
Defining and Measuring Balance in Adults

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The ability to maintain balance is often taken for granted, yet it is the foundation for mobility and overall functional independence throughout the life span. The purpose of this article is to define balance, review the components of balance, and describe common instruments used to measure balance. Clinical screening instruments, functional performance tests, and technological measures of balance are reviewed addressing their uses, strengths, and limitations.

Key words: Balance, balance assessment, postural balance

The ability to maintain balance is often taken for granted, yet it is the foundation for mobility and overall functional independence throughout the life span. Because aging is associated with a decline in the ability to maintain balance (Horak and others 1989; Wolfson 1997), the efforts of scientists to understand the multiple factors contributing to balance takes on added significance as the population shifts toward the senior age group.

Balance problems occur most frequently among the elderly, with approximately one-third of elders 65 years or older falling each year (Howland and others 1998; Tinetti and others 1988). Frail elderly fall more frequently and incur more serious injuries than any other adult group (Speechley and Tinetti 1991). An estimated 40% of all nursing home admissions are related to instability and falls (Rawsky 1998). Falls can result in permanent reduction in function, loss of independence, and death in this age group. Additionally, the psychological consequences of limited balance can have debilitating effects on elders' mental and physical health as manifested by loss of confidence in performing physical tasks, loss of self-esteem, feelings of vulnerability, and fear of future falls (Iverson

and others 1990; Tinetti and others 1990). With the estimated annual cost of physical frailty rising to over \$132 billion by 2030 unless disability rates are lowered (Rikli and Jones 1997), a major health concern is to delay or prevent disability in the performance of activities of daily living of older adults.

Balance research in the nursing literature has primarily focused on patient falls and exercise interventions to decrease falls. Few nurses have studied balance and its components, yet balance is clinically important in multiple populations—older adults, children, and individuals with developmental disabilities, sports injuries, brain injury, and neurological and/or neuromuscular dysfunction. The purpose of this article is to define balance, review the components of balance, and describe common clinical screening instruments, functional performance tests, and technological measures of balance.

Definitions of Balance

Balance can be simply defined as the ability to maintain the body's center of gravity within the limits of stability as determined by the base of support (Alexander 1994; Horak 1987; Nashner 1997c, 1997d; Woollacott and Shumway-Cook 1997a). The *center of gravity* of an object is the single point at which we can compute the gravitational torque for the object as if gravity were acting at that point (Colletta 1995, 127-242).¹ In humans, the center of gravity is located in the pelvis (Nashner 1997c). Biomechanically, the *limits of stability* of an individual are the sway angles, which, if exceeded, will place the center of gravity outside the base support (Nashner 1997c). The range of the limits of stability includes approximately 12.5 deg

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of body sway in the anterior-posterior plane and 16 deg in the lateral plane. Moving outside of these limits results in falling (Nashner 1997d). During standing, the *base of support* is the area contained within the perimeter of the area of contact between the feet and the support surface (Nashner 1997c).

Balance can also be categorized based on overall body position and/or neuromuscular response to a destabilizing event; thus, it is necessary to broaden that definition to include static, dynamic, and reactive components. A destabilizing event is any event that may cause a loss of balance including an external shove or self-initiated rapid movement (Duncan and Studenski 1994). *Static balance* is defined as the ability to maintain the center of gravity within a base of support in a quiet upright position during standing or sitting. *Dynamic balance* involves maintaining an upright posture while (a) the center of gravity and base of support are moving and (b) the center of gravity is moving outside the base of support (for example, in walking) (Woollacott and Tang 1997b). *Anticipatory balance control* are actions taken in preparation for a potential destabilizing event (i.e., preparing for the forward motion of a bus). *Reactive balance control* in contrast is a response to an external disturbance in stability. Maintaining *functional balance control* to perform activities of daily living then usually involves elements of both anticipatory and reactive balance control (for example, carrying groceries while climbing stairs).

Components of Balance

The current view of balance is based on a systems model (Nashner 1997c; Shumway-Cook and Woollacott 1995). Prior to this, the prevailing model for 50 years had been the view of balance as a neurological reflexive function based on the work of neurophysiologist Sir Charles Sherrington in the early 1900s (Shumway-Cook and Woollacott 1995). The systems model of postural control views the body as a mechanical system with mass, subject to forces like gravity and internal forces. The nervous system, muscles, joints, reflexes, skeletal system, gravity and inertia, sensory input (vision, vestibular, and proprioception), central processing time, and learned strategies all function to maintain balance within an environment (Shumway-Cook and Woollacott 1995) (see Fig. 1).

