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Methods to assess and improve the physical parameters associated with fall risk in older adults

Michael E. Rogers, Ph.D.,[a,*] Nicole L. Rogers, MA, M.Ed.,[b] Nobuo Takeshima, Ph.D.,[c] and Mohammod M. Islam, M.D., Ph.D.[c]

[a] *Center for Physical Activity and Aging, Department of Kinesiology and Sport Studies, 1845 N. Fairmount, Wichita State University, Wichita, KS 67260-0016, USA*
[b] *Department of Psychology, 1845 N. Fairmount, Wichita State University, Wichita, KS 67260-0034, USA*
[c] *Laboratory of Exercise Gerontology, Graduate School of Natural Sciences, Nagoya City University, 1 Mizuho-cho, Mizuho-ku, Nagoya 467-8502, Japan*

Abstract

Background. Falls are common among older adults. Many physical parameters including reduced postural stability, decreased dynamic balance, gait disorders, strength deficits, difficulty standing from a chair, and other impairments have been shown to be strongly associated with fall risk in the elderly.

Assessments. To identify those at risk for falls, tools that accurately measure physical performance parameters associated with falls are essential. Several tools are available to measure these parameters including clinical evaluations, functional performance tests, and questionnaires. The article describes many of the tools that can be used to evaluate the physical parameters associated with fall risk in older adults.

Conclusions. The described instruments can help in identifying those who are most likely to fall, and those who would benefit from targeted interventions. The final part of the article includes a brief discussion of the potential role of exercise training interventions to improve these physical parameters and prevent falls.
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Introduction

Falling is the leading cause of injury-related deaths in older adults [1,2]. For those of ages 70–79 years, 27.7% of injury-related deaths are attributable to falling. This proportion increases to 46.4 and 64.8% for those of ages 80–89 years and 90–99 years, respectively [1]. Gryfe et al. [3] reported that 45% of adults over 65 years of age will experience at least one fall per year and many of these individuals will fall repeatedly. Furthermore, increasing age is correlated with an increased number and severity of falls [2].

Identifying an individual's risk for falling can be difficult because there are a variety of risk factors that must be assessed. One of the most important risk factors for serious falls is a history of falls: if a person has already had a fall, they are more likely to suffer a subsequent fall [4–10]. However, a history of falls does not explain why the fall itself occurs.

Falls often result from a variety of physiologic factors associated with the aging process, disease, medications, and/or environmental factors (Table 1). Physiological factors that have been shown to be moderately to strongly associated with the risk for falls include reduced ability to maintain a stance [7,9], increased postural sway [9–12], reduced dynamic balance [6,7,9,13], reduced walking speed [9,10,14,15], decreased mobility [6,9,10], reduced knee, hip, or ankle strength [7,9,10], and difficulty rising from a chair [7,9,10]. Any of these factors alone can lead to a fall. However, oftentimes these factors will interact, causing the stimulus for a fall [4,16,17]. As an individual becomes

* Corresponding author. Fax: +1-316-978-5451
E-mail address: michael.rogers@wichita.edu (M.E. Rogers).

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Table 1
Summary of internal (age-related deteriorations) and external (environmental) contributors to falls in older adults

Internal contributors
Reduced visual acuity, depth perception, and peripheral vision
Vestibular impairment
Reduced ability to sense touch and vibration
Reduced static and dynamic balance
Reduced walking speed
Poor mobility and gait disorders
Reduced strength of the lower extremities
Reduced reaction time
Acute illness
Chronic disease (e.g., Parkinson's disease, dementia) that affects sensory, neurological, cognitive, and muscular functions
Cognitive impairment
Polypharmacy, especially the use of four or more prescription drugs
External contibutors
Inadequate lighting brightness and placement of switches and fixtures
Lack of handrails on stairs inside and outside of home
Cords and wires on floor
Lack of grab bars around toilet and bathtub
Lack of nonslip strips on bathtub floor
Toilet seat that is too low
Polished or waxed floors
Furniture that is too low or is not sturdy
Throw rugs that are not secured
Sidewalk cracks and ridges
Ice and snow
Prosthetic and cane or walker use

increasingly frail, it takes less of a stimulus from these factors to precipitate a fall [18].

