CHAPTER 19

Gait and Balance

GREGORY L. WELCH

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In the simplest of terms, the human gait pattern is the way people walk and balance, and is responsible for the ability to maintain an upright posture. The components of gait and balance are fundamental to physical function. Together, normal gait and balance enable ambulation, also known as mobility. Personal mobility is essential to effective functioning, which, for the older adult, is commonly referred to as the ability to perform activities of daily living (ADL). Although the hierarchy of ability for this population will vary tremendously, the older adult must pay close attention to maintaining an upright posture. Controlling postural balance is a prerequisite to performing many ADLs, and emphasizes the ability to maintain a mobile and independent lifestyle (Black, Maki & Femie, 1993).

For most individuals, independent functioning
Presupposes the ability to walk (Bohannon, 1997). While it appears relatively simple, walking is actually a complicated physiological process. A successful gait pattern is dependent on sufficient control at three levels: 1) basic reflexive stride and support patterns; 2) postural and equilibrium control; and 3) mechanisms that allow the body to adapt to unexpected changes in the environment (Spirduso, Franco & MacRae, 2005). Tinetti, Speechly and Ginter (1988) state that balance impairment, which is common among the elderly, is one of the most important risk factors for falls and injuries. Additionally, falls, instability and immobility are among the most common reasons for medical intervention for the older adult.

As society places more emphasis on maintaining an independent lifestyle, more attention must be given to maintaining mobility as the population ages. The intent of this chapter is twofold: to educate Clinical Exercise Specialists with regard to current information on gait and balance, and to help them implement a gait and balance training strategy.

### Defining the Population

For years, older adults were lumped into the general category of special populations. However, as researchers learn more about the elderly they realize there are often special subpopulations. This is especially true with regard to gait and balance, since the mechanisms leading to reduced mobility are complex. While age-related changes in the neural, sensory and musculoskeletal systems can lead to balance impairments that have a significant impact on the ability to maneuver safely (Maki & McIlroy, 1996), some older adults maintain normal gait into their ninth decade, suggesting that a disordered gait is not an inevitable component of aging (Bloem et al., 1992). Additional challenges occur when immobility is the result of a multifactorial etiology. Multiple chronic diseases, cognitive impairment, upper- and lower-extremity disabilities, and medication also contribute to the instability of the elderly. Attempting to define a population with gait and balance disorders based on any one problem would be difficult at best. The most effective approach in dealing with a gait and balance disorder is to communicate directly with a client's attending physician to obtain precise information specific to each individual.

### Etiology

The root of the problem for gait and balance disorders is multifactorial. There may be many independent reasons for an affliction, as well as several issues undermining posture and ambulation. The effects of aging, deterioration caused by disease and alterations due to medication all are contributing factors.

Age-related changes occur in all of the sensory systems that support postural control (Maki & McIlroy, 1996). In a study of the healthy elderly, it was determined that progressive, functionally evident, age-related quantitative balance changes occur independent of typical geriatric pathological changes (Camicioli, Panzer & Kaye, 1997). Gait velocity slows, stride length shortens and double-support time increases due to the effects of aging (Judge, Ounpuu & Davis, 1997).

Nutt, Marsden & Thompson (1993) have classified gait and balance dysfunction by way of the following pathophysiological scheme:

- lower level disorders due to problems with sensation or strength
- middle level disorders due to problems within the spinal cord or brainstem
- higher level disorders due to problems with the cerebellum basal ganglia or cortical spinal tracts
- highest level disorders due to problems in the frontal cortex

Sherlock (1996) adds identification of three categories causing balance disorders:

- peripheral causes of balance disorders such as vestibular neuronitis, an abrupt onset of severe vertigo
- disease processes of the central nervous system such as stroke and traumatic brain injury
- degenerative neurological diseases such as multiple sclerosis

Be aware of these classifications should they be included on a physician's report.

Table 19.1 lists common medical conditions that cause gait and balance disorders in elderly persons (Tinetti, Williams & Mayewski, 1986).
Components of Balance

In the broadest sense, balance involves an individual's capability to control upright posture under a variety of conditions and to sense their stability limitations (Berg & Norman, 1996). Postural control can be defined as the process by which the central nervous system (CNS) generates the patterns of muscle activity required to regulate the relationship between the center of gravity (COG) and the base of support (BOS) (Maki & McIlroy, 1996). In a study conducted to determine the relationship of postural balance to self-reported functional ability and general physical activity, Era et al. (1997) concluded that good balance is one of the prerequisites for mobility and activities of daily living. To maintain stability, the body's center of gravity must be positioned vertically over the base of support. The latitude of stability where the COG is still within the BOS is considered the area of sway. Controlling postural sway while standing is called static balance. Normal units of sway are approximately 12.5 percent for anterior/posterior sway and 16 percent for lateral sway (Sherlock, 1996). A study by Lucy and Hayes (1985) determined that sway in the anteroposterior direction was 52 percent greater in subjects 70 to 80 years old than in subjects 30 to 39 years old. Thus, postural stability, normally considered to be under automatic control processes, requires more conscious attention in the elderly than in younger individuals (Spirduso, Franco & MacRae, 2005).