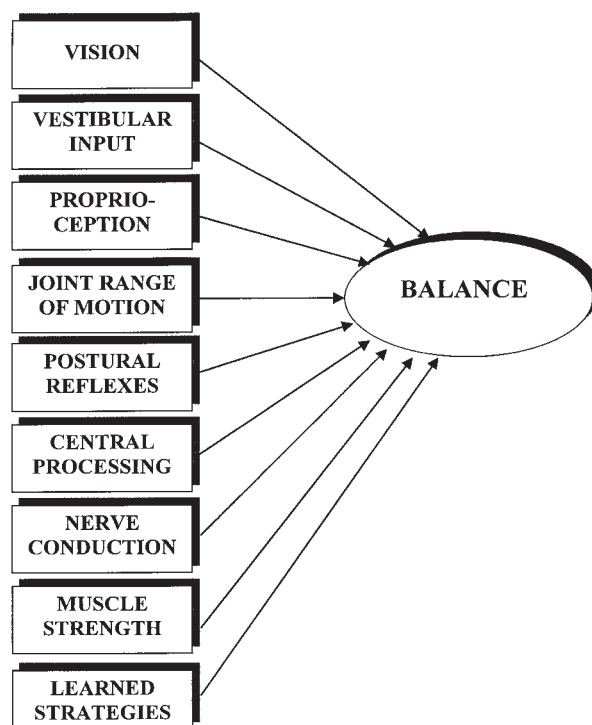


Figure 1. Model of components of balance control.

The central nervous system maintains balance by continuously monitoring input from sensory systems and regulating corresponding automatic and voluntary adjustments in motor output. One's balance capability can thus fluctuate from hour to hour depending on attention to task, prior experiences, and/or medications, to mention but a few factors. As a result, balance assessments cannot be expected to be as consistent as two samples of serum glucose drawn 10 min apart. It is the interaction between systems and ability of the systems to compensate for each other in maintaining balance that makes balance retraining possible.

Sensory inputs arising from the visual, vestibular, and proprioceptive/somatosensory systems frequently provide redundant information on balance control. The relative priority that each system receives in situations where input is contradictory varies according to age and context (El-Kashlan and others 1998). In automatic reactions, proprioceptive stimuli from the ankles normally take precedence over opposing visual information in healthy adults (El-Kashlan and others 1998; Horak 1987; Kristinsdottir and others 1997; Nashner

1997d). Young children who are learning to stand are more dependent on vision than are young adults (Woollacott and Shumway-Cook 1990). The brain then uses these sensory inputs to organize the appropriate motor responses involving movements of the ankle, knee, leg, and trunk to maintain balance control against the forces of gravity. Increased postural sway in conditions where the subject is instructed to stand quietly is assumed to represent poor balance or decreased stability (Panzer and others 1995).

When a person's balance is disrupted, muscle strength, past experience, and size and stability of the base of support are some factors that determine the various strategies (ankle, hip, stepping) used by an individual to move the center of gravity back to a stable position (Guskiewicz and Perrin 1996). There are stereotyped muscle patterns called "synergies" that occur with disturbances to equilibrium (Horak and others 1997). Maintaining balance depends on adequate muscle strength and nerve function, both of which are capable of improvement. Strength can be improved by resistance training (Kraemer and others 1998; McArdle and others 1996). Nerve function (i.e., the recruitment of muscles) can be improved through biofeedback and the use of sensory stimulation (Horak and others 1997; Perrin and others 1997).

Common Assessments of Balance

Because of the complex nature of balance, multiple measurement protocols have been developed to characterize its various components (Duncan and Studenski 1994). Practically, balance assessments may be simple and easy to administer or more sophisticated and time consuming. Balance assessments should, however, be selected depending on the intended use that may range from a screening test to a diagnostic balance evaluation to balance retraining and/or research on mechanisms of balance control.

