck chin in, suck stomach in and keep back straight. Do not hold your breath. Bend your elbows with arms by your side, SQUEEZE shoulder blades together in back. Hold in this position for 5 seconds. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: When able to perform 2 sets of 10 easily and correctly, progress to BC 1-II.



BC 1-II: Upper Trunk Postural Correction A (shoulder blade squeeze while leaning forward with elbow bending)

Purposes: to strengthen shoulder, back and shoulder blade muscles to correct upper trunk posture.

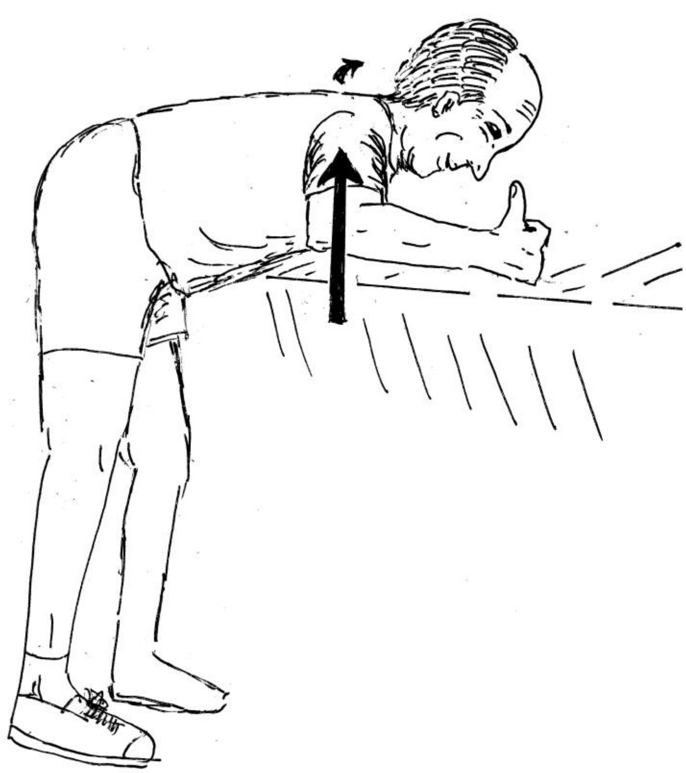
Start position: Direct the participant to lean over a steady table with one forearm resting on it, and the other arm dangling off the edge of the table.

Verbal Instruction: Please lean over this table with one forearm resting on the table. Look straight down, tuck chin in, suck stomach in, and keep your back straight. DO not hold your breath. Bend the other elbow, slowly raise your arm (shoulder) as high as you can by pointing the thumb up toward the ceiling as if you are "Hitch hiking" while you SQUEEZE your shoulder blade toward the other. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; repeat the same thing with the other arm; 3 sessions per week.

Progression: When able to perform 2 sets of 10 easily and correctly, progress to BC 1-III.

Note for therapist: Keep shoulder/arm aligned at 90-degree angle to trunk and elbow at 90 degrees to avoid substitutions.



BC 1-III: Upper Trunk Postural Correction A (scapular squeeze while leaning forward with elbow straight)

Purposes: to strengthen shoulder, back and shoulder blade muscles to correct upper trunk posture.

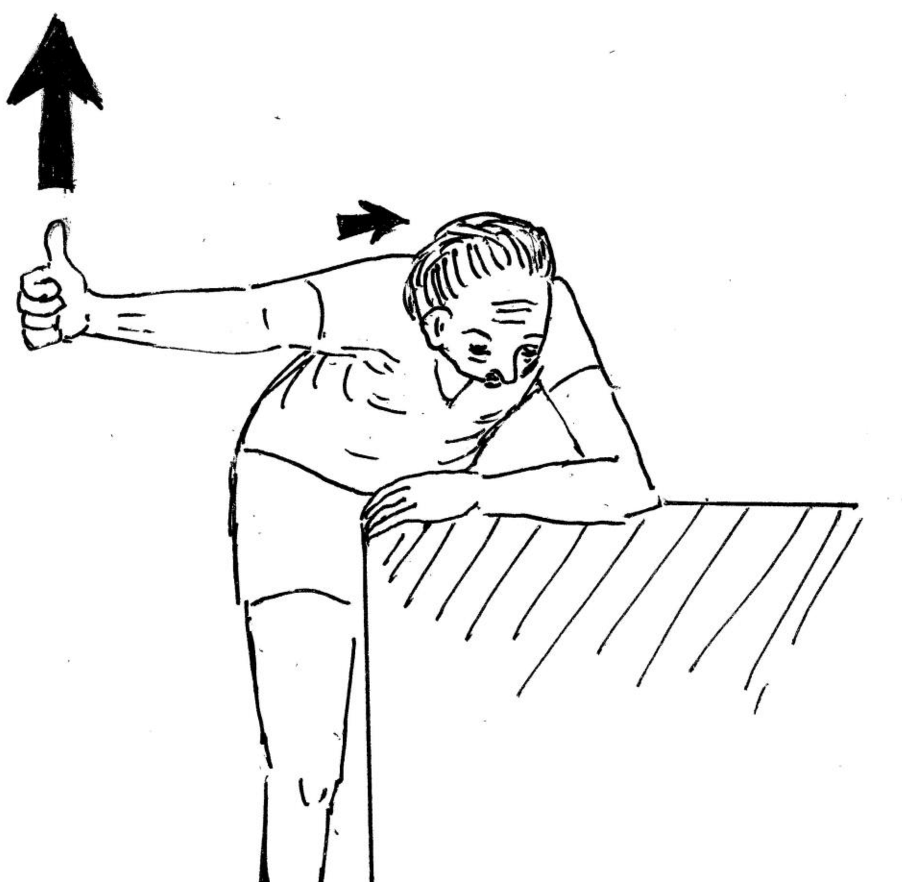
Start position: Direct the participant to lean over with one forearm resting on a steady table, and the other dangling off the edge of the table.

Verbal Instruction: Please lean over with one forearm resting on this table. Look straight down, tuck chin in, suck stomach in, and keep back straight. Do not hold your breath. Slowly raise the other arm straight as high as you can by pointing the thumb up toward the ceiling as if you are "Hitch hiking" while SQUEEZE shoulder blades together in upper back. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; repeat the same thing with the other arm; 3 sessions per week.

Progression: Continue with adding 5 repetitions each week.

Note for therapist: Keep shoulder/arm aligned at 90-degree angle to trunk and elbow straight, thumb pointing toward the ceiling to avoid substitutions.



BC 2-I: Trunk Postural Correction B (stand against wall)

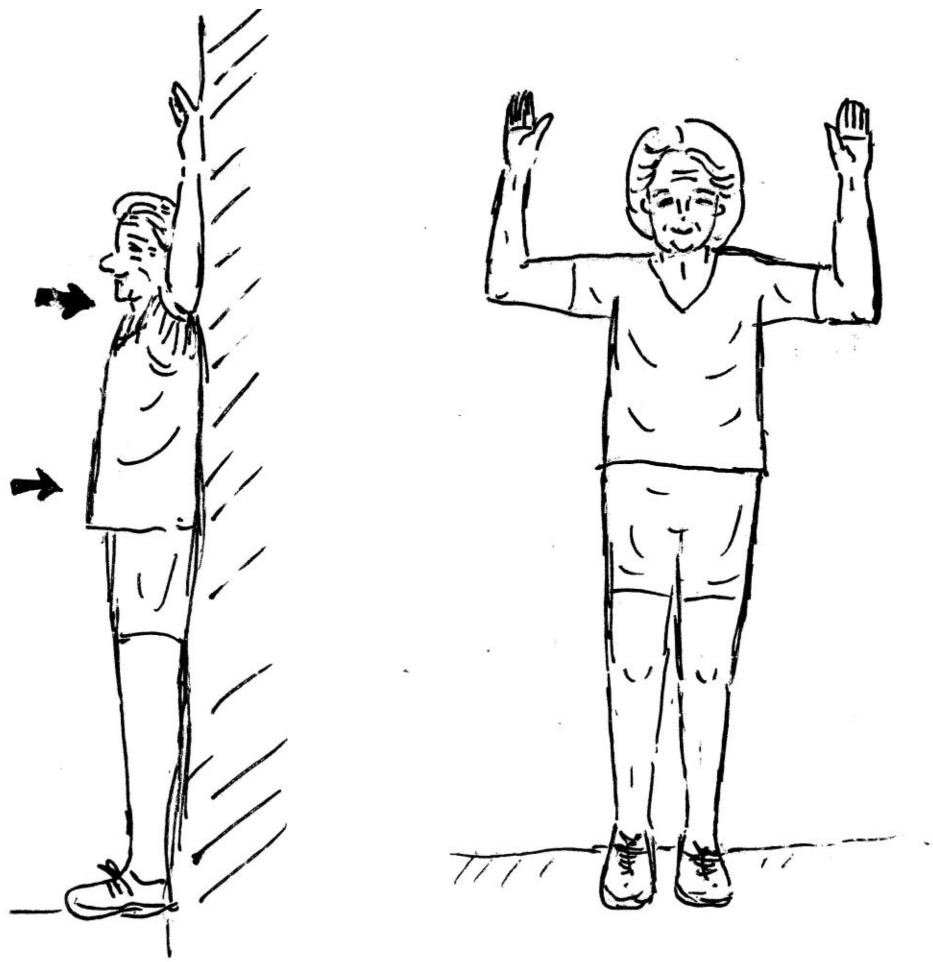
Purposes: to strengthen back muscles to correct upper trunk posture.

Start position: Direct the participant to stand against a wall.

Verbal Instruction: Please stand with your back against the wall. Raise both arms and bend your elbows to 90 degrees against the wall. Head look straight ahead, tuck chin in, suck stomach in, and keep back straight. Do not hold breath. Tense the muscles of back and neck to keep upper torso as close to wall as possible. Hold in this posture for 10 seconds. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: to BC 2-II when able to perform 2 sets of 10 easily.



BC 2-II: Trunk Postural Correction B (prone isometric contraction)

Purposes: to strengthen back muscles and to correct upper trunk posture.

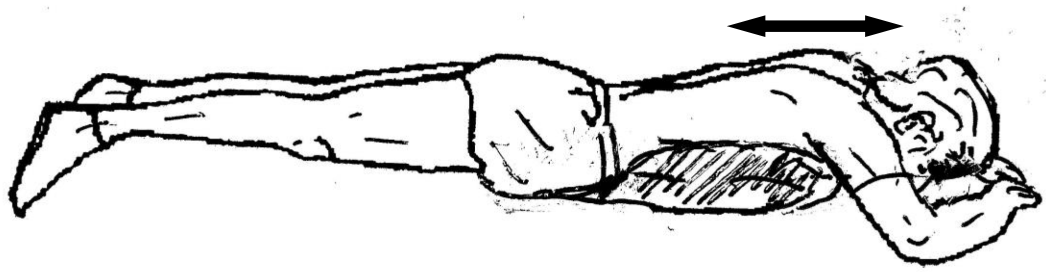
Start position: Direct the participant to lie on stomach on a standardized mat (4'x8' Aeromat), place a roll of towel or a small soft pillow under abdomen for support.

Verbal Instruction: Please lie down on your stomach. Tuck your chin in, suck stomach in and do not hold breath. Tense the muscles of back and neck but without moving or lifting trunk for 10 seconds. Relax and return to starting position.

Repeat __ times; do __ sets each session; 3 sessions per week.

Progression: to BC 2-III when able to perform 2 sets of 10 easily.

Permissible variation: Lie on a bed if participant is unable to lie on a mat on the floor.



BC 2-III: Trunk postural correction B (prone trunk extension)

Purposes: to strengthen back muscle and to correct upper trunk posture.

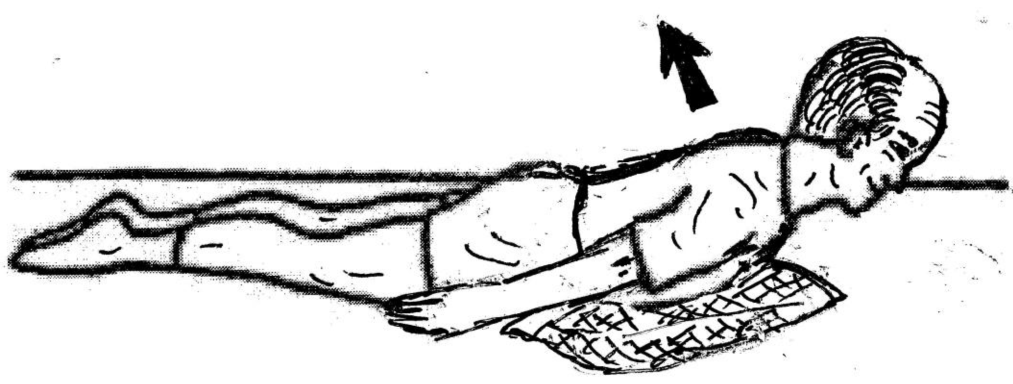
Start position: Direct the participant to lie on stomach on a standardized mat, place a roll of towel or a small soft pillow on abdomen for support.

Verbal Instruction: Please lie down on your stomach. Tuck your chin in, suck stomach in and do not hold breath. Tense the muscles of back and neck to lift upper trunk upward as high as possible. Avoid bending neck back. Hold up for up to 10 seconds. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Permissible variation: Lie on a bed if participant is unable to lie on a mat on the floor.

Progression: Continue with adding 5 repetitions each week.



BC 3_I Hip Abduction Strengthening (side lying clamshell with no resistance)

Purposes: to strengthen hip muscles for sideways lifting.

Start position: Direct the participant to lie down on side and bend both knees on a mat. Place one pillow between knees and another pillow under the participant's head for support.

Verbal Instruction: Please lie on your side. Tuck chin in, suck stomach in and do not hold breath. Bend your hips and knees while keeping your feet together. Slowly lift up the top knee against the weight of your leg as much as you can toward the ceiling. Relax and return to starting position.

Note for therapist: Keep top hip forward. Place hand behind hip to keep from rotating backward while performing the exercise.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: to BC 3-III when able to perform 2 sets of 10 easily.

Permissible variation: Lie on a bed if participant is unable to lie on a mat on the floor.

BC 3_II Hip Abduction Strengthening (side lying clamshell)

Purposes: to strengthen hip muscles for sideways lifting.

Start position: Direct the participant to lie down on side and bend both knees on a mat. Tie a theraband (3ft, green) around participant's thighs above knees. Place one pillow between knees and another pillow under the participant's head for support.