Assessing and treating the physical parameters associated with falls is a complex task. Nonetheless, a variety of assessment tools focusing on fall risk and balance performance have been developed. These tools are designed to provide objective measurement for screening, baseline status, changes over time, and the effects of interventions. Many of the available measurements were developed for research purposes and are not suitable for use with older adults because of their length, complexity, safety concerns, and/or equipment requirements. However, several tests have been successfully used with older adult populations. The increased interest in using such tests with older adults reflects the fact that limitations in physical performance may lead to falls or an inability to perform specific activities of daily living. Developing a better understanding of the physiological systems that contribute to falls is a primary way in which researchers can develop interventions which effectively reduce the risk for falls in older adults.

Assessments of the physical parameters associated with fall risk tend to have two forms: (1) observation of the participant performing an activity with a rating of performance, and (2) performance measures that are often equipment-based. There are advantages and disadvantages to each that should be considered. For example, the subjective nature of observational assessments limits the reliability of data compared to equipment-based assessments. However, equipment-based evaluations usually are more expensive because of equipment purchase and upkeep. In addition, the equipment is often not easily transportable, and thus individuals must come to the laboratory for testing.

When choosing an assessment, one must consider not only the type of assessment but must also distinguish between assessment tools that are multidimensional and those that focus on a single factor. Multidimensional tools typically assess a variety of physical characteristics and provide a summary score across all aspects of function. Oftentimes, a researcher or clinician may prefer to choose tools that focus on one, or only a few, function(s). In addition, the assessment that is chosen should be sensitive to detect clinically significant changes in performance. Many assessment instruments use categorical scales that address a restricted range of performance and may fail to detect clinically meaningful changes.

Declining balance, gait disorders, strength deficits, difficulty standing from a chair, and other impairments increase the risk of falls for older adults. To identify those at risk for falls, tools that accurately measure physical performance are essential. Many of the tools described below were selected because they are commonly used with older adults. In some cases, however, research on the tools described is still in the initial stages.

Assessments

Composite ratings of performance

Several assessments are available that combine measures of balance with measures of gait and mobility to determine a person's risk for falls. Many of these score each task subjectively on a scale (e.g., 0 = cannot perform, 1 = can perform but is noticeably unstable, 2 = can perform without hesitation) and produce a total score that represents the participant's fall risk. These assessments can typically be administered in approximately 15 to 20 min.

Guralnik Test Battery

The Guralnik Test Battery consists of three items: static balance, ability to stand from a chair, and walking speed [19]. Each item is scored on a scale of 0 to 4. Static balance is evaluated using three different, progressively more difficult stances starting with the side-by-side stance, moving to the semi-tandem stance, and ending with the tandem stance. To test the ability to rise from a chair, participants are asked to sit with their arms folded across their chests in a straight-backed chair placed with its back against a wall, and then to stand up from the chair one time. If they are successful in performing this task, they are asked to stand up and sit down as quickly as possible five times in a row. Timing starts from the signal to start and ends at the final standing position at the end of the fifth stand. For the walk speed, the participant is instructed to walk a distance of 8 feet at their normal pace using any walking aid(s) that they typically require.

Berg Balance Scale

The Berg Balance Scale contains 14 items that simulate tasks common in everyday life [20]. This test evaluates the participant's ability to perform movements of increasing difficulty. Tasks progress from a sitting position to bilateral stance to a tandem stance and then to a single leg stance. The ability to change positions is also assessed. Each task is graded on a scale of 0 to 4 and a total score of 56 can be achieved.

Tinetti Balance Assessment

The Tinetti Gait and Balance Assessment [21] includes items that address transitional skills such as sitting to standing and standing to sitting, static balance activities, and balance in response to external perturbations. The assessment also addresses gait initiation, step length and height, symmetry, continuity, and other gait variables. Each of the nine items receives a score of 0 to 2, and the final balance score is summed.

Performance measures

Static balance

Falls have been associated with a decrease in static balance, as determined by the ability to maintain a stance [7,9] and postural sway [9–12]. For example, one study looked at the difference in static balance between elderly individuals of ages 60 to 96 years who had fallen fewer than five times and those who had fallen more than five times annually. Individuals who had fallen greater than five times swayed more than those who fell fewer than five times per year [12]. Therefore, static balance may be a valuable predictor for determining individuals who are at a greater risk of falling.