As noted above, a comprehensive balance assessment should include measures of both static and dynamic balance, regardless of whether it is intended for clinical or research use. Using a single protocol designed for a diagnostic assessment may have limitations because only a few components of the balance system are being assessed. For example, one-legged stance tests altered somatosensory input and de-

creased base of support, but visual input and conditions requiring different balance strategies were not tested (Horak 1987). Clinical and performance assessments of balance provide a quick screening and are practical and easy to administer. In the past 25 years, quantitative assessments of balance based on computerized technology have been developed that can assess and train individuals in balance control. The balance tests discussed in this article were chosen to illustrate the wide range that is available depending on the intended purpose of testing. Only computerized systems manufactured in the United States and commercially available were reviewed because they are encountered most frequently in clinical and research settings.

Clinical Screening and Functional Performance Measures of Balance

The classic assessment of static balance is the Romberg test, which remains the most well-known measure of balance since Romberg introduced its use in 1853 (see Table 1) (Romberg 1853). A variant of the Romberg test is the Sharpened Romberg that measures static balance with a narrowed base of support. The subject stands barefoot with feet in tandem (heel to toe, with dominant foot in front), arms folded across the chest, and eyes open. The test is repeated with eyes closed. The score is the number of seconds the subject is able to maintain the position up to 60 seconds. Although the Sharpened Romberg has been reported to have good interrater reliability and test-retest reliability (Franchignoni and others 1997), one study concluded performance of the Romberg is too variable to develop age-based normative scores especially for subjects younger than 20 or older than 50 years old (Black and others 1982). We conclude that this classic test and its variant should be used cautiously and certainly not as the only measures of balance. Reliability should be investigated at the onset of use to determine its robustness as a balance measurement.

More recently, the timed one-leg stance, that is, how long an individual can stand on one leg, has gained popularity as a static test and is often used in the elderly population (Vellas and others 1997). Both the Romberg and the one-leg stance tests show wide variability in performance, especially in the elderly population where many healthy elders are unable to stand on one leg. In addition, comparisons of scores between

Table 1. Clinical Screening and Functional Performance Measures of Balance

Test	Description	Method	Response/Scoring	Reliability/Validity
Romberg ¹	Static balance	Stand with feet close together, EO and EC	Response scored objectively as number of seconds or subjectively as 1) Steady position with only slight swaying 2) arts to fall, needs assistance to keep erect	Reliability and validity not established due to variability in performance ²
Sharpened Romberg ^{3,4}	Static balance	Stand with feet heel to toe, EO and EC	Response scored objectively as number of seconds or subjectively as 1) Steady position with only slight swaying 2) Starts to fall, needs assistance to keep erect	Test-retest reliability: ⁴ 0.90-0.91 EO 0.76-0.77 EC Interrater reliability: 0.99 EO and EC Validity: Does not predict falls
Timed one-leg stance ^{3,4}	Balance over a narrow base of support Clinical screen for low functional level	Subject stands on one leg EO and EC	Response is scored as 1) Steady with one-leg stand 2) Unable to maintain stance for 5 seconds	Test-retest reliability: ^{4,5,6} 0.90-0.91 EO 0.74-0.75 EC Interrater reliability: 0.99 EO and EC Validity: poor
Sternal shove or nudge test ³	Reactive balance	Subject stands with feet close together. Examiner pushes with light even pressure over the sternum three times.	The response is graded using a 0-2 scale: 0 = Starts to fall, needs assistance, 1 = Maintains balance with feet movement, 2 = Stance remains steady	Reliability and validity not established ³
Postural Stress Test (PST) ^{3,7}	Motor response to postural perturbations of varying force	Pulley weights secured to the waist produce a destabilization force. Graded destabilization forces cause subject to rapidly correct the displacement to remain standing	Two response measures are 1) Number of trials with an effective balance response (ability to prevent a fall) 2) Balance strategy score based on a 9-point grading scale, ranges from 0 to 23, with higher scores indicating better balance (appropriateness of the response) Poor performance is associated with falls	Test-retest reliability: ^{3,7,8,9} — Interrater reliability: 0.83-0.99 Validity: +Predictive validity
Clinical Test of Sensory Integration of Balance (CTSIB) or "foam and dome" ¹⁰	Sensory interaction on static balance	Subject maintains standing balance	Scoring may include 1) numeric ranking of sway 2) time standing 3) plumb line with grid Instability suggests a sensory problem Not sensitive to pathology	Test-retest reliability: ^{5,10} 0.99 Interrater reliability: 0.68-1.0 Validity: Some predictive validity
Functional Reach test ^{3,11}	Anticipatory balance control with anterior movement	Subject makes a fist while extending arm forward at 90 deg from trunk (position 1) Baseline measurement is recorded using a leveled yardstick attached to the wall. Subject reaches as far forward as possible without taking a step (position 2) The distance between	Compared to subjects who reach greater than 10 inches, subjects who reach 1) 6 to 10 inches were 2 times more likely to fall 2) less than 6 inches were 4 times more likely to fall 3) unable to reach were 8 times more likely to fall	Test-retest reliability: ^{4,5} 0.86-0.88 Interrater reliability: 0.96-0.97 Validity: Correlated to walking speed ($r = 0.71$), tandem walk ($r = 0.71$), mobility skills ($r = 0.65$), one-legged stance ($r = 0.64$), and center of pressure ($r = 0.71$) +Predictive validity