The act of processing internal and external information to react to destabilizing forces and cause the muscles to anticipate balance changes is called dynamic balance (Spirduso, Franco & MacRae, 2005). Three different sensory systems derive the information necessary to maintain balance: 1) the visual system, 2) the vestibular system and 3) the somatosensory system.

The Visual System

Visual information provides feedback regarding the changing environment, and movement of the head with respect to surrounding objects (Sherlock, 1996).
Location, direction and speed of movement also are discerned through vision. Age-related changes in the visual system include reduced acuity, contrast sensitivity, depth perception and dark adaptation (Verrillo & Verrillo, 1985). Sekuler and Hartman (1980) state the importance of the need for up to three times more contrast to compensate for a loss in the ability to discriminate low spatial frequencies.

The Vestibular System

Located in the inner ear, the vestibular system is a network of receptors that provides information about position and movements of the head, with respect to gravity (Spirduso, Franco & MacRae, 2005). Regardless of whether the head is upside down, tilted or changing positions, this system activates motor neurons, leading the muscle tissue to contribute substantially to maintaining balance. Both the size and number of vestibular neurons begins to decrease after the age of 40 (Rosenhall & Rubin, 1975). Because many postural reflexes triggered by the vestibular system also may be triggered by visual stimulation, vision can compensate for some loss of vestibular function (Spirduso, Franco & MacRae, 2005).

The Somatosensory System

Somatosensory information on the position and motion of the body's support surface is gained from receptors in skin, muscles and joints (Sherlock, 1996). Pressure receptors in the skin and proprioceptors in the muscles, joints and ligaments provide information about weight shifts and joint angles. While sense of joint position in the arms and legs does not markedly decline in the elderly, cutaneous or skin sensation does decrease with age (Kokmen, Bossemeyer & Williams, 1978; Brocklehurst, Robertson & James-Groom, 1982).

Characteristics of Gait

Generally speaking, walking is the most common activity of daily living. It can be defined as the process of transferring the center of gravity of one foot to the other by alternately moving the legs forward. This performance of gait creates a continuous disturbance of the mechanical equilibrium as it forms new bases of support (Spirduso, Franco & MacRae, 2005). Normal gait is dependent on the capacity of multiple-organ systems, specifically the neurologic (sensory, motor control), musculoskeletal (muscle force, joint range of motion and posture), and cardiovascular systems (Judge, Ounpuu & Davis, 1996).

Although many individuals may take the simplicity of gait mechanics for granted, approximately 50 percent of falls occur during walking (Patla & Winter, 1990).

Gait Mechanics

It is necessary to understand the mechanics of the normal gait cycle to better comprehend assessment and training procedures. Follow-

Figure 19.1
The Subdivisions of Stance and Their Relationship to the Bilateral Floor-Contact Pattern

Vertical dark bars are the periods of double-limb stance (right and left feet). Horizontal shaded bars represent single-limb support (single stance). Total stance includes three intervals: the initial double stance, single-limb support and the next (terminal) double stance. Swing is the clear bar that follows terminal double stance. Note that right single-limb support is the same time interval as left swing. During right swing there is left single-limb support. The third vertical bar (double stance) begins the next gait cycle.
ing is an explanation of the normal gait cycle by Perry (1992). The corresponding graphic description of a normal gait cycle is provided in Figure 19.1.

The mechanics of walking are referred to as the gait cycle, which is defined as a sequence of events between two sequential contacts by the same limb. There are two phases that make up the gait cycle: stance and swing. The stance phase, which constitutes approximately 60 percent of the normal gait cycle, is the interval in which the foot of the reference extremity is in contact with the ground. The swing phase, which makes up the remaining 40 percent of the gait cycle, is the interval in which the reference extremity does not contact the ground.

Stance is further subdivided into three intervals, according to the sequence of floor contact by the two feet:

1) Initial double stance, also known as double-limb support, begins the gait cycle (GC). It is the time both feet are on the floor after initial contact (10 percent GC).