Maintaining different stances. Older adults have significant decrements in postural stability when their base of support is reduced, as in single stance positions (i.e., standing on one foot). Single stance measures are important because single leg stance is used during stair climbing and walking, which both require one-foot stance 20 to 40% of the time [22].

Static balance is often evaluated using three different, progressively more difficult stances [19]: (a) *side-by-side stance*: feet side by side, touching; (b) *semi-tandem stance*: one foot placed forward with the heel in line with the toes of the other foot; (c) *tandem stance*: heel of one foot directly in front of and touching the toes of the other foot. Static balance can also be evaluated using a *One-Leg Balance with Eyes Closed Test*. The participant stands on the preferred foot while resting the hands at waist level and then raises the other foot approximately 10 cm off the floor. Balance is scored by the number of seconds for which the foot is kept raised or until balance is lost. This is repeated with the eyes closed, with the neck extended and the participant looking upward (this manipulates the vestibular system), and a combination of eyes closed and neck extended. Each leg can be tested with each condition. Timing is terminated when the subject touches the free foot to the floor, removes the hands from the hips, moves the supporting foot from the original starting position, hooks the free leg behind the support leg, or (for the eyes closed trial) opens the eyes.

Postural sway. Postural sway is a measurement of an individual's center of pressure and it is used to determine postural stability during static balance. Postural sway is determined via the use of a force plate or platform, consisting of a rigid plate with force transducers at each corner, capable of sampling three orthogonal components of force moments and applied forces [23]. The applied force and force-moment signals are used to electronically calculate an individual's center of pressure. Increased postural sway, in both amplitude and speed, is associated with increased postural instability and may be associated with a greater risk for falling.

Static balance measures are often taken while the subject stands on different surfaces with the eyes open or closed. The surfaces may include standing on the platform directly or standing on a thick (e.g., 12 cm high) piece of foam. The Clinical Test of Sensory Interaction for Balance (CTSIB) is one test of postural sway that is designed to measure the influence of sensory input on balance [24]. This requires the participant to stand (a) on a flat surface with the eyes open; (b) on a flat surface with the eyes closed; (c) on thick foam with the eyes open; and (d) on thick foam with the eyes closed. The force platform is marked to maintain consistency in foot placement. For each stance, the participant stands with their eyes at the horizon and their arms at the sides in a neutral position. An anthropometric kit can be used to measure the standing height, foot length, and foot width of each participant. This information can be used later to express the results relative to the height and base of support of each participant. Trials typically require 10 s of data collection. A trial is considered unsuccessful if the participant takes a step or is unable to balance for the required time period without aid from a spotter. Using the X and Y coordinates determined on the force platform, Excel worksheets can be used to calculate the sway index, amplitude (anterior–posterior and median–lateral direction), XY area, radial area, maximum instantaneous speed, and mean instantaneous speed.

Dynamic balance

Dynamic balance is the ability to anticipate changes and coordinate muscle activity in response to perturbations of stability. Dynamic balance is also used during forward, sideways, and backward leaning. Static balance is maintained in the elderly until significant functional declines occur, while losses in dynamic balance occur much earlier

[25]. Dynamic balance tests stress the balance control systems and therefore greater losses in balance are typically seen during these types of tests. Oftentimes, dynamic tests are performed with static balance tests.

Functional reach. Dynamic balance can be evaluated using the Functional Reach Test [26]. Functional Reach is the maximal distance an individual can reach forward beyond arm's length while maintaining a fixed base of support in the standing position. A functional reach scale (or measuring ruler) is hung from a wall at a height just below shoulder level. The participant stands by the wall with the feet placed together, raising the arms and holding the tips of the clasped hands at the 0-cm level of the scale while keeping the arms straight and horizontal. On a signal, the participant moves the hands forward along the scale as far possible while keeping the heels in contact with the ground. Performance is assessed as the maximal distance the participant can reach forward beyond arms' length. A tester is always ready to help prevent falls or any other injury.

A limitation of the test is that it only measures dynamic stability in one direction. Many activities that put older adults at risk for falling involve movements in the lateral direction and outside the stability limits. To overcome this limitation, functional reach in multiple directions is sometimes used.

Limits of stability. Limits of Stability is a relatively new measure used to determine the maximum distance a person can lean in a given direction without stepping, losing balance, or reaching for assistance [27,28]. As the limits of stability decrease, so does the area of support used to sustain balance during dynamic activities, such as leaning forward, backward, and sideways. Therefore, a reduction in limits of stability increases the risk for an individual to be in a situation in which his or her balance is destabilized outside the individual's area of control, resulting in a fall.