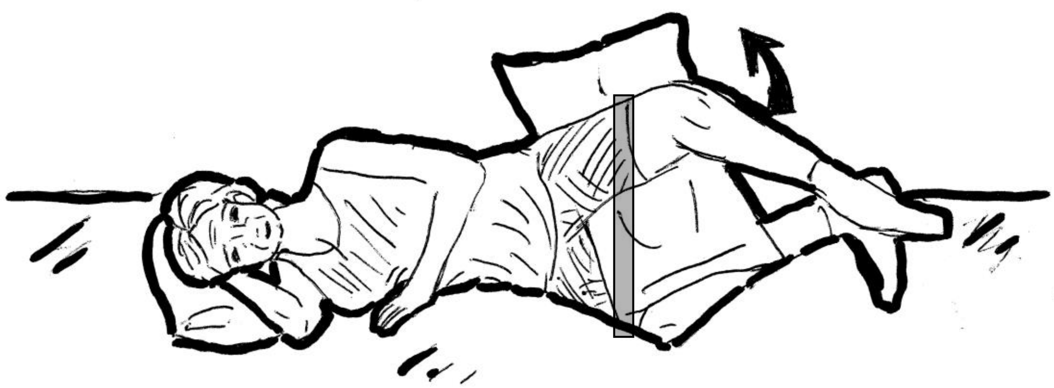
Verbal Instruction: Please lie on your side. Tuck chin in, suck stomach in and do not hold breath. Bend your hips and knees while keeping your feet together. Slowly lift up the top knee against the rubber band as much as you can toward the ceiling. Relax and return to starting position.

Note for therapist: Keep top hip forward. Place hand behind hip to keep from rotating backward while performing the exercise.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: to BC 3-III when able to perform 2 sets of 10 easily.

Permissible variation: Lie on a bed if participant is unable to lie on a mat on the floor.



BC 3_III Hip Abduction Strengthening (side lying leg straight)

Purposes: to strengthen hip muscles for sideway lifting.

Start position: Direct the participant lie on side with hips and knees straight on a mat. Place a roll of towel or a small soft pillow under the participant's head for support.

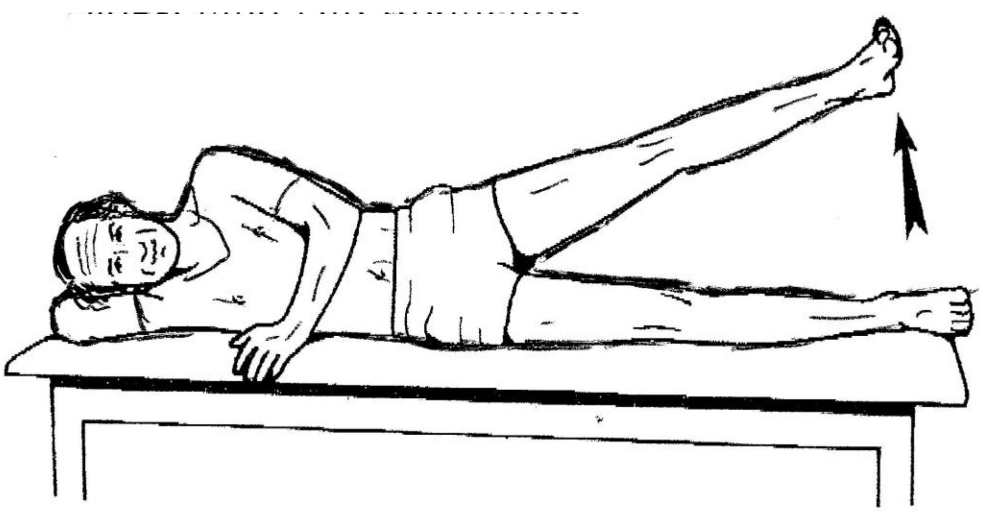
Verbal Instructions: Please lie down on your side. Tuck chin in, suck stomach in and do not hold breath. Keep your hips and knees as straight as possible. Turn the top knee slightly outward. Lift the top leg straight upward toward the ceiling as high as you can go without turning your pelvis. Relax and return to starting position.

Note for therapist: Avoid hip/pelvic rotation.

Repeat ___ times; do ___ sets session; 3 sessions per week.

Permissible variation: Lie on a bed if participant is unable to lie on a mat on the floor.

Progression: Continue with adding 5 repetitions each week.



BC 4_I Hip Extensor Strengthening (bridging)

Purposes: to strengthen trunk and hip muscles required for standing straight.

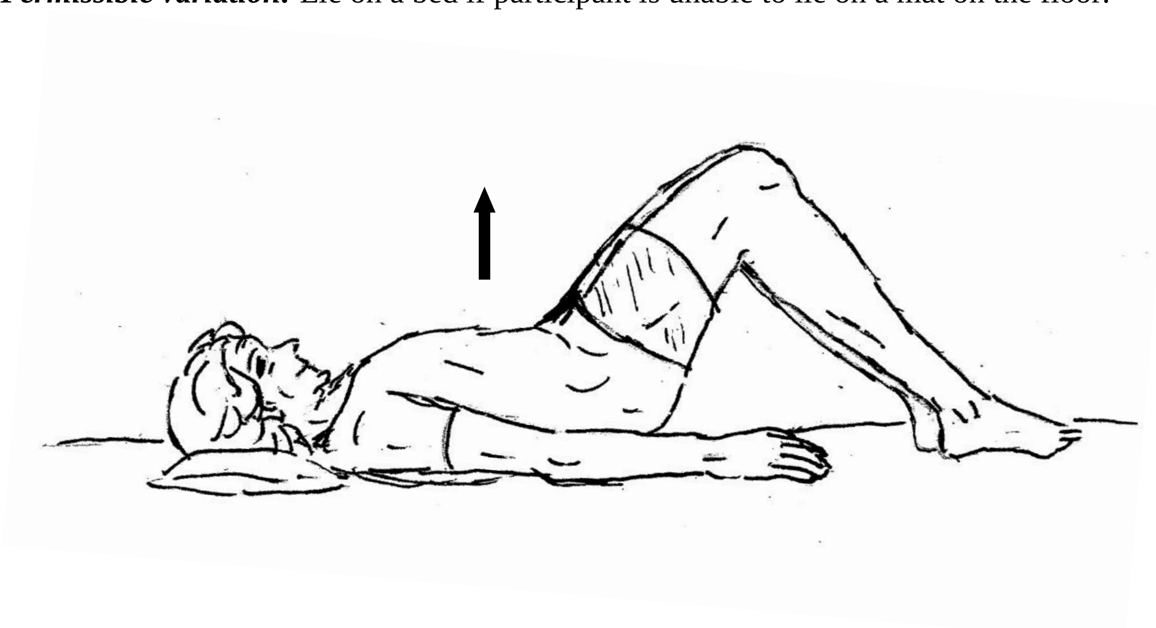
Start position: Direct the participant lie down on his/her back with both knees bent and feet resting on a standardized mat. Place a roll of towel or a small soft pillow under the participant's head for support.

Verbal Instruction: Please lie down on your back. Bend your knees with your feet rest on bed. Tuck chin in, suck stomach in and do not hold your breath. Slowly lift up your buttock off the bed toward the ceiling as high as possible. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: to BC 4-II when able to perform 2 sets of 10 easily.

Permissible variation: Lie on a bed if participant is unable to lie on a mat on the floor.



BC 4_II Hip Extensor Strengthening (Bridging with one foot lifting)

Purposes: to strengthen trunk and hip muscles required for standing straight.

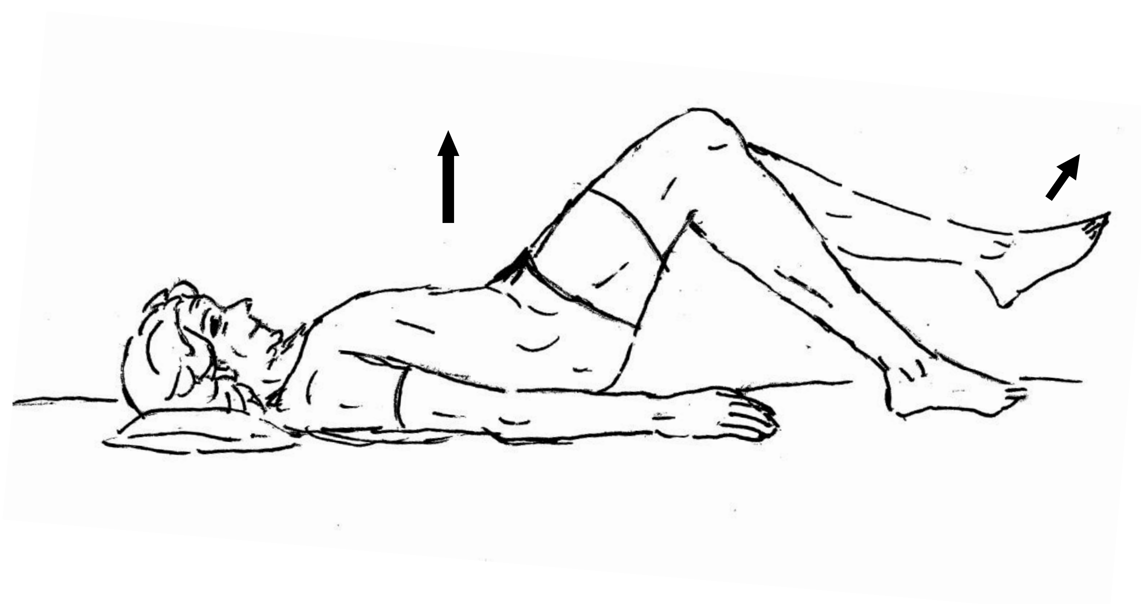
Start position: Direct the participant to lie on his/her back with the knees bend on a mat. Place a roll of towel or a small soft pillow under head for support.

Verbal Instruction: Please lie on your back. Bend your knees and rest your feet on the mat. Tuck chin in, suck stomach in and do not hold breath. Slowly lift up your buttock off the bed as high as possible. Hold the position; now slowly lift one foot off the bed. Hold in this position for 3 seconds. Put down the foot. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: to BC 4-III when able to perform 2 sets of 10 easily.

Permissible variation: Lie on a bed if participant is unable to lie on a mat on the floor.



BC 4_III Hip Extensor Strengthening (All four with leg lift)

Purposes: to strengthen trunk and hip muscles required for standing straight.

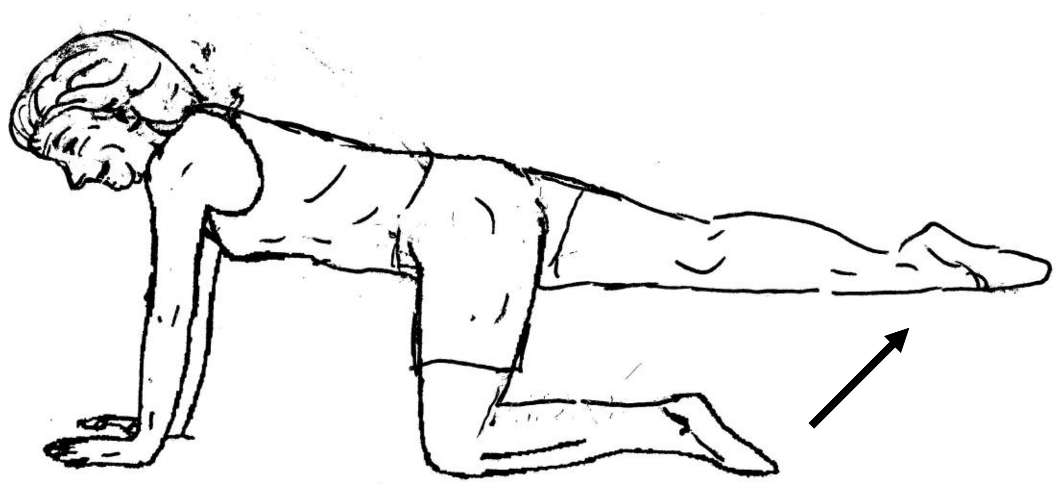
Start position: Direct the participant on his/her hands and knees (all-fours) position on a mat. Make sure hips are above knees and shoulders are above wrists. Can place towel or pillow under the knees for comfort.

Verbal Instruction: Please get onto your hands and knees. Make sure that your hips are above knees and keep back straight. Slowly lift up one leg up as high as possible with foot straight. Hold at this position for 3 seconds. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Permissible variation: Perform on a bed if participant is unable to tolerate on a mat on the floor.

Progression: Continue with adding 5 repetitions each week.



BC 5_I Knee Extensor (Quads) Strengthening (slow motion)

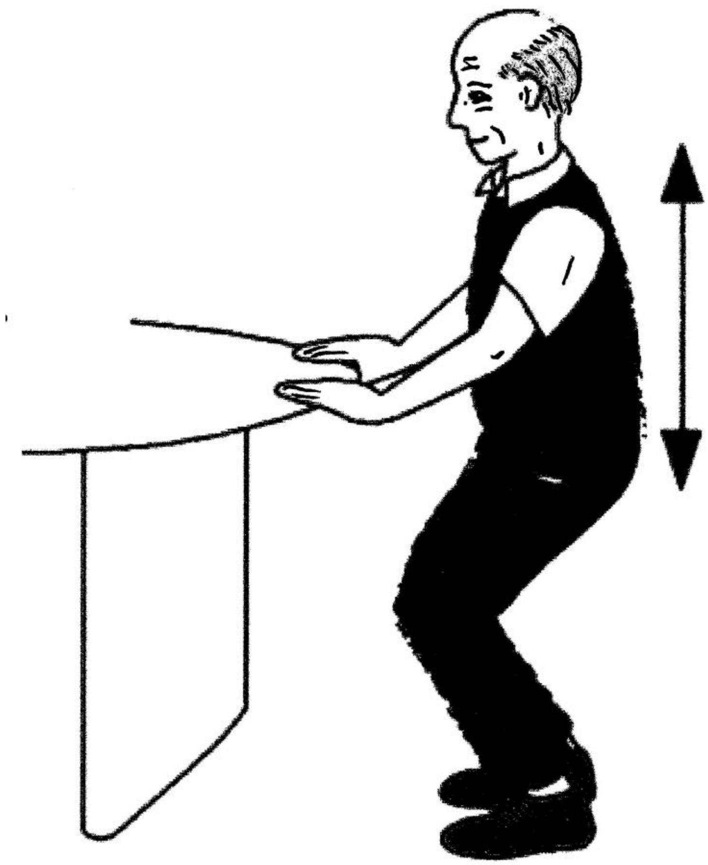
Purposes: to strengthen leg muscles required for standing, walking and climbing stairs.

Start position: Direct the participant stand in front of a steady counter with BOTH hands on top of counter for balance and feet shoulder width apart.

Verbal Instruction: Keep your back straight. Slowly bend both knees down as low as tolerable. Slowly stand up to return to starting position.

Repeat ___ times; do __ sets each session; 3 sessions per week.

Progression: to BC 5-II when able to perform 2 sets of 10 easily.