Table 1 Continued

Test	Description	Method	Response/Scoring	Reliability/Validity
Get-up-and-go test ^{3,12}	Functional balance	position 1 and position 2 is the functional reach score. Stand up from a chair, walk 10 feet, turn around, return and sit.	Scores range from 1 to 5. 1 = normal 2 = very slightly abnormal 3 = mildly abnormal 4 = moderately abnormal 5 = severely abnormal A score of 3 or higher indicates increased risk for falls	Interrater reliability: ^{3,12} Kendall coefficient = 0.85, $df = 9$ Validity: Correlated to sway path ($r = 0.50$) Test-retest reliability and predictive validity have not been reported
Timed get-up-and-go test ^{3,13}	Functional balance	Same performance as above Record time required to perform activities	Scoring: Less than 10 s = independent in balance and movement skills Greater than 15 s = at increased risk for falls	Test-retest reliability: ^{8,13} 0.99 Interrater reliability: 0.99 Validity: +Predictive validity
Tinetti's Performance-Oriented Assessment of Mobility ^{3,14}	Functional balance	15-item performance-based scale measuring gait and balance	Scored as normal or abnormal Total score less than 19 indicates high risk for falls, 19-24 indicates a greater risk for falls	Test-retest reliability: ^{5,14} Not reported Interrater reliability: 0.85 $\pm$ 10% Validity: Correlated to Berg Balance Scale ($r = -0.91$), stride length ($r = 0.62$ -0.68), and one-legged stance ($r = 0.59$ -0.64) +Predictive validity
Berg Balance Scale ³	Functional balance	Performance-based scale with 14 items that examine functional movements during daily life.	Total score less than 50 predicts falls (sensitivity = 91%, specificity = 82%)	Test-retest reliability: ^{5,15,16} Not reported Interrater reliability: 0.98 Internal consistency: 0.96 Validity: Correlated to Tinetti Balance Test ($r = 0.91$), Timed "Up and Go" ($r = -0.76$), and Barthel Index of ADL (an estimate of functional capacity, $r = 0.67$) +Predictive validity

NOTE: EO = eyes open; EC = eyes closed.

1. Romberg (1853).

2. Black and others (1982).

3. Duncan and Studenski (1994).

4. Franchignoni and others (1997).

5. Whitney and others (1998).

6. Vellas and others (1997).

7. Wolfson and others (1986).

8. Chandler and others (1990).

9. Hill and others (1990).

10. Shumway-Cook and Horak (1986).

11. Duncan and others (1990).

12. Mathias and Mayak (1986).

13. Podsiadlo and Richardson (1991).

14. Tinetti (1986).

15. Berg and others (1992).

16. Shumway-Cook and others (1997).

raters can be problematic if the evaluation is subjective. Furthermore, the static nature of the tests is not reflective of conditions that challenge balance (Duncan and Studenski 1994; Guskiewicz and Perrin 1996) nor those that result in falls, since the majority of falls occur during movement such as walking or position changes (Berg and others 1997).

Other clinical tests have been designed to evaluate an individual's ability to maintain balance when stability is disrupted. The Sternal Shove and the Postural Stress Test (PST) are typical of this group (see Table 1). The Sternal Shove is a simpler measure of balance recovery since the amount of force generated by the shove is not quantifiable. The Postural Stress Test is more precise in this regard and has good reliability and predictive validity (Duncan and Studenski 1994; Wolfson and others 1986). Although the equipment for the PST is inexpensive and readily available, a limitation of the PST is the difficulty transporting it for community assessments (Duncan and Studenski 1994).