During the assessment, the individual stands on a force platform facing a computer monitor. The monitor displays a central box with eight targets in an elliptical pattern surrounding the central box. These targets represent the individual's estimated limits of stability (based on their height). The eight targets are displayed on the computer screen at 0, 45, 90, 135, 180, 225, 270, and 315 degrees. The participant's center of gravity appears as a human-shaped cursor on the computer screen, which moves freely with the participants as they shift their weight. To initiate each trial, the participant is instructed to adjust and then maintain the human-shaped cursor in the center box. Upon hearing an auditory signal from the computer, the subject moves toward the highlighted target in a straight line, as fast as possible, and holds the position for 5 s. Targets are highlighted sequentially in a clockwise manner.

The test provides information regarding the individual's postural control as indicated by the initial shift toward the target (end point excursion), and the actual extent of the movement (maximum excursion). Information is also provided regarding the quality of the movement as indicated by the speed of movement (movement velocity) and a comparison of the amount of movement in the intended direction toward the target and extraneous movement away from the target (directional control). Lower time values and straighter path movements are indicators of better performance and control of balance. The amount of time from the auditory signal until movement is initiated (reaction time) is also calculated.

Only a few studies have looked at limits of stability and how they change with age. Hageman et al. [28] compared limits of stability values in a group of elderly and young adults and found that young adults performed the timed portion of the limits of stability tests significantly faster than the older adults. They also found that older adults had far less path accuracy in reaching the targets than did young adults. Accuracy and speed are both required for postural response and any reduction in speed and accuracy contributes to a reduction in one's ability to maintain postural control.

Walking velocity and mobility

Reduced walking velocity [9,10,14,15] and limited mobility [6,9,10] have been identified as risk factors for falls. Walking and mobility impairments in older adults are common. Cross-sectional studies indicate that gate speed declines at a rate of 12 to 16% per decade after the age of 60 [14]. It has been estimated that at least 8% of noninstitutionalized elderly U.S. residents, or an estimated 2.2 million people, have difficulty walking or require the assistance of another person or assistive devices to walk [15]. Limited mobility is often associated with nursing home placement, and as many as 63% of institutionalized elderly have problems with mobility [29]. Furthermore, slower gait speeds have been reported in individuals who sustained multiple falls [30,31].

Walking velocity. Timed walks of short length (e.g., 8 feet, 10 m) are simple measures of self-selected walking speed which is a good predictor of function and overall physical performance [9,10,14,15]. The walking distance is measured with a tape measure and marked with tape on the floor. Three meters both ahead and at the end of the distance are generally measured and marked to allow the subject enough distance to accelerate and decelerate. The participant is instructed to walk at their normal pace using any walking aid(s) that they typically require. The time is measured to the nearest one-hundredth of a second using a digital stopwatch. Timing begins when the subject crosses the start line and ends when the first foot crosses the finish line. The subject performs one practice trial and three test trials to determine self-selected gait velocity which can be expressed in feet per second or meters per second. Measures of gait speed are very simple to perform, and require only a stopwatch and a measuring tape. The test can also be re-

Fig. 1. Rogers modular obstacle course used to develop balance and mobility in older adults.

peated at the participant's maximum pace to determine the walking speed reserve.

8-Foot Up-and-Go. The purpose of the 8-Foot Up-and-Go Test assessment is to measure physical mobility involving speed, agility, and dynamic balance [32]. The test begins with the participant fully seated in the chair, hands on thighs, and feet flat on the floor. The participant is allowed to push off the sides or arms of the chair to aid in getting up from the chair. On the signal "go", the participant is instructed to stand up from the chair as quickly as possible, walk around a cone placed 8 feet in front of the chair, and return to a seated position in the chair. The participant is told that the test is timed and that the object is to walk around the cone as fast as possible (without running) and return to a seated position. A timed score is recorded to the nearest 0.1 s from the time the signal "go" is given until the participant returns to a seated position in the chair. The participant is allowed to walk through the test for practice. The participant's score is recorded as the best of the two most consistent times measured.