BC 5_II Knee Extensor (Quads) Strengthening (fast motion)

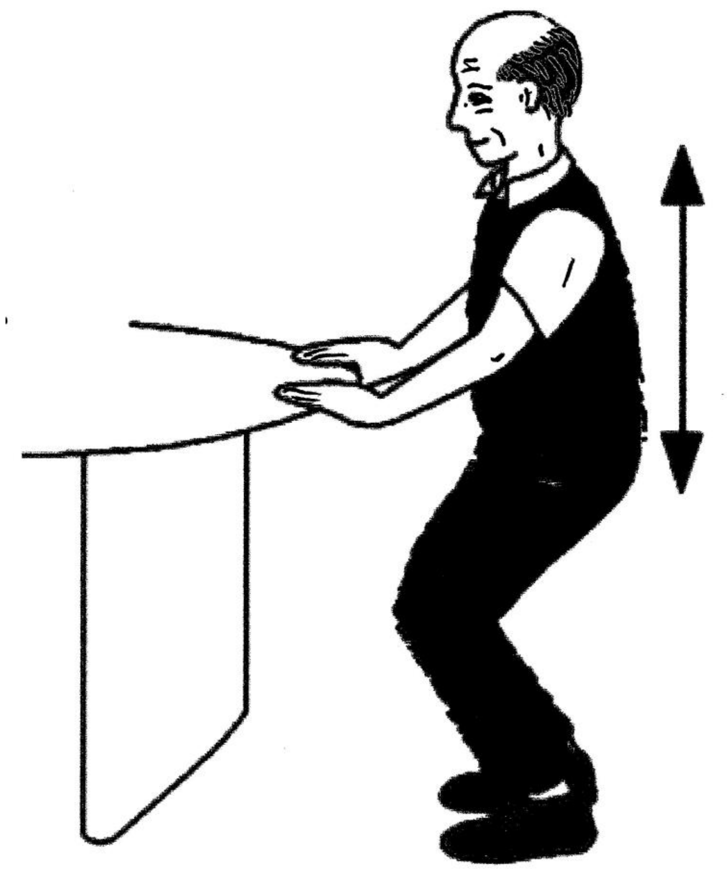
Purposes: to strengthen leg muscles required for standing, walking and climbing stairs.

Start position: Direct the participant stand in front of a steady counter with BOTH hands on top of counter for balance and feet shoulder width apart.

Verbal Instruction: Keep your back straight. Quickly bend both knees down as low as tolerable without hurting your knees. Quickly stand up to return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: to BC 5-III when able to perform 2 sets of 10 easily.



BC 5_III Knee Extensor (Quads) Strengthening (wall slide)

Purposes: to strengthen leg muscles required for standing, walking and climbing stairs.

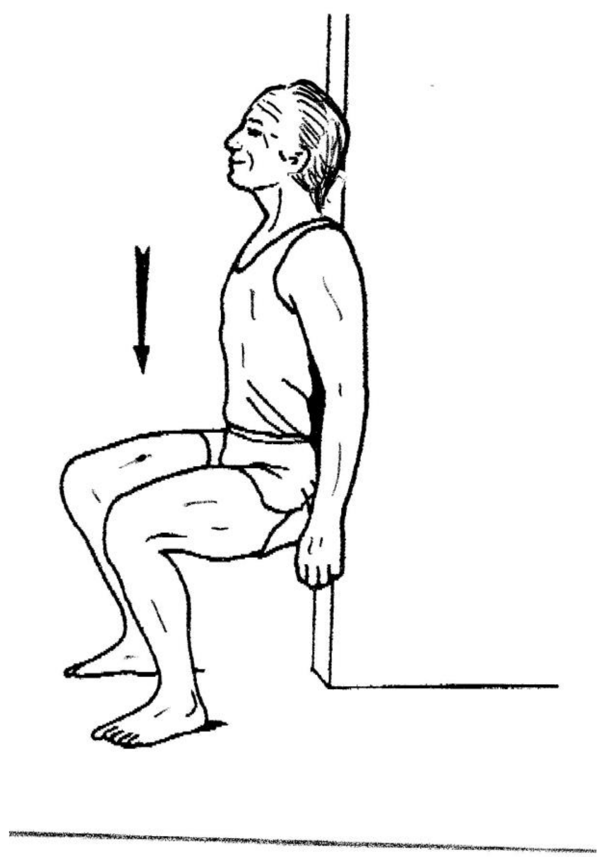
Start position: Direct the participant stand straight with your back against a wall with feet shoulder width apart.

Verbal Instruction: Please stand here with your back against the wall. Keep your feet shoulder width apart. Bend both knees down with your back sliding along the wall as low as tolerable. Stand up to return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: Continue with adding 5 repetitions each week.

Note to therapist: Make sure that the ankles are aligned beyond the knees.



BC 6_I Strengthening Plantar Flexors (sitting with resistance)

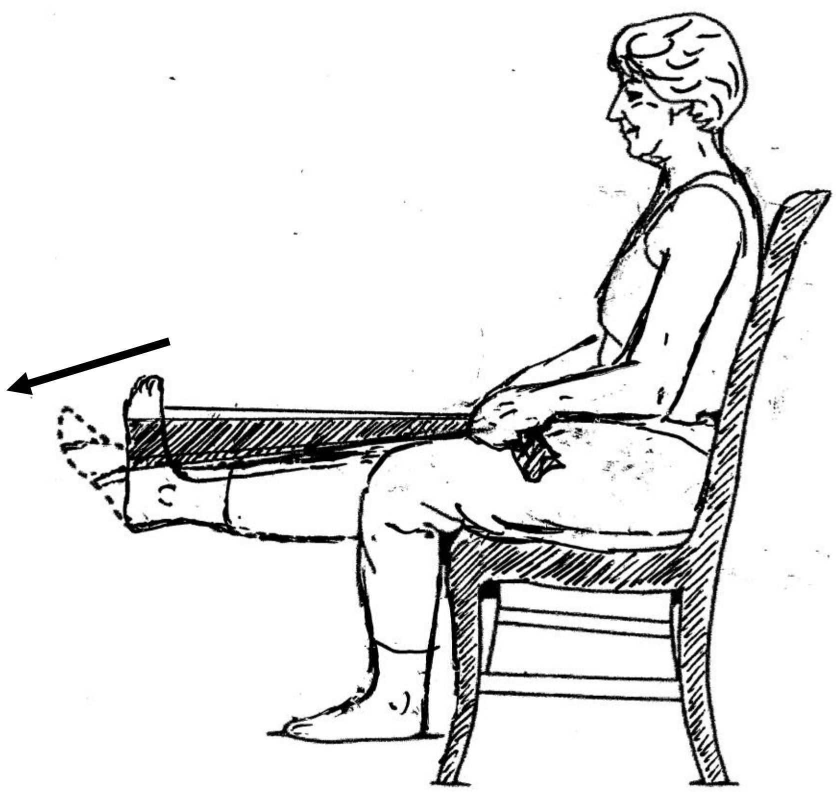
Purposes: to strengthen calf and ankle muscles.

Start position: Direct the participant sit in a straight back chair. Place the green theraband around his/her sole of foot and ask the participant to hold the ends with his/her hands.

Verbal Instruction: Please sit in this chair. I will loop this rubber band around your foot. Please hold the ends in your hand. Lift up this leg straight. Now slowly push this foot down away from your body against the resistance of the rubber band as much as you can. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: to BC 6-II when able to perform 2 sets of 10 easily.



BC 6_II Strengthening Plantar Flexors (stand on tiptoes 10 seconds)

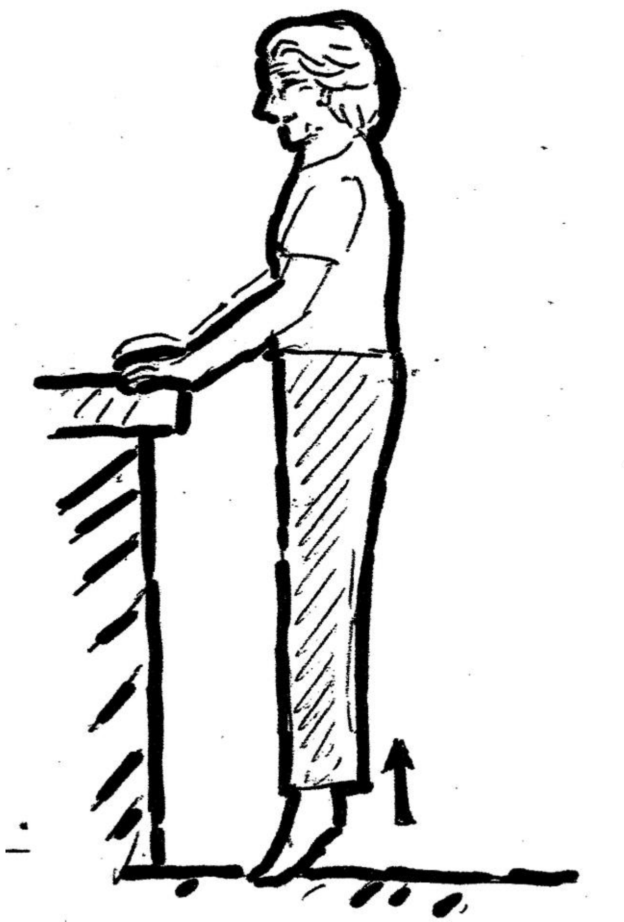
Purposes: to strengthen calf and ankle muscles.

Start position: Direct the participant stand in front of a steady counter with both hands on countertop for balance.

Verbal Instructions: Please stand in front of the counter. Place your hands on top of counter for balance. Slowly lift your heels off the ground as high as possible while keeping hips and knees straight. Stand on your tiptoes for 10 seconds. Relax and return to starting position.

Repeat ___ times; do __ sets each session; 3 sessions per week.

Progression: to BC 6-III when able to perform 2 sets of 10 easily.



BC 6_III Strengthening Plantar Flexors (stand on tiptoes 20 seconds)

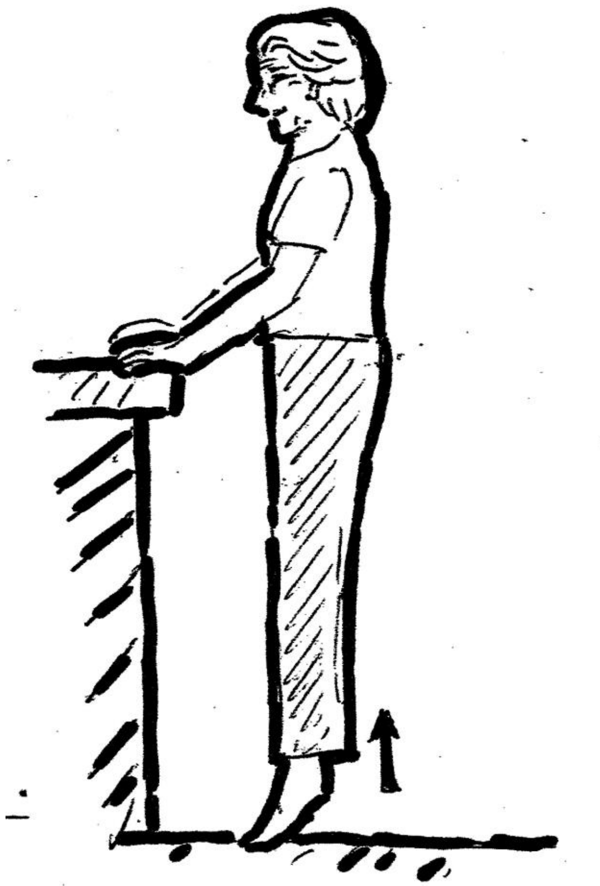
Purposes: to strengthen calf and ankle muscles.

Start position: Direct the participant stand in front of a steady counter with both hands on countertop for balance.

Verbal Instructions: Please stand in front of the counter. Quickly lift heels off the floor to stand on tiptoes as high as possible while keeping hips and knees straight. Hold on tip of toes for 20 seconds. Relax and return to starting position.

Repeat 10 times; do ___ sets each session; 3 sessions per week.

Progression: Continue with adding 5 repetitions each week.



BC 7_I Strengthening Dorsiflexors (sitting without resistance)

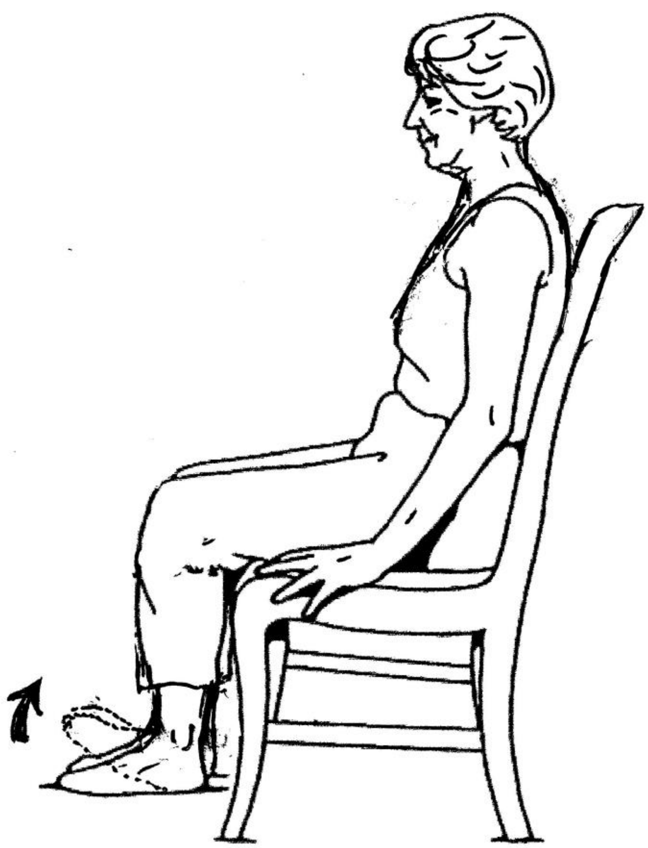
Purposes: to strengthen ankle muscles.

Start position: Direct the participant to sit in a straight back chair.

Verbal Instructions: Please sit down. Slowly lift the front of your feet as high as possible while keeping your heels on the floor. Hold this position for 10 seconds. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: to BC 7-II when able to perform 3 sets of 10 easily.