The Clinical Test of Sensory Integration of Balance (CTSIB), originally described by Shumway-Cook and Horak (1986), was designed to evaluate if sensory input from the visual, somatosensory, and vestibular systems is contributing appropriately to balance control. Also known as the "foam and dome" test, it evaluates balance during 6 sensory conditions—3 visual (eyes open, blindfold, and the dome) by 2 surface conditions (floor and foam) (Shumway-Cook and Horak 1986). Interrater reliability and test-retest reliability were reported to be high (0.68-1.0 and 0.99, respectively) (Whitney and others 1998). There is some evidence of predictive validity of the CTSIB, as persons who had fallen 2 to 3 times in the 6 months before the study had more difficulty standing on the foam (Whitney and others 1998). The modified CTSIB (mCTSIB—without the dome component) is a good test to assess the impact of sensory inputs on balance and is currently used in the elderly and in vestibular disorder patients. It correlates with the more technological Sensory Organization Test (SOT) of the Equitest; however, the Equitest SOT is more sensitive in detecting abnormalities (El-Kashlan and others 1998).

A number of functional performance tools are available that evaluate balance during mobility in a series of performance tests that require both static and dynamic balance. Some examples include the Timed Get-Up-

and-Go Test, the Tinetti Performance-Oriented Assessment of Mobility, and the Berg Balance Scale (Berg and others 1989; Duncan and others 1990, 1992; Podsiadlo and Richardson 1991) (see Table 1). Advantages of these tests are their direct relevance to functional abilities, ease of administering in any setting, short time of administering, and in some instances, their established reliability, validity, and ability to predict falls. Weaknesses of functional tests are their inability to detect the cause of the balance deficit and, in some cases, their low sensitivity in predicting falls.

The Timed "Up and Go" Test (TU>) measures the time it takes in seconds for the subject to rise to standing from an armchair, walk 3 m, turn, walk back to the chair, and sit down (Mathias and Mayak 1986). Interrater reliability and test-retest reliability have been reported to be very good (both 0.99) (Podsiadlo and Richardson 1991). Concurrent validity has been established with correlations to scores on the Berg Balance Scale ($r = -0.81$), gait speed ($r = -0.61$), and the Barthel Index of ADL (an estimate functional capacity, $r = -0.78$). Predictive validity was established as follows: subjects with scores less than 10 were normal (15 s is at risk for falls, less than 20 s were independent in transfers and were able to climb stairs, scores greater than 30 s needed help with chair, toilet, and tub transfers and did not climb stairs (Podsiadlo and Richardson 1991). This quick and easy-to-administer test can be completed by most older adults and is used frequently in the elderly population.

Another widely used functional tests is the Tinetti Performance-Oriented Assessment of Mobility Test that measures balance and gait (Tinetti 1986). This test was developed for use in an elderly nursing home population and assesses 15 performance activities using a 3-point interval scale. Activities include standing from a sitting position or stepping over an obstacle on an uneven surface. It is widely used in clinics, takes about 20 min to administer, and has established reliability and validity in community-dwelling elderly (Dewane 1997; Duncan and Studenski 1994).

The Berg Balance Scale was developed for community-dwelling adults and is a performance test of 14 increasingly difficult mobility tasks that are graded on a scale from 0 to 4 with a best total of 56 points. It tests strength, flexibility, and balance and has

been shown to have more sensitivity to change in healthy older adults than the Tinetti Scale. The Berg has high interrater reliability (0.88-0.98), intrarater reliability (0.98), and internal consistency (0.96) (Berg and others 1992; Riddle and Stratford 1999). Concurrent validity and predictive validity have been established (Berg and others 1992). A score less than 50 was shown to be predictive of multiple falls (sensitivity was 91% and specificity was 82%) (Shumway-Cook and others 1997). The test takes 15 min to administer and has been widely used in multiple populations (Bogle Thorbahn and Newton 1996).

Technological Measures of Balance

Advancements in technology have made computerized quantitative measurements of balance possible. In some cases, these systems may be used to isolate the functional abnormalities that may be associated with the cause of balance deficits, assess balance improvements, and even train balance. Some examples of technology-based balance systems are listed in Table 2.