Walking around Two Cones Test. The purpose of the Walking around Two Cones Test [33] is similar to the 8-Foot Up-and-Go Test. The test starts with the participant sitting in a straight-backed chair located between a cone placed 1.8 m to each side of the chair. On a signal, the participant rises from the chair, walks around the cone on the right side of the chair (going to the inside and around the back of the cone, or counterclockwise), and returns to a fully seated position on the chair. Without pause, the participant walks around the other cone (clockwise) and returns to a fully seated position. One trial consists of two complete circuits. Performance time is recorded in units of 0.1 s. The test is performed three times and the fastest time is used for analysis.

Rogers modular obstacle course. We have developed a modular obstacle course to assess mobility [34], modified from that previously described by Means [35]. The course consists of nine stations where common functional conditions encountered in a general environment are presented (Fig. 1). The stations are designed to challenge different balance and mobility related strategies. The nine stations, in order of appearance, are (1) walking across a 2 foot × 12 foot piece of low-pile carpet, (2) stepping over four foam props (two are 2 × 2 inches and two are 4 × 4 inches), (3) walking across a 2 × 12-foot piece of deep-pile carpet, (4) walking up and descending two stairs (each 6 inches high, painted with white and black checkers to challenge the visual system), (5) walking across a 12-foot piece of upholstery foam that is 2 inches thick, (6) slalom walking through six plastic cones positioned 24 inches apart, (7) walking across a 12-foot piece of upholstery foam that is 4 inches thick, (8) walking up and down a ramp, and (9) climbing and descending four stairs (each 8.5 inches high). The modular stations are presented in order of increasing difficulty. Participants complete one practice trial to familiarize themselves with the course prior to the testing trial. Participants are instructed to walk through the course as quickly as they can. To reduce the risk of injury, every participant wears a gait belt that is held by a research assistant during the test.

Performance on the course is videotaped with a digital video recorder and the videotapes are reviewed following testing to determine the time to complete the entire course as well as the time to complete each individual task. The on-screen timer of the recorder is used to quantify all station time scores to the nearest 0.01 s. Individual station times are determined by identifying the point where the task was started (e.g., stepping onto the ramp) and the point where the task was completed (e.g., stepping off of the ramp). The time to walk from one station to the next is only included in the total time to complete the entire course.

Qualitative scores are also determined by the presence or absence of apparent difficulty with mobility during performance of the tasks, according to specific criteria. A 0- to 3-point ranking, ranging from "unable to complete the task without assistance" (0 points) to "no observed difficulty or unsteadiness while performing the task" (3 points), is made for each of the tasks.

Muscle strength

Reduced muscular strength is another important factor that contributes to falls [7,9,10]. All body movements are produced via contraction of skeletal muscles and strength deficits may contribute to impaired balance in older adults and increase their risk of falling. Muscular strength and mass have been shown to decrease with age [36]. As muscle strength deteriorates, the ability to perform activities of daily living, such as performing housework and carrying groceries, declines. Furthermore, reduced strength has been reported to have a significant deleterious effect on gait function and mobility [37–39], both of which are commonly limited in older populations. Jette and Branch [40] reported that 23% of older adults of ages 75–84 years had difficulty walking, while 55% had trouble crouching, kneeling, and stooping. Further evidence regarding the association between strength and fall risk is provided by Wolfson et al. [41], who reported that lower extremity strength of elderly individuals who suffered a fall was 47.9 to 61.3% less than in older adults who had not fallen. It has also been reported that lower leg and ankle dorsiflexor strength were 30 and 39% lower, respectively, in those who suffered five or more losses of balance during dynamic platform tests compared to those who lost their balance fewer than five times [42]. In the same study, greater muscle strength was associated with a 20% decrease in the odds of suffering a loss of balance while performing dynamic balance tests [42].

One-Repetition Maximum. Muscle strength is often measured as the force generated during a maximum voluntary contraction. For several reasons, the One-Repetition Maximum (1RM) Test is typically used to measure strength in the research setting. One advantage is that this test is more specific to the type of training subjects would most likely perform to enhance strength levels. The test provides values reflecting the absolute amount of weight that can be lifted, so test values are often more meaningful to subjects. Additionally, the 1RM test is representative of the strength needed to perform functional tasks such as moving heavy objects.