BC 7_II Strengthening Dorsiflexors (sitting with resistance 2 lb)

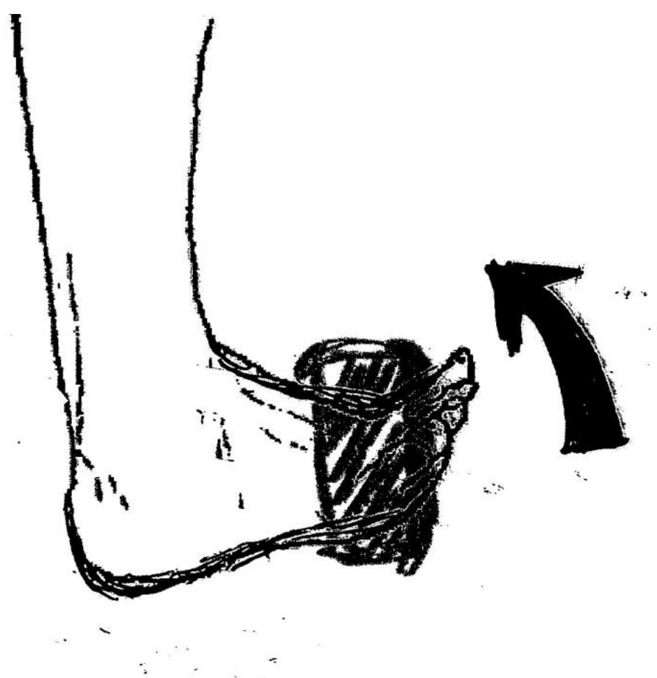
Purposes: to strengthen ankle muscles.

Start position: Direct the participant sit in a straight back chair. Place 2-lb cuff weight around both forefeet.

Verbal Instructions: Please sit down. I will place these weights around your forefeet for resistance. Slowly lift the front of your feet as high as possible while keeping your heels on floor. Hold at this position for 10 seconds. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: to BC 7-III when able to perform 2 sets of 10 easily.



BC 7_III Strengthening Dorsiflexors (sitting with resistance 4 lb)

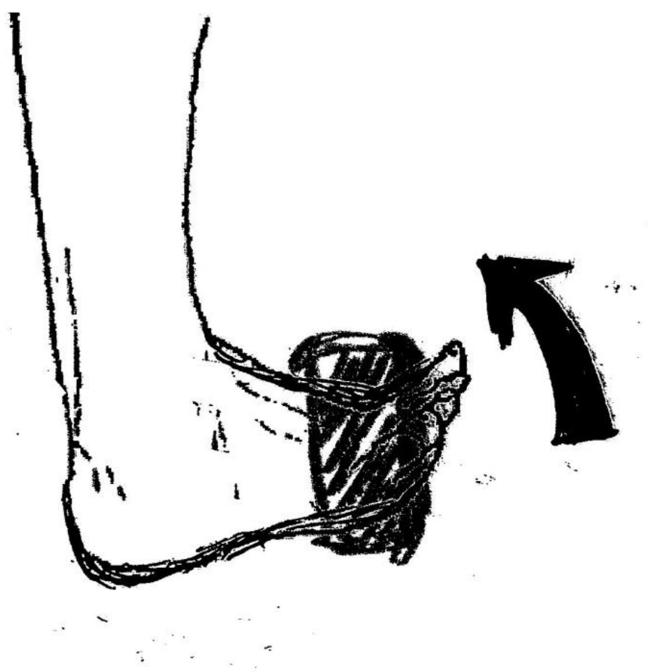
Purposes: to strengthen ankle muscles.

Start position: Direct the participant sit in a straight back chair. Place 4-lb cuff weight around both front feet.

Verbal Instructions: Please sit down. I will place these weights around your forefeet for resistance. Slowly lift the front of your feet as high as possible while keeping heels on the floor. Hold at this position for 10 seconds. Relax and return to starting position.

Repeat ___ times; do ___ sets each session; 3 sessions per week.

Progression: Continue with adding 5 repetitions each week.



BC 8_I Flexibility (supine straight leg raise)

Purposes: to increase the flexibility of hamstring muscles behind the thigh/knee.

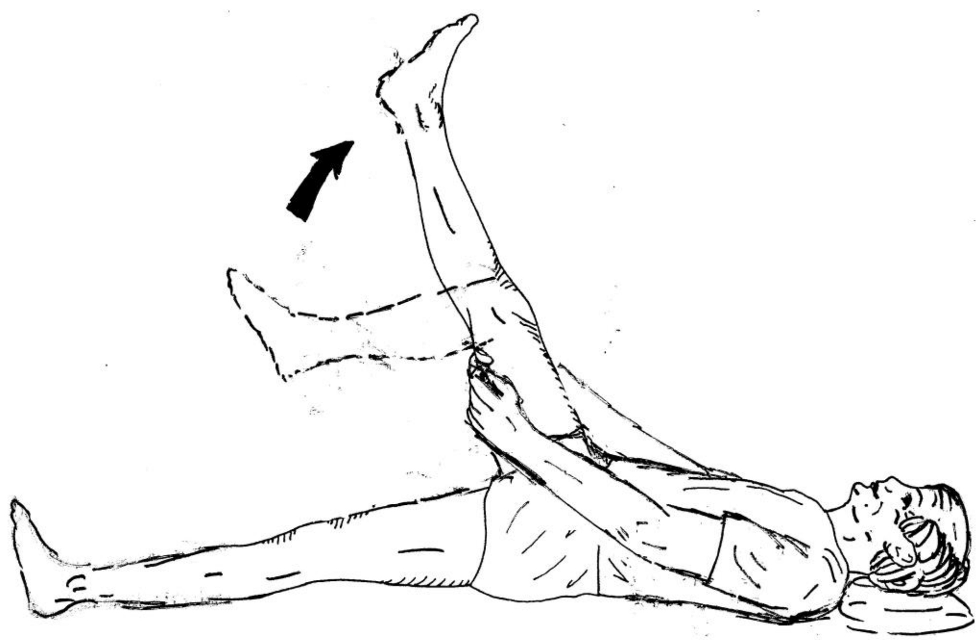
Start position: Direct the participant to lie down on back with both legs straight on a mat.

Verbal Instructions: Please lie down on your back and straighten your legs. Bend one knee, and clasp both your hands behind the back of the thigh. Slowly straighten the knee as much as possible with your toes toward ceiling. Make sure your other leg stays straight. Hold up for up to 30 seconds. You should feel a comfortable stretch at the back of the raised leg. Relax and return to starting position.

Repeat ___ times; Hold position for ___ seconds; Perform both legs. 3 sessions per week.

Progression: to BC 8-II when able to perform 4 stretches with foot pointing at ceiling easily.

Permissible variation: Lie on a bed if participant is unable to lie on a mat on the floor.



BC 8_II Flexibility (standing leaning on wall)

Purposes: to increase the flexibility of calf and hamstring muscles.

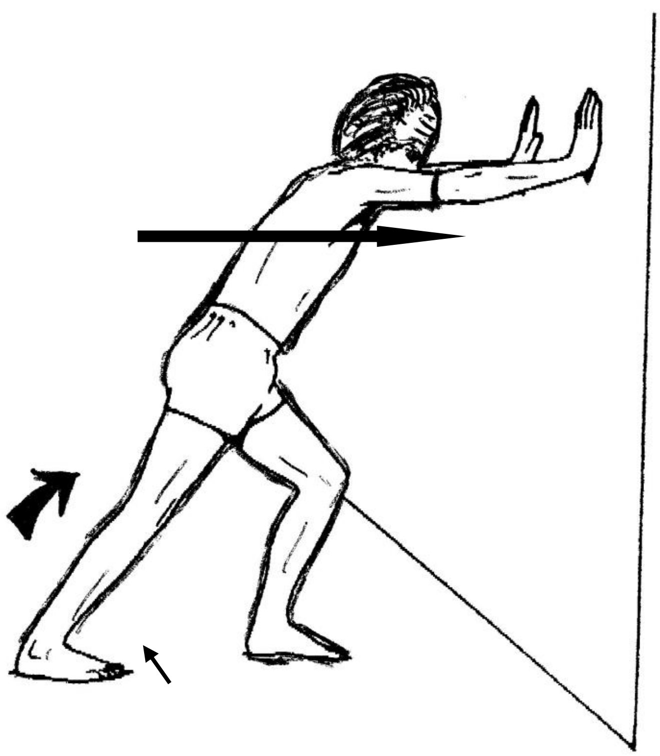
Start position: Direct the participant to stand facing a wall approximately a foot away from the wall.

Verbal Instructions: Please stand in front of wall, facing the wall. Place one foot in front of the other. Turn the foot behind slightly inward. Place your hands on the wall. Lean forward on both hands with elbows straight and one knee bent while keeping the other knee straight. You should feel a comfortable stretch at back of your calf. Keep your back straight; suck your stomach in and do not hold breath. Hold in this position for up to 20 seconds. Relax and return to starting position.

Repeat ___ times; Hold position for ___ seconds; Perform both legs. 3 sessions per week.

Note: Avoid bending both of the legs or tilting back while performing the exercise.

Progression: to BC 8-III when able to perform 4 stretches easily.



BC 8_III Flexibility (supine hip and knee flexibility)

Purposes: to increase the flexibility of hip and knee.

Start position: Direct the participant lie down on back with both legs straight on a mat.

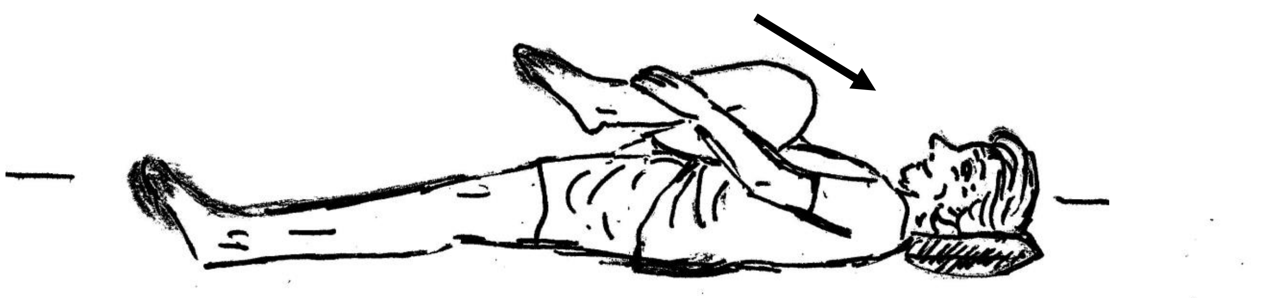
Verbal Instructions: Please lie down on your back with both legs straight. Bend one knee toward your chest and keep the other leg straight. Clasp both hands on the bent knee and hug the leg as close to your body as possible. Hold in this position for up to 20 seconds. Relax and return to starting position.

Repeat ___times; Hold position for ___ seconds; Perform both legs. 3 sessions per week.

Note: Avoid bending both of the legs or tilting back while performing the exercise.

Permissible variation: Lie on a bed if participant is unable to lie on a mat on the floor.

Progression: Continue with adding time of stretching by 5 seconds each week.



BC 9_I Transitioning (sit to half-kneeling)

Purposes: to achieve strength and flexibility necessary for getting up from floor.

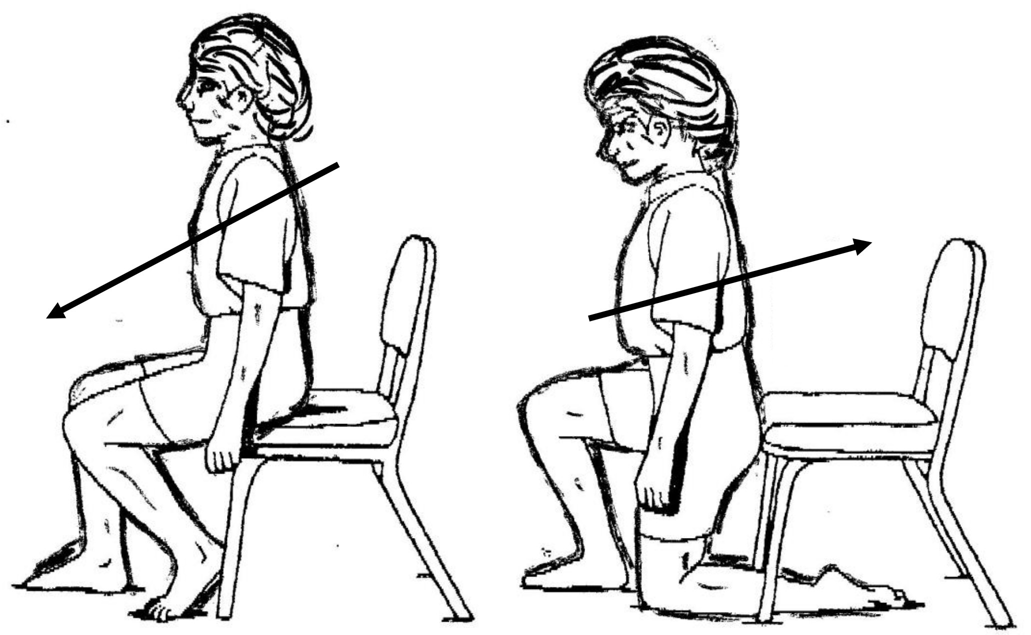
Start position: Direct the participant sit in a straight back chair.

Verbal Instructions: Please sit in this chair. Slowly move to the edge of chair, lean forward and move one foot out. Slowly get down to half kneeling position. Keep your stomach tucked in and back straight. Rise up to return to the edge of chair by pressing one hand on knee and one hand on seat.

Repeat ___ times each session; 3 sessions per week.

Progression: to BC 9-II when able to perform 5 times easily.

Permissible variation: Can place pillow or towel under the knee if unable to tolerate kneeling on the floor.



BC 9_II Transitioning (stand to half-kneeling)

Purposes: to achieve strength and flexibility necessary for getting up from floor.

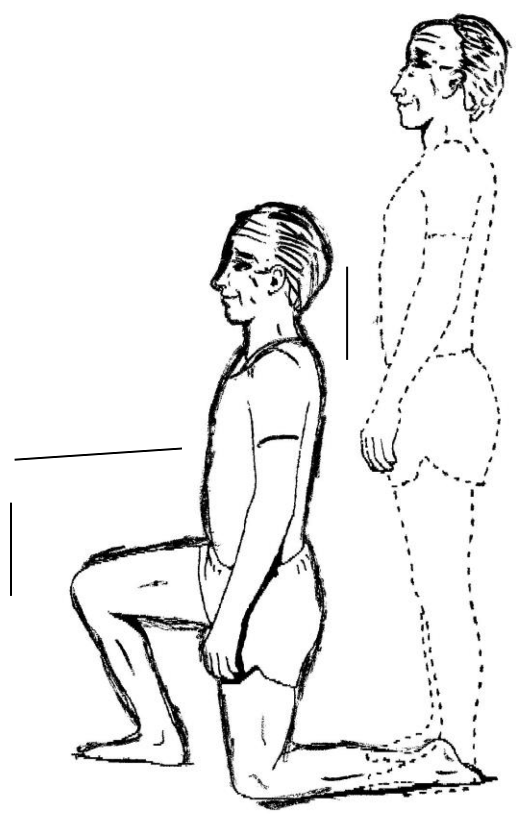
Start position: Direct the participant stand by a steady armchair.