The computerized forceplate is the most widely reported method of quantitative balance measurement in the literature. The AMTI AccuSway Plus Force Platform is an example of a computerized forceplate. They consist of a flat, rigid surface supported on 3 or more points by force-measuring devices. When the subject stands on the plate, the position of the center of vertical forces exerted over time is recorded and used to calculate the direction and extent of postural sway (Nashner 1997a). Most forceplate platforms evaluate 4 aspects of balance: 1) postural sway or steadiness, that is, the ability of the individual to remain as motionless as possible; 2) symmetry, that is, the distribution of weight evenly between the two feet; 3) dynamic stability, that is, the ability to move the center of vertical forces to remain in a stationary position; and 4) the automatic motor responses to disturbances of the platform surface (Guskiewicz and Perrin 1996).

The sensitivity of a forceplate system to balance deficits can be further enhanced by adding a moving visual surround to disrupt vision as in the Equitest of NeuroCom. The Equitest, also called computerized dynamic posturography, permits diagnostic assessment of adaptive functioning of multiple components contributing to balance unlike any current perform-

ance or laboratory balance tool (Nashner 1997b). It assesses human posture according to the systems model of postural control. Test protocols are designed to assess the functioning of sensory, motor, and biomechanical components contributing to balance individually and as an integrated whole using two sets of tests, the motor control tests (MCT) and the sensory organization tests (SOT). The first set of tests (MCT) examines the responses to sudden, balance-threatening movements of the force plate that the subject stands on. The second set of tests (SOT) examines subjects' abilities to maintain upright stance when visual and/or ankle muscle and joint sensory reference information are modified mechanically.

When using instruments, reliability and validity are affected by the equipment, in addition to the environment, subject, and tester. (DiFabio 1996). A study of the reliability of postural responses in elderly individuals as measured by the Equitest showed the 4 vertical strain gauges are reliable over repeated measures; however, the horizontal strain gauge output had low correlations for repeated measures, indicating the shear measurements are not reliable (Coogler and Wolf 1992). Practice sessions also affect reliability because subjects learn to improve their balance performance. Variation in measurement of balance in elders between the 1st and 2nd trial of the Equitest can be as much as 10%; however, results of the 2nd and 3rd trials show little difference, indicating most learning takes place between the 1st and 2nd trial (Nashner ID: 389; Black, Paloski, and others 1995, ID: 3). A recent meta-analysis of the sensitivity of the Equitest to identify patients with peripheral vestibular deficits showed poor sensitivity and specificity (50% for both), with a positive effect size of 0.13 (DiFabio 1996).

Another technological application is the use of a computerized compressed air bladder to quantify the ability to maintain dynamic balance and train balance using a biofeedback system as in the Kinesthetic Ability Trainer 2000 (KAT 2000, see Table 2). The degree of surface instability can be controlled by the amount of air in the bladder. Thus, training conditions can be adjusted from a completely firm surface to progressively more unstable levels that stimulate lower extremity proprioception and joint mechanoreceptors.

The Biodex Balance System is similar to the KAT 2000 in its use of an unstable platform to train dynamic

Table 2. High-Technology Balance Systems

Test	Description	Cost/Main Features
AMTI AccuSway Plus Force Platform	Static balance Computerized forceplate	Approximately \$6000 Portable, easy to use Assesses limited number of aspects of balance
NeuroCom Equitest Series	Static balance and motor responses to perturbations Motorized forceplate, computer, and visual surround Additional information can be collected—that is, EMG data on leg muscles, head velocity (roll and pitch), and data on hip and shoulder movement	Approximately \$80,000-\$90,000 Sophisticated, requires trained testers and data analysts Takes 30-45 min per test Not portable Most complete assessment of sensory inputs affecting balance Does not characterize functional status Used in vestibular disorders, aviation medicine, geriatrics, brain injury, neuromuscular disorders, medical-legal cases, sports medicine
NeuroCom Balance Master Series	Assesses and trains static balance and motor responses to perturbations Forceplate with biofeedback Assesses performance of functional tasks (i.e., sit to stand, walk, turn, step up/over, lunge) Measures components of balance (i.e., weight symmetry, weight shifts, limits of stability, mCTSIB)	Approximately \$60,000 Assesses sensory inputs using the mCTSIB Assesses sitting and standing balance Used in elderly, orthopedic, sports medicine, and neurology populations
Biodex Stability System	Assesses and trains motor responses to perturbations Assesses neuromuscular control, proprioceptive, and mechanoreceptor input Multiaxial tilting platform on 8 moveable springs with biofeedback	Approximately \$7,500 Does not assess sensory inputs to balance control except for proprioception Portable Used in elderly, orthopedic, sports medicine, and neurology populations
Kinesthetic Ability Trainer 2000 (KAT2000)	Assesses and trains static balance and motor responses to perturbations Computerized compressed air bladder that provides biofeedback	Approximately \$6,900 Does not assess sensory inputs to balance control except for proprioception Used in health clubs, high school sports programs, postorthopedic surgery, elderly