In aging research, 1RM testing is typically not performed unless there is a strength training program involved because there are some associated disadvantages. Some have reported higher rates of injuries during 1RM testing than during the training program [43], while others have concerns regarding the difficulty in establishing objective testing criteria [44]. Furthermore, 1RM performance can require more motor learning than other testing modalities, which could affect test reliability.

After formal instruction in the use of weight-training equipment, participants should perform each exercise several times at a low resistance to ensure proper warm-up and familiarization. All exercises are repeated with weight increments of 0.25 to 25.00 pounds until failure occurs despite verbal encouragement. Failure is reached when the participant fails to lift the weight through the entire range of motion on at least two attempts spaced 45–60 s apart. Lifts are discounted if the participant utilizes momentum or changes body position in a manner not directly related to the movement of the weight during the exercise motion. To stabilize the body, subjects are typically allowed to grasp handles that are attached to the seat. To minimize fatigue resulting from repetition, each test should begin at a weight near a predicted maximum and the 1RM should be identified with fewer than six repetitions. Likewise, approximately 45–60 s of rest should be given between repetitions.

Isokinetic dynamometery. Isokinetic dynamometers provide information on muscle dynamics throughout the full range of extension and flexion that may provide a more functionally relevant profile of muscle contraction properties than 1RM tests [45]. These dynamometers are accommodating resistance devices that permit contraction at a constant speed (e.g., 30°/s, 60°/s, 180°/s, and 240°/s) regardless of the amount of torque generated by the subject. These devices can provide better isolation of muscle groups and allow a more objective criterion than the 1RM test. Peak torque, total work, strength ratios of opposing muscle groups, and fatigue ratios can be determined using a computer interface.

30-Second Chair Stand. The purpose of the 30-Second Chair Stand Test is to measure lower body strength without large, expensive equipment [32]. The test begins with the participant seated in the middle of a chair, back straight, and feet approximately shoulder width apart and flat on the

Fig. 2. Older adults using Stability Trainers to improve balance during a community-based exercise program.

floor. The arms are crossed and held against the chest. At the signal "go," the participant rises to a full standing position (body erect and straight) and then returns back to the initial seated position. The participant is encouraged to complete as many full stands as possible within a 30-s time limit. Participants are given two or three practice repetitions. The score is the total number of stands executed correctly within 30 s. If the participant was more than halfway up upon completion of the 30 s, it is counted as a full stand.

Interventions

A variety of physical activity (i.e., exercise) programs have been used to improve the physical parameters associated with fall risk. The benefits of regular physical activity for older adults have been extensively documented in the scientific literature [46]. Regular exercise is associated with many health-related improvements within this population. For example, physical activity can reduce or prevent the need for medical treatment, or it can be an important addition to medical treatment. Furthermore, regular physical activity improves the functioning of the cardiovascular, respiratory, metabolic, endocrine, and immune systems. By doing this, it greatly reduces risk factors associated with coronary artery disease, and may also prevent the development of, or effectively treat, diseases such as non-insulin-dependent diabetes mellitus, osteoarthritis, osteoporosis, obesity, colon cancer, peripheral vascular occlusive arterial disease, arthritis, and hypertension. Regular physical activity also reduces body fat stores, increases muscle strength and endurance, strengthens bones, and improves mental health. Many of these benefits may have a positive, albeit indirect, effect on balance in older adults.

Several studies have examined the effects of general exercise programs on balance. For example, Cress et al. [47] randomly assigned older adults to a control or combined (aerobic and strength exercise) group and observed no changes in balance measures in either group upon completion of a 6-month training program. In another study, static balance on one foot with eyes closed was significantly improved in older adults following a 1-year training program consisting of back extension exercises, strength training, and flexibility/relaxation exercises [48].

Other studies have utilized more balance-specific training programs. One study divided older adults into a flexibility-only group and a combined group engaging in resis-