Verbal Instructions: Please stand by this armchair. Use this armchair as support, slowly get down to half kneel position by leaning forward and sliding one foot backward. Keep stomach tucked in and back straight. Slowly return to standing position by leaning forward and pressing one hand on knee and one hand on seat.

Repeat ___ times each session; 3 sessions per week.

Progression: to BC 9-II when able to perform 5 times easily.

Permissible variation: Can place pillow or towel under the knee if unable to tolerate kneeling on the floor.



BC 9_III Transitioning (stand to kneeling)

Purposes: to achieve strength and flexibility necessary for getting up from floor.

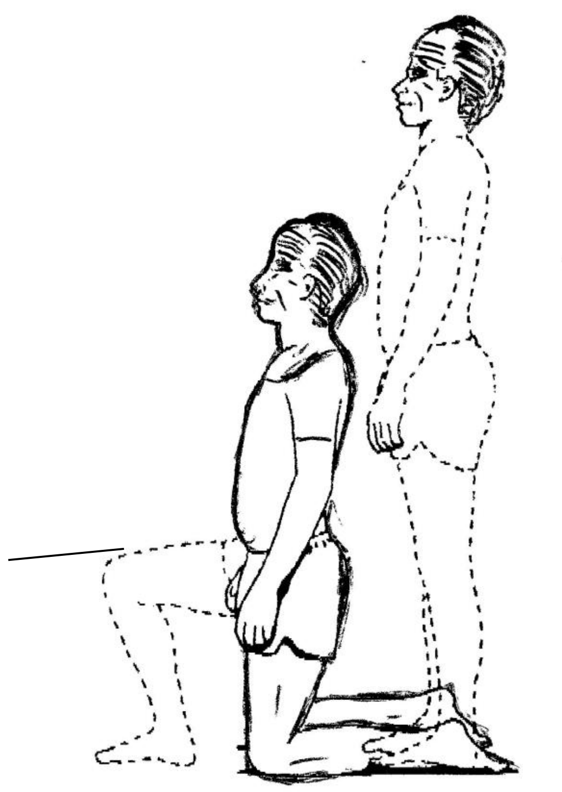
Start position: Direct the participant stand along a steady armchair.

Verbal Instructions: Please stand by this seat. Use the seat as support, Slowly get down to kneeling position by leaning forward and sliding one foot backward to half kneel; then slide the other foot backward to reach kneeling position. Keep stomach tucked in and back straight. Return to half kneeling position by placing one foot in front. Use the chair for support if needed. Return to standing position by leaning forward and pressing one hand on knee and one hand on seat.

Repeat ___ times each session; 3 sessions per week.

Permissible variation: Can place pillow or towel under the knee if unable to tolerate kneeling on the floor.

Progression: Continue with adding one repetition each week.



<u>Exercises for older adults with Anticipatory Postural Adjustment impairments</u>

Criterion: score of Anticipatory Postural Adjustments < 70% (raw score ≤ 12/18)
Frequency: 3 times/week with treating PT; or maximum of 18 sessions over 6 weeks.

Before you start exercises:

Pain: If you experience "sharp pain" (not muscle aching or soreness) while doing any of the exercises, consult with your therapist before resuming the program.

Dosage: It is important to follow the repetitions as recommended in your instructions to avoid overdoing.

Stiffness: You may feel some tightness, stiffness, or soreness/aching in your movements when you first begin the program. It takes persistence and patience to work toward your goal.

Frequency: It is important that you perform the instructed exercise at least 3 times every week with me to get the best results. It would be best if we could do them at a certain time of the day as much as possible.

Breathing: It is important that you breathe normally while doing your exercises and avoid holding your breath.

Posture: Maintain good posture and proper head/neck alignment when performing the exercises.

Shoes: Please wear comfortable walking shoes (like sneakers or other sturdy shoes, not bedroom slippers) when you perform exercises involved seated, standing and walking activities. Please take off your shoes when you perform exercises involved mat or bed activities.

Exercise equipment: Standardized exercise mat (4'x8' Aeromat), Cuff weights (1 lb, 1.5 lb, 2 lb, 2.5 lb, 3 lb, 4 lb, 5 lb), Theraband (Green, 3 ft long; loop length 12 inches), Step stool (9-inch height), Metronome (for speed of measure).

APA 1_I Rise to tiptoes (slow motion)

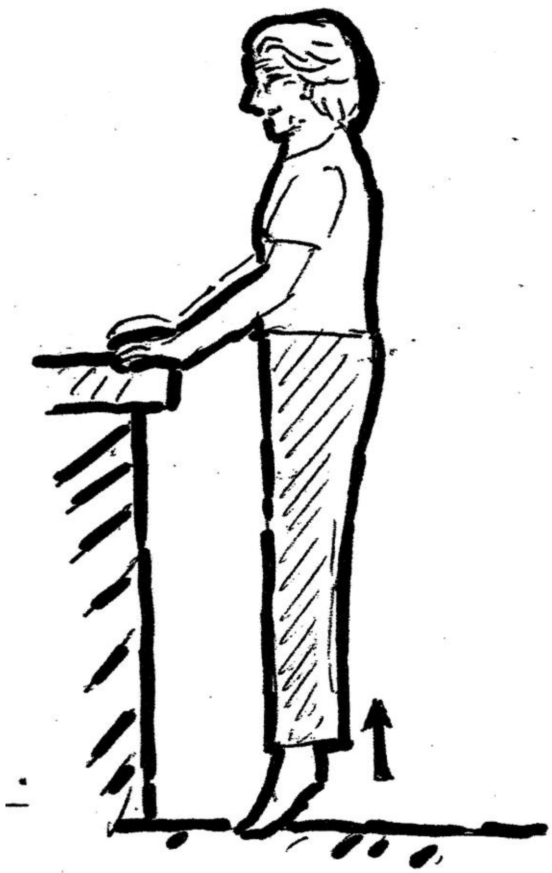
Purposes: to balance stand on tiptoes.

Start position: Direct the participant to stand in front of a steady counter.

Verbal Instruction: Please place both of your hands on countertop for balance. Stand straight. Tuck your chin in, suck stomach in. Make sure that you do not hold your breath. Keep your knees straight. Shift your weight to your tiptoes, SLOWLY lift your heels up as high as possible and stay up for __ second, then SLOWLY return down to start position.

Repeat ___ times each set, ___ sets each session; 3 sessions per week.

Progression: to APA 2_ Level II when able to perform 2 sets of 10 times easily.



APA 1_II March-in-place on tiptoes

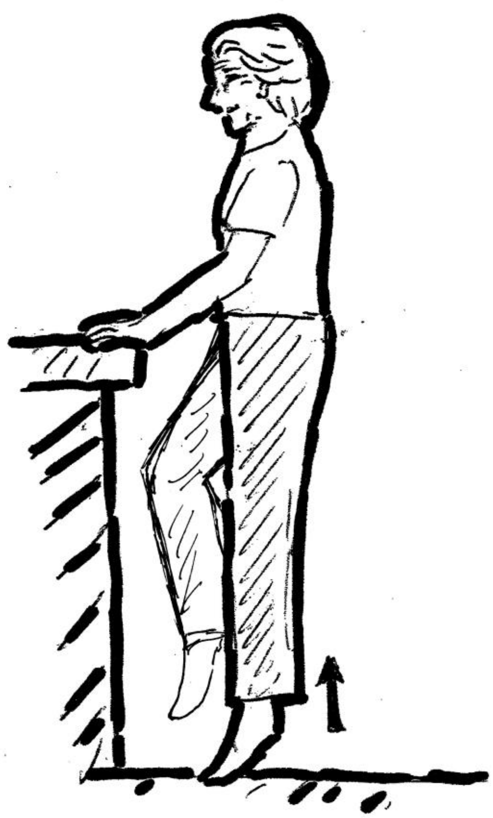
Purposes: to balance stand on tiptoes.

Start position: Direct the participant to stand in front of a steady counter.

Verbal Instruction: Please place ONE hand on countertop for balance. Tuck chin in, suck stomach in and make sure that you do not hold breath.
Shift your weight to your toes. SLOWLY raise your heels up as high as possible to stand on your tiptoes. Now March-in-place on your toes with alternate foot for 20 steps (this makes 10 steps at each side). Keep your stomach tucked in and back straight the whole time.

Perform ___ sets each session; ___ sessions per week.

Progression: to APA 1-III when able to perform 2 sets of 10 times easily.



APA 2_III Walk on tiptoes at progressive speed

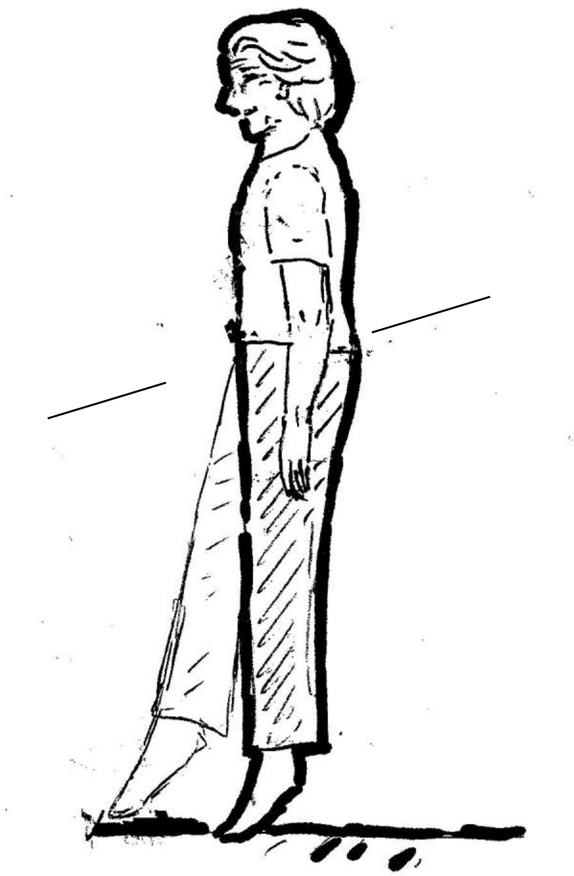
Purposes: to balance stand on tiptoes.

Start position: Direct the participant to stand in front of a steady counter or by a railing.

Verbal Instruction: Lift your heels off the ground and stand on your tiptoes. Walk on tiptoes alongside the countertop or railing for 30 steps. Keep stomach tucked in and posture straight.

Repeat ___ times each set, ___ sets each session; 3 sessions per week.

Progression: Gradually increase the speed of walking determined by a metronome.



APA 2_I Stand on Heels

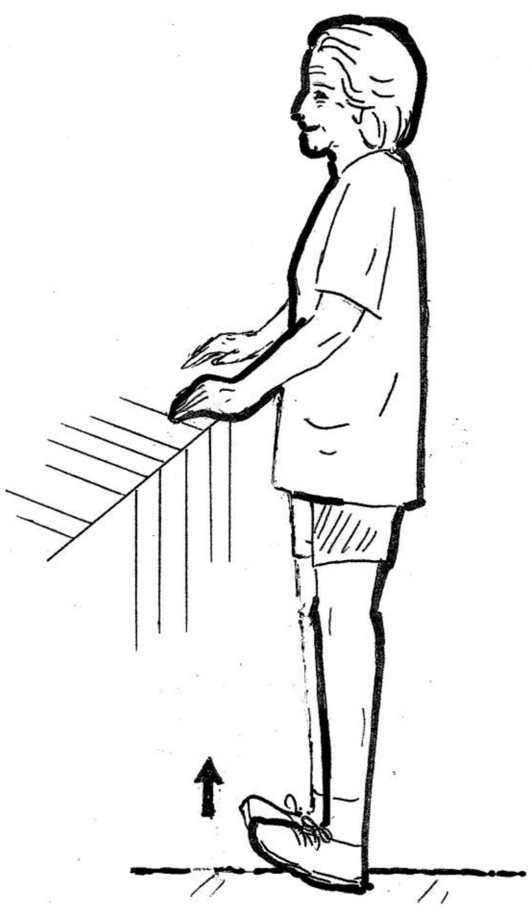
Purposes: to balance stand on heels.

Start position: Direct the participant to stand in front of a steady counter.

Verbal Instruction: Please stand in front of a steady counter. Place BOTH hands on countertop for balance. Tuck chin in, suck stomach in and do not hold breath. Shift your weight to your heels. SLOWLY raise your toes off the floor as high as possible and stay for 3 second while keeping both knees straight, then SLOWLY return down to start position. Keep stomach tucked in and back straight.

Repeat ____ times each set; ____ sets each session; 3 sessions per week.

Progression: to APA 2-II when able to perform 2 sets of 10 times easily without losing balance or toes drop-down.



APA 2_II March-in-place on Heels

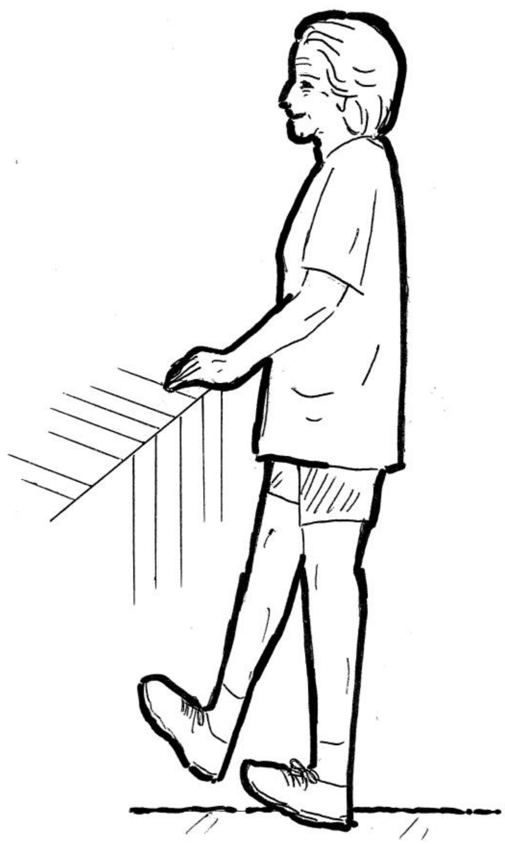
Purposes: to balance stand on heels.

Start position: Direct the participant stand in front of a steady counter.

Verbal Instructions: Please stand by the countertop. Place ONE hands on countertop for balance. SLOWLY raise your toes off as high as possible and March-in-place on your toes 20 steps with alternate foot (10 at each side). Keep stomach tucked in and back straight.

Perform ___ sets each session; 3 sessions per week.

Progression: to APA 2-III when able to perform 2 sets of 10 times easily without losing balance or toes drop-down.



APA 2_III Walk on Heels with progressive speed

Purposes: to balance stand on heels.

Start position: Direct the participant stand in front of a steady counter or a railing.

Verbal Instructions: Please stand by the counter. SLOWLY raise your toes off the floor as high as possible and walk on heels for 30 steps. Keep your stomach tucked in and back straight.