balance. Gradations of platform instability are accomplished by using a platform positioned on a U-joint whose motion is dependent on 8 adjustable springs. The KAT 2000 and the Biodex are similar in their scope of assessment, which includes assessing neuromuscular control, proprioceptive input, and mechanoreceptor input. They do not have the capacity to detect vestibular or visual inputs to balance control. Used commercially in health clubs, athletic programs, and

rehabilitation programs, reliability and validity for both could not be located by this author.

The Relationship between Clinical/Functional Performance and Technological Balance Measures

It is questioned whether clinical measures and the more technological computerized measures of balance assess the same property. Currently, there is no accepted “gold standard” measure of balance (Berg and

others 1992). Thus, there is no external measure to judge the validity of these tools in assessing the complex function of balance. Research is ongoing to determine the relationship between tests. For example, in a group of healthy elders, one study found significant correlations ($r = 0.44-0.62$) between Equitest posturography and clinical measures (Tinetti Balance Scale, timed one-leg stance, and time and number of steps to walk 9 m) (Camicioli and others 1997). In a group of patients with vestibular problems, the CTSIB showed correlation coefficients ranging between 0.41 to 0.89 with balance evaluation measurements from the Balance Master, a computerized dynamic posturographic tool (El-Kashlan and others 1998).

It is important to know if tests measure the same property to know if one test can substitute for another or if one test is a more complete assessment than another. The general consensus is that computerized measures have greater precision and potential to detect subclinical balance impairments, but clinical functional tests have more direct functional relevance and are usually less costly and easier to administer (Berg and others 1992). However, clinical balance tests that are reliable at the functional level are not always sensitive to changes in performance. Computerized measures are reliable at both the functional level and the impairment level, and many are sensitive enough to document changes during rehabilitation.

Significance to Nursing

A major gap in balance research is the omission of environmental factors that have an impact on balance. Research conducted in a laboratory or clinical setting isolates individuals from the physical and social environment in which they live. Published research on balance has focused primarily on quantifying and understanding the physiologic components of balance and loss of balance within a laboratory setting, with little attention focused on the everyday physical and psychosocial problems of individuals with equilibrium problems (Newman and Jacobson 1997). In addition, many balance studies have used convenience samples of largely Caucasian adult, middle-class individuals who are removed from their usual physical, social, and cultural environment. Few studies have looked at the

Table 3. Referral Services for Programs Addressing Balance Deficits

Community Resources with Programs Addressing Balance Deficits

1. Hearing and balance center
2. Hospital-based outpatient balance training program—may be located in physical therapy department
3. Gerontology wellness center for mobility training
4. University research-based gerontology program within schools of public health, nursing, medicine, physical education, kinesiology, or exercise physiology
5. Vestibular disorder and balance center
6. Rehabilitation program
7. Senior centers with exercise programs

influence of environment and behavioral factors on balance and unsteadiness (Connell and others 1997). This focus has persisted despite the fact that it has been known that social factors impact health and physical function.

Oftentimes, the nurse is in the best position to assess for balance problems in the patient interview and perform balance screening or recommend screening. Knowing the available resources in your client's community is important to make appropriate referrals (see Table 3). Careful assessment can serve as a basis for a plan of care. Further diagnostic assessment identifies the specific components of balance that need remediation allowing a balance training protocol to be formulated that addresses specific deficits focusing on compensatory strategies, exercise, or functional training to improve balance. Assessment followed by targeted intervention programs can improve balance and preserve functional ability in adults with balance deficits.

Note

1. To determine the center of gravity, remember the object is a collection of many particles, each with its own weight and moment arm. The center of gravity relative to an arbitrary origin, the ground in this case, is calculated mathematically by finding the weighted average of particles times the distance they are from the origin, that is, center of gravity = $(m_1g_1x_1 + m_2g_2x_2 + m_3g_3x_3 + m_4g_4x_4 + \dots) \div MG$, where m is the mass of each particle, g is the gravitation force acting on each mass, x is the distance from the ground, M is the sum of

all small ms , and G is the average gravitational force (Colletta 1995, 127-242).

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