Table 2
Summary of tests to assess fall risk

Composite ratings of performance
Guralnik Test Battery
Berg Balance Scale
Tinetti Balance Assessment
Rogers Modular Obstacle Course (qualitative score)
Performance measures of balance
Maintaining Different Stances
○ Feet together
○ Semi-tandem,
○ Tandem
○ One foot
Functional Reach
Limits of Stability
Performance measures of mobility
Walking Velocity
8-Foot Up-and-Go
Walking around Two Cones Test
Rogers Modular Obstacle Course
Strength measures
One-Repetition Maximum
Isokinetic Dynamometery
30-Second Chair Stand

tance exercises, brisk walking, flexibility, and postural control tai chi exercises. Significant improvements in single-leg stance were observed in the combined group, whereas no changes were observed in the flexibility group after 6 months of training [49]. Wolfson et al. [50] assigned elderly adults into four different training groups: a strength training group, a balance training group, a balance plus strength training group, or an educational control group and evaluated changes in single-stance balance, strength, and loss of balance measures before and after 3 months of training. Loss of balance was significantly less in the balance group than in the control, strength training, and balance plus strength training groups. Both the balance and balance plus strength groups showed significant improvements in single-stance time after 3 months of training.

Hu and Woollacott [51] studied the effects of ten, 1-h multisensory training sessions, consisting of balance training on a firm or foam support surface with eyes open or closed and head neutral or extended 5 times for 10 s each, on balance in older adults between the ages of 65 and 90 years. The subjects had significant improvements of postural sway while standing on foam and on a firm support with eyes closed and/or head extended in the training group compared to the control group. Older individuals in the training group significantly improved their ability to stand on one foot with eyes open or closed up to 4 weeks upon completion of the training program. Kronhed et al. [52] studied the effects of a 9-week multisensory balance training program which included balance tasks (e.g., jogging around a chair, moving the head side to side, walking four steps backward), dance steps, ball exercises (e.g., throwing, bouncing, and catching balls in various directions), balance board, trampoline, balance-ball, and many other exercises in adults of ages 70 to 75 years. Participants in the exercise group showed significant improvements in single-leg stance with eyes closed, single-leg stance with head rotation, and the 30-meter walk compared to the control group.

We have evaluated the effects of a 10-week program, utilizing Thera-Band exercise balls (inflatable balls that are ~55 cm in diameter), on balance in adults 61 to 77 years of age [53]. Postural sway (medial–lateral amplitude, speed of sway, and instantaneous speed) was significantly reduced when subjects stood with the feet apart and in the semi-tandem position with the eyes open and closed. Dynamic balance was measured via functional reach, which improved by 20.3%, after the 10-week Thera-Band exercise ball program.

Recently, we completed a 12-week program utilizing 16 × 9 × 2-inch elliptical-shaped foam pads (Thera-Band Stability Trainers) and strength-training exercises using elastic bands in a community senior center [54]. While standing behind a chair and holding the back of the chair for support, participants performed exercises such as standing with one foot in front of the other or standing on one foot. Participants were instructed to shift their body weight from foot to foot and to lift the feet from the floor. They also closed the eyes and/or moved the head to target the visual and vestibular systems, respectively. To increase the difficulty of these exercises, and to target the somatosensory system, the participants performed the exercises while standing on the foam pads (Fig. 2). To enhance muscular strength, participants performed a series of exercises using elastic bands while sitting in chairs. Improvements were observed for the Limits of Stability in the directions that are most associated with falls that result in hip fracture [55], namely the right, left, and back directions. In the right/back direction, the end-point excursion improved by 67.2% and the maximum end-point excursion improved by 27.8%. In the left/back direction, the end-point excursion improved by 66.7% and the maximum end-point excursion improved by 23.4%. In the back direction, the end-point excursion improved by 77.1% and the maximum end-point excursion improved by 63.4%. In addition, both upper and lower body strength improved. The number of times a person could stand from a chair in 30 s increased by 17.1% (from 10.5 to 12.3 repetitions). No changes were observed in any of the balance or strength variables for the control group.

The use of exercise balls, stability trainers, tai chi, and the performance of other balance-specific tasks appears to improve balance in older adults. It is likely that these training programs are effective because they target the specific physiological systems involved in balance control, specifically the visual, vestibular, somatosensory, and musculoskeletal systems. Such training may be more effective in improving balance than general exercise programs or those consisting of only aerobic, strength, or flexibility exercises.

Conclusions

The assessment tools summarized in this article cover several aspects of fall risk, including balance, mobility, and strength (Table 2). In general, these assessments are easy to conduct and widely used. Careful selection and use of assessment tools can greatly assist in identifying those individuals who are at risk for falling. Several exercise-based strategies exist to improve the physical parameters associated with fall risk. However, additional strategies are needed to target physical deficits that place older adults at an increased risk for falls.

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