Perform ___ sets each session; 3 sessions per week.

Progression: Gradually increase the speed of walking determined by a metronome.

APA 3_I Stand on one leg (bilateral support)

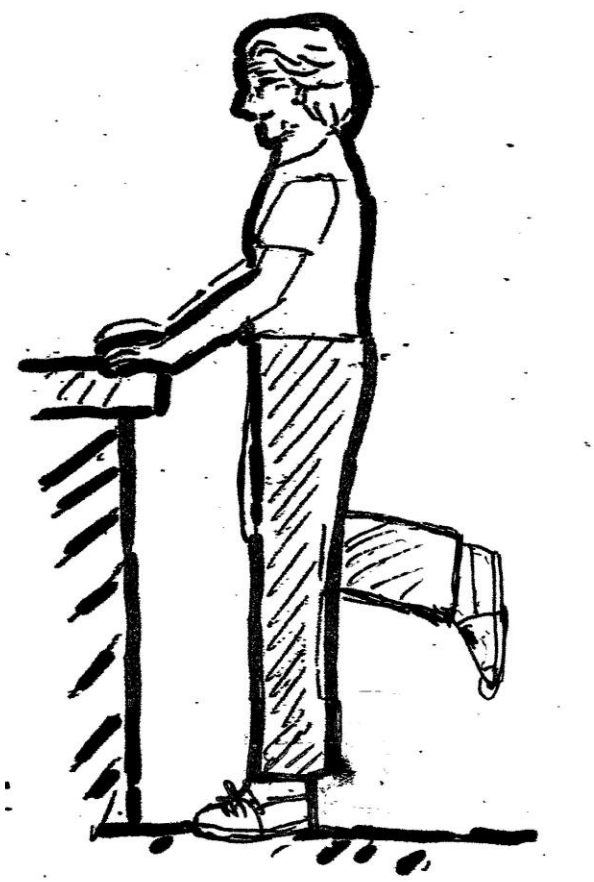
Purposes: to balance stand on one leg.

Start position: Direct the participant stand in front of a steady counter.

Technique: Please stand in front of the counter. Place BOTH hands on countertop for balance. SLOWLY raise one foot off the floor and hold that foot behind without knees touching each other for 20 seconds while keeping the standing knee straight. Return to the starting position. Keep stomach tucked in and back straight.

Repeat ___ times each side, ___ sets each session; 3 sessions per week.

Progression: to APA 3-II when able to perform 2 sets of 10 times easily without losing balance, knees buckling or foot drop-down.



APA 3_II Stand on one leg (unilateral support)

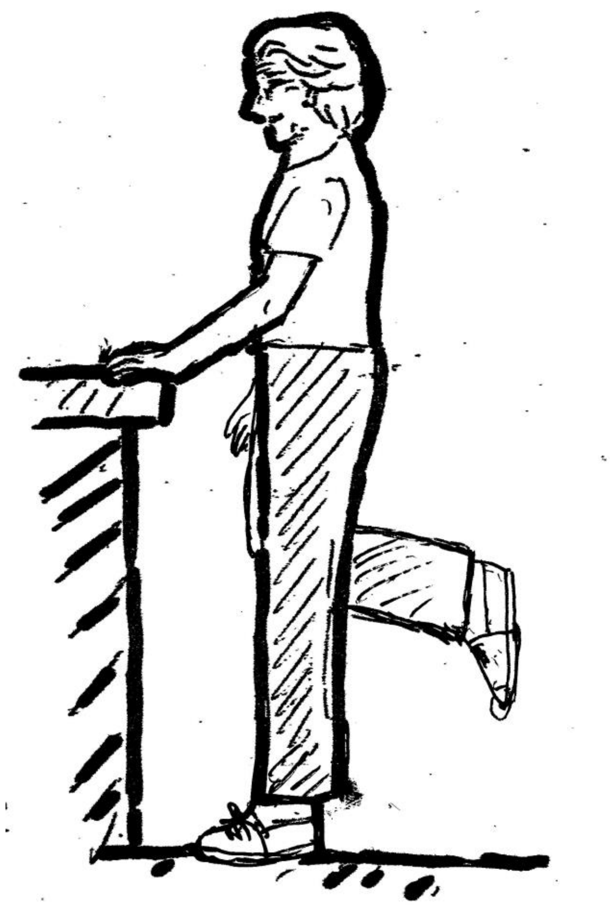
Purposes: to balance stand on one leg.

Start position: Direct the participant stand in front of a steady counter.

Verbal Instructions: Please stand in front of the counter. Place ONE hands on countertop for balance. SLOWLY raise one foot off the floor and hold that foot behind without knees touching each other for 20 seconds while keeping the standing knee straight. Return to the starting position. Keep stomach tucked in and back straight.

Repeat ___ times each side, ___ sets each session; 3 sessions per week.

Progression: to APA 3-III when able to perform 2 sets of 10 times easily without losing balance, knees buckling or foot drop-down.



APA 3_III Stand on one leg (no hand support)

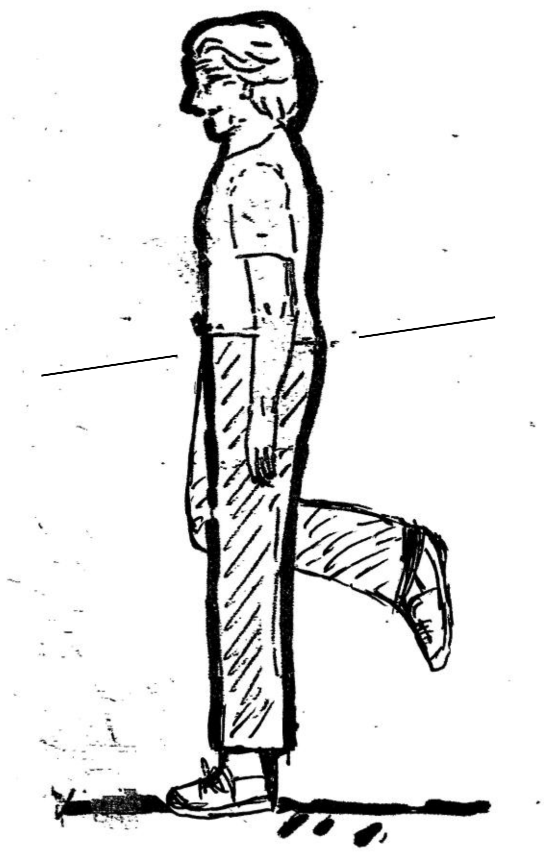
Purposes: to balance stand on one leg.

Start position: Direct the participant stand in front of a steady counter.

Verbal Instructions: Please stand in front of the counter. SLOWLY raise one foot off the floor and hold that foot behind without knees touching each other for 20 seconds while keeping the standing knee straight. Return to the starting position. Keep stomach tucked in and back straight.

Repeat ___ times each side, ___ sets each session; 3 sessions per week.

Progression: Continue with adding 5 repetitions each week



APA 4_I Stair touching with both hands support

Purposes: to balance reaching steps.

Start position: Direct the participant stand in front of a steady counter. Place a small steady footstool against the bottom of counter.

Technique: Please stand in front of the counter. Place BOTH hands on countertop for balance. Touch the ball of each foot alternately on the top of the stool. Continue until each foot touches the stair 10 times (20 total taps). Keep stomach tucked in and back straight.

Perform ___ sets each session; 3 sessions per week.

Progression: Gradually increase speed of touching; move to APA 4-II when able to perform 2 sets easily and quickly without losing balance, knees buckling or tip of foot kicking the stool.

Permissible Variation: Use a standard walker to adjust to the participant's height if the participant needs to flex his/her trunk to hold onto the counter. Therapist will stabilize the walker.

APA 4_II Stair touching up and down

Purposes: to balance reaching steps.

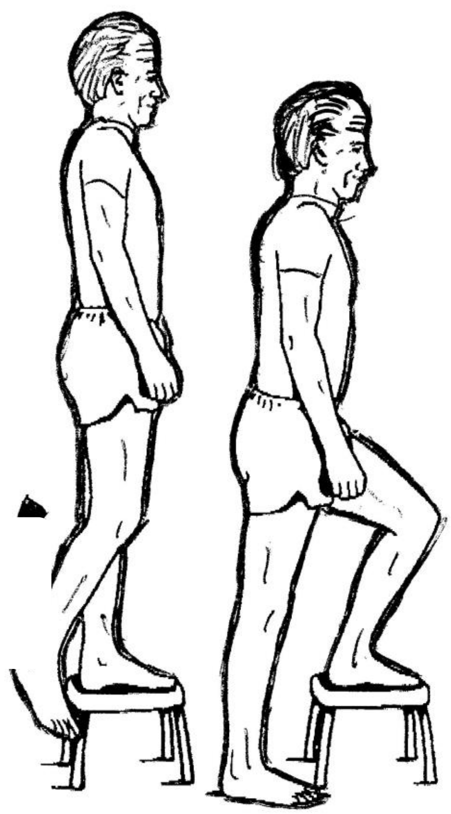
Start position: Direct the participant stand in front of a steady counter. Place a small steady footstool against the bottom of counter.

Technique: Please stand in front of the counter. Place ONE hands on countertop for balance. Place one foot on top of the stool. Keep this foot on the stool. Step the other foot on and off the step stool. Keep your back straight.

Repeat ___times each side. Do ___ sets each session; 3 sessions per week.

Progression: Gradually increase speed of touching determined by a metronome; progress to APA 4-III when able to perform 2 sets of 10 easily and quickly without losing balance, knees buckling or tip of foot kicking the stool.

Permissible Variation: Therapist can offer hands as support to prevent participant from falling if necessary.



APA 4_III Stair touching up/down backward

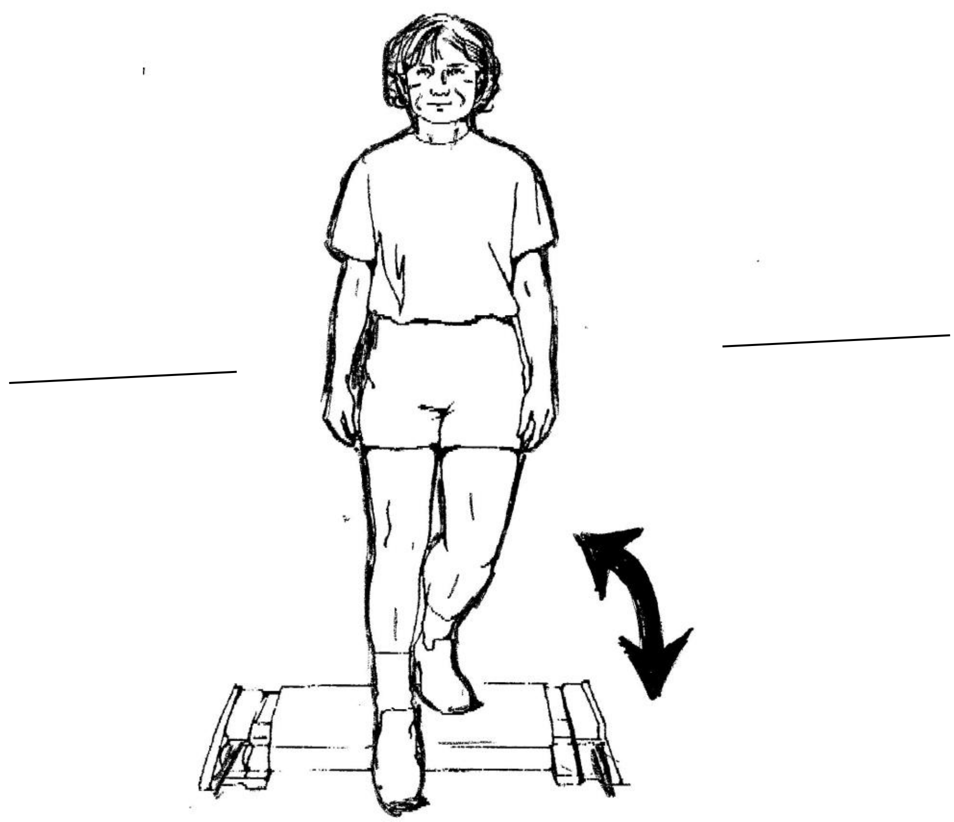
Purposes: to balance reaching steps.

Start position: Direct the participant stand in front of a steady counter with their back facing the counter. Place a small steady footstool against the bottom of counter.

Verbal Instructions: Please stand in front of the counter with your back toward the counter. Step backward with your foot. Touch the stool with your foot alternately. Continue until each foot touches the stair 10 times (20 total taps). Keep your back straight.

Gradually increase speed of touch determined by a metronome. Perform ___ sets each session; 3 sessions per week.

Permissible Variation: Therapist can offer hands as support to prevent participant from falling if necessary.



APA 5_I Lunge forward

Purposes: to balance when shift center of gravity out of base.

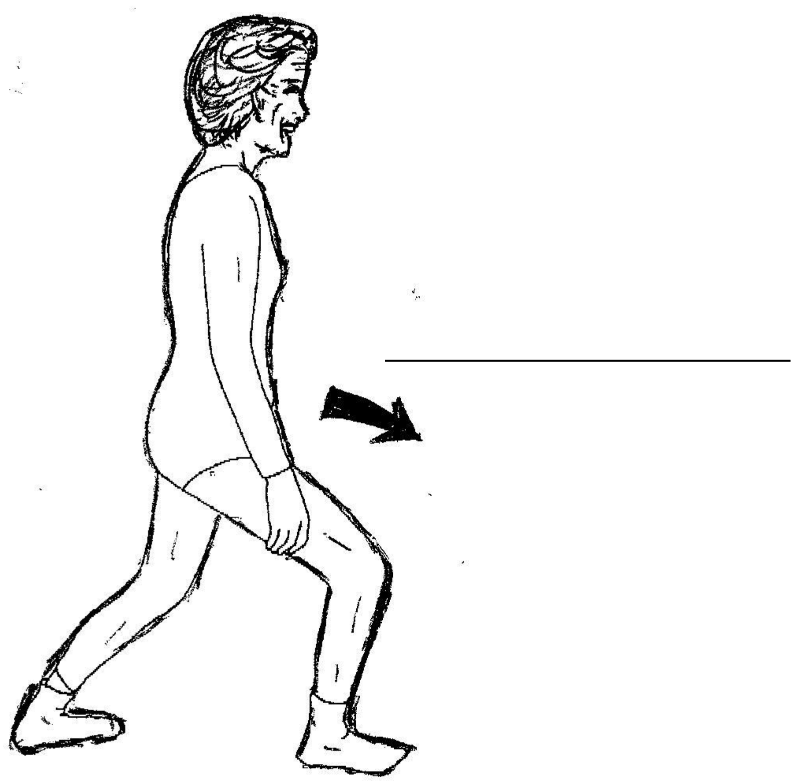
Start position: Direct the participant stand by a steady counter.

Verbal Instructions: Please stand by the counter. Take a large step forward with one foot. Keep both knees bend. Slowly shift weight to the front foot. Hold in this position for up to 10 seconds. Return to the starting position. Keep stomach tucked in and back straight.

Repeat ___ times each side, ___ sets each session; 3 sessions per week.

Progression: to APA 5-II when able to perform 2 sets of 5 repetitions easily without losing balance.

Note to therapist: Keep the knee and ankle of the front leg aligned so knee is not beyond ankle.



APA 5_II Lunge forward with alternate arm reaching and progressive speed

Purposes: to balance when shift center of gravity out of base.

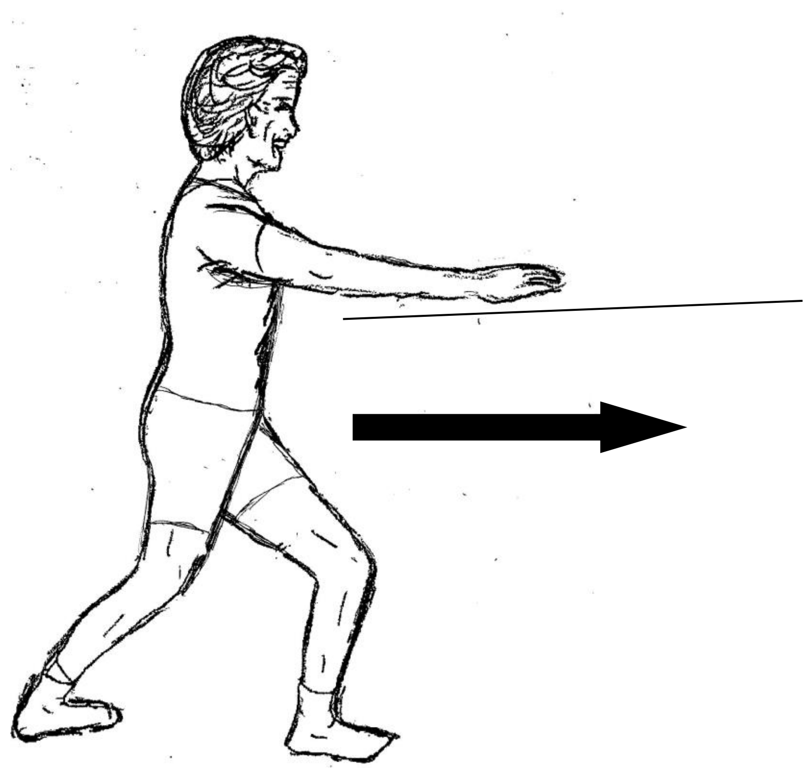
Start position: Direct the participant stand by a steady counter.

Verbal Instructions: Please stand by the counter. Take a large step forward with one foot and reach the opposite arm forward at the same time. Keep both knees bend while raising the arm shoulder height. Slowly shift weight to the foot in front. Reach forward without losing balance. Hold in this position for up to 10 seconds. Return to the starting position. Keep stomach tucked in and back straight.

Repeat ___ times each side, ___ sets each session; 3 sessions per week.

Progression: Move to APA 5-III when able to perform 2 sets of 5 easily without losing balance.

Note to therapist: Keep the knee and ankle of the front leg aligned so knee is not beyond ankle.



APA 5_III Lunge sideway with arm reaching sideway

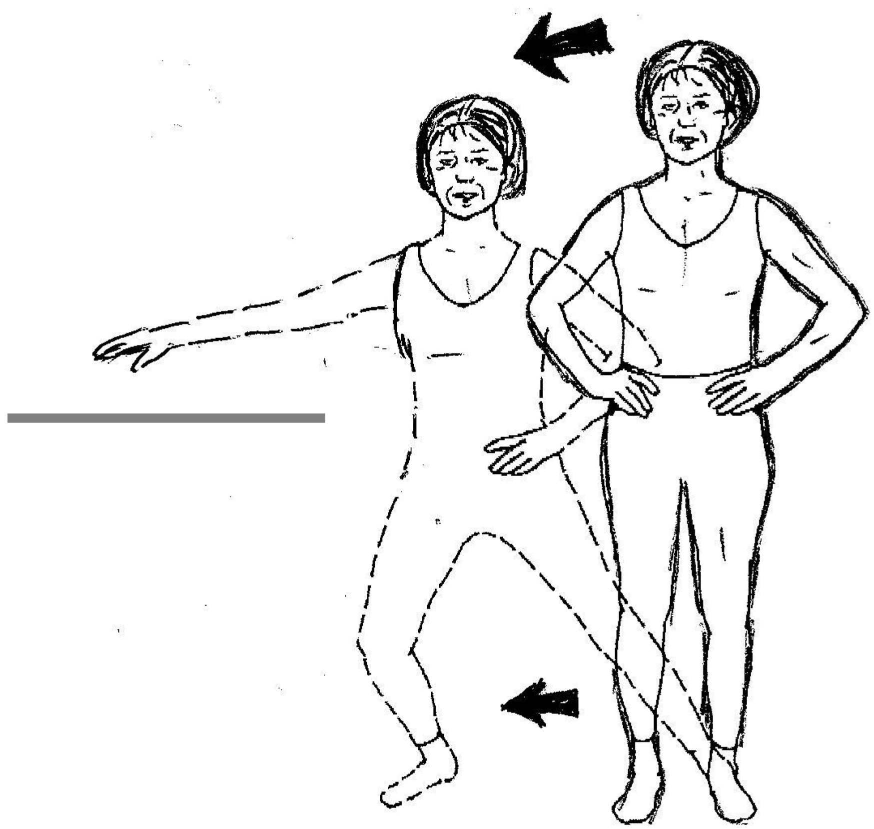
Purposes: to balance when shift center of gravity out of base.

Start position: Direct the participant stand in front of a steady counter.

Technique: Please stand in front of the counter. Bring one leg sideways with both knees bent. Raise the same side of arm up to shoulder height. Slowly shift weight to the foot at side. Reach sideway as far as possible without losing balance. Hold in this position for up to 20 seconds. Return to the starting position.

Repeat ___ times each side, ___ sets each session; 3 sessions per week.

Progression: Continue with adding 2 repetitions each week.



APA 6_I Figure 8 (bilateral support)

Purposes: to balance on one foot with the other foot tracing on floor.

Start position: Direct the participant stand by a steady counter.

Verbal Instructions: Please stand by the counter. Place BOTH hands on countertop for balance. Shift weight on one foot. Lift up the other foot, trace a FIGURE "8" on the floor with your toe tips. Return to the starting position, now trace a REVERSED FIGURE "8" with the same toe tips. Do the other foot as well. Keep your torso and back straight.

Repeat 5 times each set, 2 sets each session; 3 sessions per week.

Progression: to APA 6-II when able to perform 2 of 5 sets easily without losing balance.

APA 6_II Figure 8 (unilateral support)

Purposes: to balance on one foot with the other foot tracing on floor.

Start position: Direct the participant stand by a steady counter.

Verbal Instructions: Please stand in front of the counter. Place ONE hand on countertop for balance. Shift weight on one foot. Lift up the other foot, trace a FIGURE “8” on the floor with your toe tips. Return to the starting position, now trace a REVERSED FIGURE “8” with the same toe tips. Do the other foot as well. Keep your torso and back straight.

Repeat 5 times each set, 2 sets each session; 3 sessions per week.

Progression: to APA 6-III when able to perform 2 sets of 5 easily without losing balance.

APA 6_III Figure 8 with progressive speed (no support)

Purposes: to balance on one foot with the other foot tracing on floor.

Start position: Direct the participant stand by a steady counter.

Verbal Instructions: Please stand in front of the counter. Shift weight on one foot. Lift up the other foot, trace a FIGURE "8" on the floor with your toe tips. Return to the starting position, now trace a REVERSED FIGURE "8" with the same toe tips. Do the other foot as well. Keep your torso and back straight.

Repeat 5 times each set, 2 sets each session; 3 sessions per week.

Progression: Continue with adding 2 repetitions each week.

APA 7_I Tandem stand forward

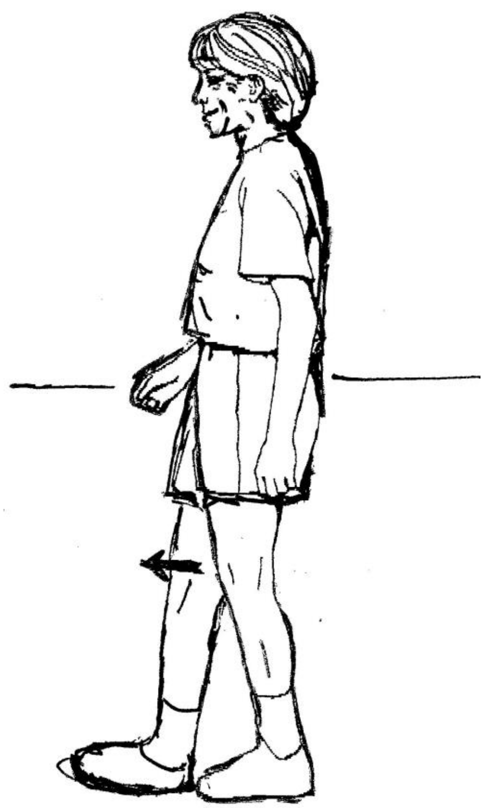
Purposes: to balance on narrow base of support.

Start position: Direct the participant stand by a steady counter.

Technique: Please stand by this counter. Place ONE hand on countertop for balance. Visualize a straight line on the floor. Place one foot in front of the other so they are heel-toe touching. Hold in this position for 10 seconds. Perform alternate foot. Keep your torso and back straight.

Perform ___ times each set, 2 sets each session; 3 sessions per week.

Progression: Move to APA 7-II when able to perform 2 sets of 5 easily with little hand support without losing balance.



APA 7_II Walk on a straight line forward with support

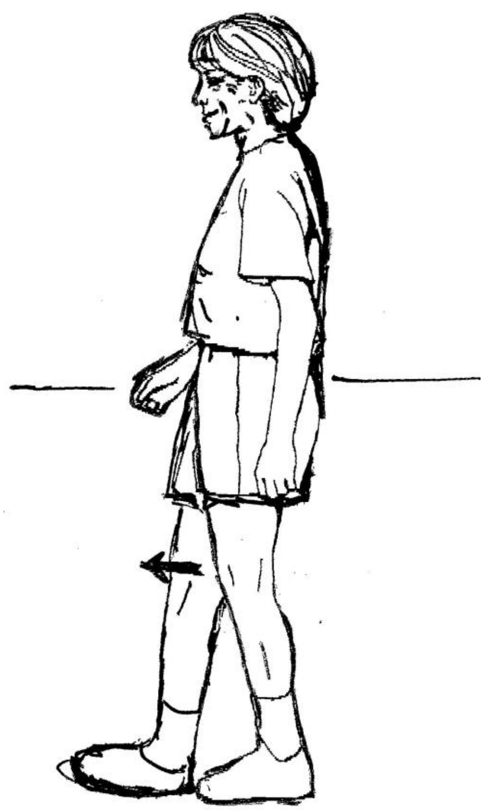
Purposes: to balance on narrow base of support.

Start position: Direct the participant stand by a steady counter.

Technique: Please stand by this counter. Place ONE hand on countertop for balance. Visualize a straight line on the floor. Walk at your normal speed on this line with heel connecting to toe for 30 steps. Keep your torso and back straight.

Perform ___ sets each session; 3 sessions per week.

Progression: Gradually increase the speed of walking. Move to APA 7-III when able to perform 2 sets easily with no hand support without losing balance or tripping.



APA 7_III Walk on a straight line forward without support

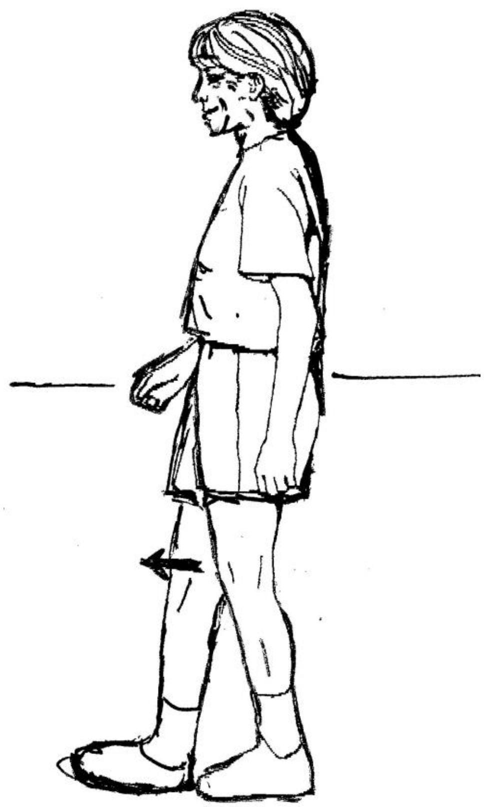
Purposes: to balance on narrow base of support.

Start position: Direct the participant stand by a steady counter.

Technique: Please stand by this counter. Visualize a straight line on the floor. Walk at your normal speed on this line with heel connecting to toe for 30 steps. Keep your torso and back straight.

Perform ___ sets each session; 3 sessions per week.

Progression: Increase speed of steps determined by a metronome.



APA 8_I Tandem stand backward

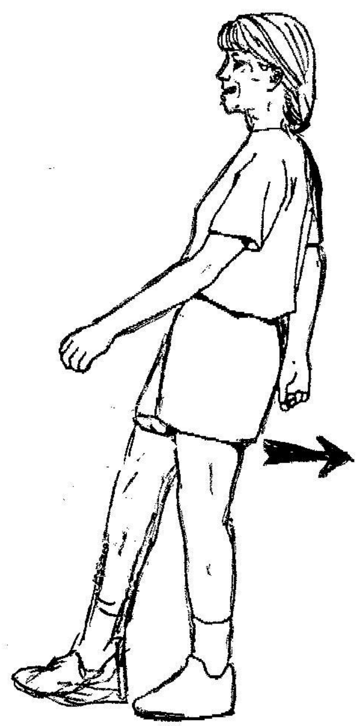
Purposes: to balance on narrow base of support.

Start position: Direct the participant stand by a steady counter.

Technique: Please stand by this counter. Place ONE hand on countertop for balance. Visualize a straight line on the floor. Place one foot behind the other so they are heel-toe touching. Hold in this position for 10 seconds. Perform alternate foot. Keep your torso and back straight.

Perform ___ times each set, 2 sets each session; 3 sessions per week.

Progression: Move to APA 8-II when able to perform 2 sets of 5 easily with little hand support without losing balance.



APA 8_II Walk on a straight line backward

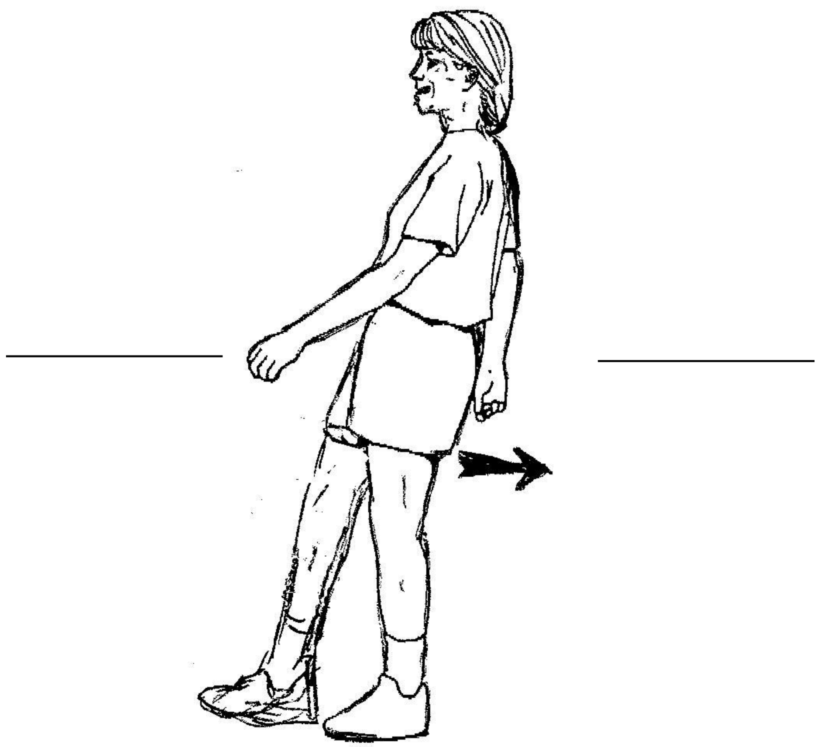
Purposes: to balance on narrow base of support.

Start position: Direct the participant

Verbal Instructions: Please stand by the counter. Place ONE hand on countertop for balance. Visualize a straight line on the floor. Walk backward at your comfortable speed on this line for 30 steps while connecting heel-to-toes. Keep your torso and back straight.

Perform ___ sets each session; 3 sessions per week.

Progression: Gradually increase the speed of walking. Move to APA 8-III when able to perform 2 sets easily with little hand support without losing balance or tripping.



APA 8_III Walk on a straight line backward

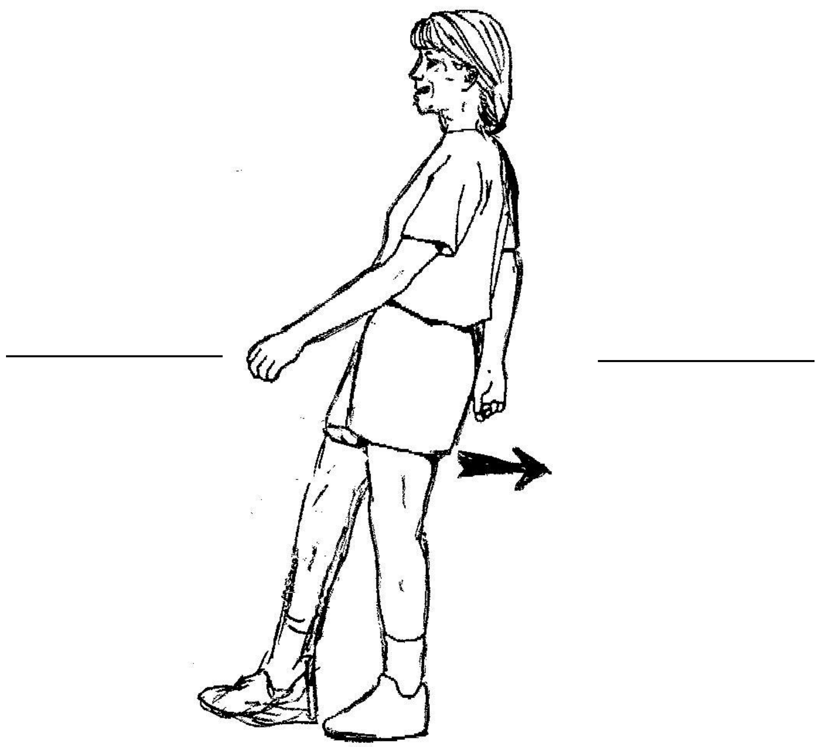
Purposes: to balance on narrow base of support.

Start position: Direct the participant

Verbal Instructions: Please stand by the counter. Visualize a straight line on the floor. Walk backward at your comfortable speed on this line for 30 steps while connecting heel-to-toes. Keep your torso and back straight.

Perform ___ sets each session; 3 sessions per week.

Progression: Gradually increase the speed of walking determined by a metronome without losing balance or tripping.



APA 9_I Sideway balance standing

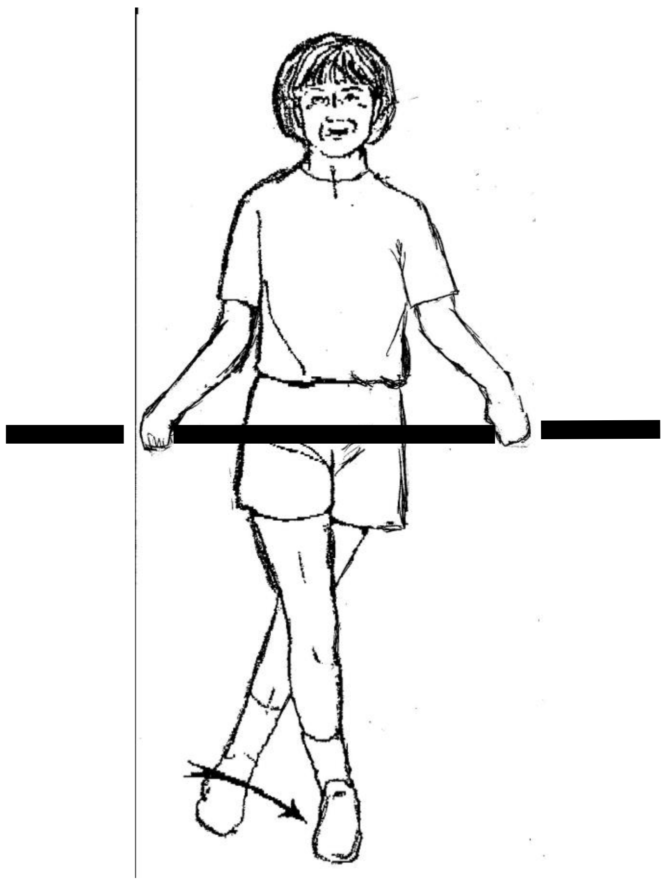
Purposes: to balance on narrow base of support.

Start position: Direct the participant stand in front of a steady counter.

Technique: Please stand in front of the counter. Visualize a straight line on the floor. Place one leg cross in front of the other, hold this position for 10 seconds. Then bring the back leg out to side, hold in this position for 10 seconds. Keep your torso and back straight. Perform alternate sides.

Perform ___ times each set, 2 sets each session; 3 sessions per week.

Progression: Gradually increase the speed of walking. Move to APA 9-II when able to perform 2 sets of 5 times easily without losing balance.



APA 9_II Walk on a straight line sideway

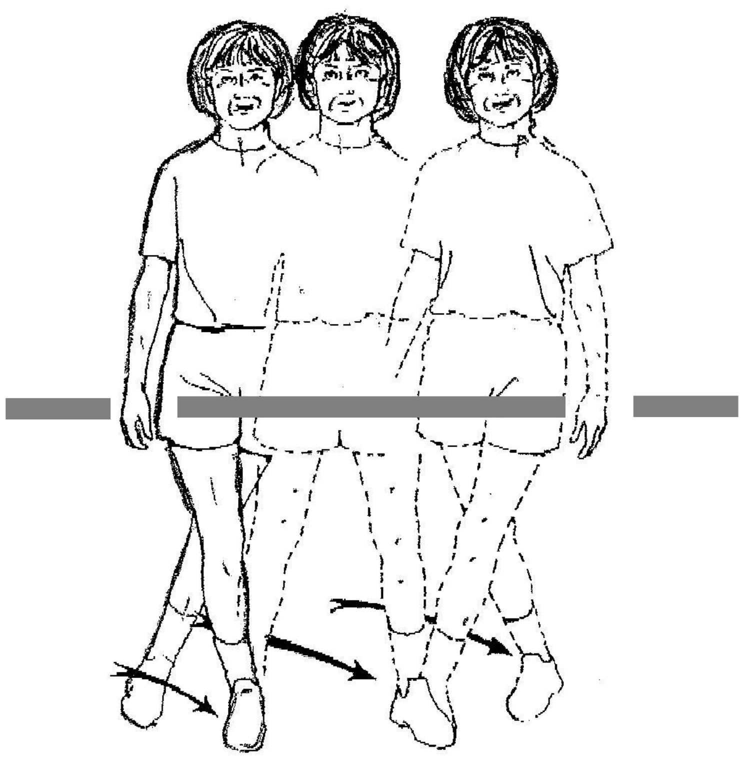
Purposes: to balance on narrow base of support.

Start position: Direct the participant stand in front of a steady counter.

Technique: Please stand in front of the counter. Visualize a straight line on the floor. Place your hands on the counter for support. Walk sideway with one leg cross in front, bring back leg out to side; then the first leg behind the other leg, and so on…; at your comfortable speed on this line for 30 steps. Keep your torso and back straight.

Perform 2 sets on both sides each session; 3 sessions per week.

Progression: Progress to APA 9_III when able to perform 2 sets each side easily without losing support or tripping with little hands support.



APA 9_III Walk on a straight line sideway

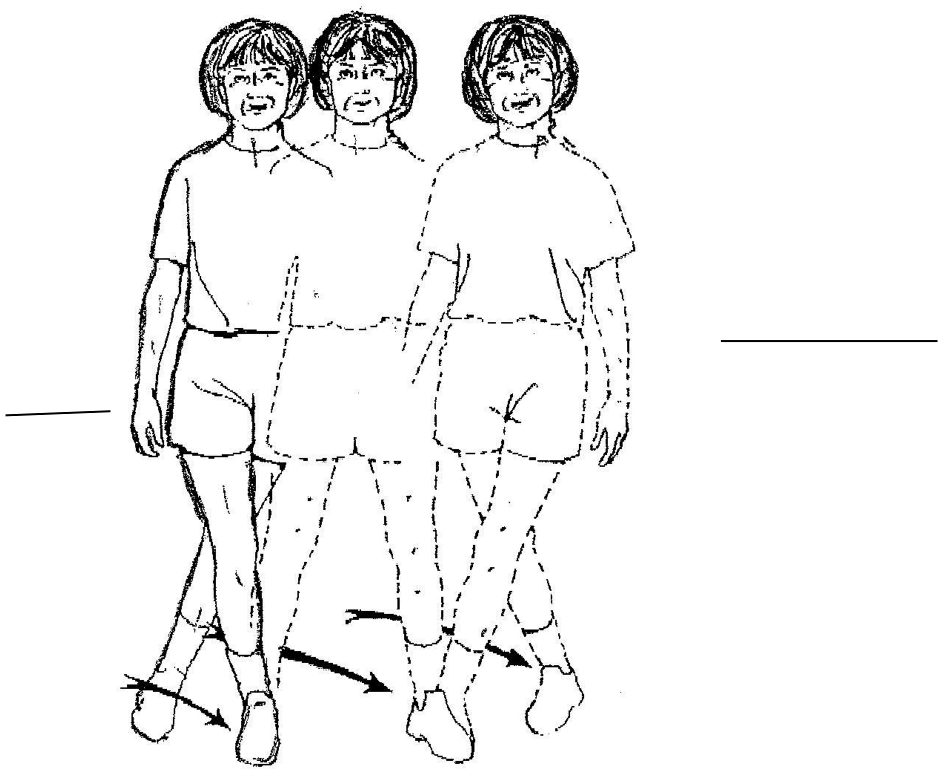
Purposes: to balance on narrow base of support.

Start position: Direct the participant stand in front of a steady counter.

Technique: Please stand in front of the counter. Visualize a straight line on the floor. Walk sideway with one leg cross in front, bring back leg out to side; then the first leg behind the other leg, and so on…; at your comfortable speed on this line for 30 steps. Keep your torso and back straight.

Perform ___ sets each session; 3 sessions per week.

Progression: Gradually increase speed of steps determined by a metronome.



VITAE

Elizabeth C Wang-Hsu, PT, MS (Formerly Che-Hsiang Elizabeth Wang)

Education:

PhD	Rehabilitation Sciences, Drexel University, Philadelphia, PA *Concentration*: Orthopedic Physical Therapy	2006-2015
MS	Orthopedic PT, Hahnemann University, Philadelphia, PA	1994-1996
BS	Physical Therapy, National Yang-Ming University, Taiwan	1988-1992

Employment and Positions Held (last 10 years):

HCR Manorcare, Douglassville, PA, Physical Therapist 2011-present

Drexel University, Department of Physical Therapy & Rehabilitation Sciences, Philadelphia, PA, Graduate Assistant 2006-Present

Main Line Health/Jefferson Homecare, Radnor, PA, Physical Therapist 2004-2010

Publications:

Full-Length Peer Reviewed Journal Articles

Wang-Hsu E, Smith, SS. Interrater and test-retest reliability and minimal detectable change of the balance evaluation systems test (BESTest) and subsystems with community-dwelling older adults. *Manuscript in progress.*

Wang-Hsu E, Horak FB, Silfies SP, Smith, SS. Using a model to prescribe impairment-specific exercises to reduce fall risk in community-dwelling older adults with fall and fracture risks: a proof-of-concept case series. *Manuscript in progress.*

Wang-Hsu E, Palisano, RJ, Silfies, SP, Horak, FB, Gracely, EJ, Smith, SS. Effectiveness of exercises to reduce specific balance impairments and fall risk in community-dwelling older adults: a randomized controlled trial. *Manuscript in progress.*

Wang CH, McClure P, Pratt NE, Nobilini R. Stretching and strengthening exercises: their effect on three-dimensional scapular kinematics. *Arch Phys Med Rehabil.* 1999;80:923-929.

Book Chapter

Smith SS, **Wang CH**, Bloomfield SA. Osteoporosis. In: Durstine JL, Moore GE, Painter PL, Roberts SO. eds. *ACSM's Exercise Management for Chronic Disease and Disability.* 3rd ed. Champaign, IL: Human Kinetics; 2009:270-279.

Honors and Awards:

Adopt-A-Doc Award, Geriatric Section, American Physical Therapy Association 2010

Florence P. Kendall Scholarship Award, Foundation for Physical Therapy, American Physical Therapy Association 2006