2) Single-limb support begins when the opposite foot is lifted for swing. The word “support” is preferred over “stance” to emphasize the functional significance of floor contact by just one foot. During the single-limb support interval, the body's entire weight is resting only on one extremity. The duration of single stance is the best index of the limb's support capability (40 percent GC).

3) Terminal double stance begins with floor contact by the other foot (contralateral initial contact) and continues until the original stance limb is lifted for swing (ipsilateral toe-off) (10 percent GC). The term “terminal double-limb support” has been avoided because weight bearing is asymmetrical.

Stride is the equivalent of a full gait cycle. The duration of a stride is the interval between two sequential initial floor contacts by the same limb. Stride length and cadence are the basic determinants of gait velocity. Of the two, stride length is the stronger factor. Stride length averages 1.5 meters in normal adults. Step refers to the timing between the two limbs. The interval between an initial contact by each foot is a step. When gait is symmetric, step length is 50 percent of stride length; when gait is asymmetric, the right and left step will differ, but right and left stride lengths will be identical. Step width is the distance between the foot contact of the left and right foot (Figure 19.2).

Physical changes associated with aging directly affect an older adult's ability to maintain postural stability and normal gait mechanics. Normal functioning depends on free, passive joint mobility, appropriate timing and intensity of muscle action, and normal sensory input (Perry, 1987). Aging can lead to several physical changes that affect these basic processes: 1) stiffening of connective tissue; 2) decreased muscle strength; 3) prolonged reaction times; 4) decreased visual acuity; 5) impaired vibratory and proprioceptive sensation, and 6) increased postural sway (Trueblood & Rubenstein, 1991).

There is a close relationship between gait, balance and muscular tissue. This relationship is especially important because much can be done to retard and even reverse age-related changes in muscle tissue. It is commonly known that muscle mass, muscle strength and muscle contractility decline with advancing age (Klitgaard et al., 1990). Cross-sectional and longitudinal studies have found that muscle strength is directly associated with gait velocity (Fiatarone et al., 1990). Spirduso, Franco & MacRae (2005) offer the following explanations for the preference by the older adult toward a reduced gait velocity: 1) endurance of weaker muscles in the lower limbs is maximized with the use of shorter strides, and the energy cost of walking is minimized; 2) less flexible ankle and knee joints constrain the stride length. Muscle strength also is associated with measures of static and dynamic balance (Judge, Ounpuu & Davis, 1995).

Studenski & Rigler (1996) add that gait stability relies upon an adequate support structure that consists of the musculoskeletal elements responsible for the mechanical work of holding the body upright while in motion. Therefore, it is logical to assume that maintaining the normal function of muscle tissue via exercise will help an individual maintain a successful gait pattern.
Aging, however, is still a factor regarding hip flexor power, as was suggested in a comparison study between a group of younger and older adults. The older adults were thought to be compensating for a reduction in ankle plantarflexor power by increasing hip flexor power. Therefore, it is possible that the reductions in ankle power found in several cross-sectional studies are responsible for at least part of the reduction in step length associated with advancing age (Judge, Ounpuu & Davis, 1996).

Falling

The most severe consequences of poor balance are accidental falls that occur in connection with normal daily activities such as walking indoors or outside, climbing stairs, using the bathroom or changing posture (Era et al., 1997). Falling constitutes a significant risk to the health, function and independence of elderly people. Falls are particularly problematic in the nursing-home setting where their incidence is approximately three times greater than in community-based living. This is due in part to a higher degree of frailty (Rubenstein, Josephson & Osterweil, 1996). The causes and risk factors associated with falls in nursing homes, however, are similar to those in community living. Rubenstein, Josephson and Osterweil (1996) state that the most common causes of falling are gait and balance disorders, weakness, arthritis, dizziness, environmental hazards, confusion, visual impairment and postural hypotension. Furthermore, the most important underlying risk factors for falls and injuries include some of these causes, as well as leg weakness, gait and balance instability, poor vision, cognitive and functional impairment, and sedating and psychoactive medications.

Older adults are hospitalized following fall-related injuries five times more often than they are for injuries from other causes (Alexander, Rivara & Wolf, 1992). In fact, more than one-third of individuals over the age of 65 fall each year (Hornbrook et al., 1994; Hausdorff, Rios & Edelber, 2001). In addition, 20 to 30 percent of older adults who fall suffer injuries severe enough to make it hard to live alone and that increase the chance of early death (Alexander, Rivara & Wolf, 1992). Seventy-five percent of serious fall injuries cause fractures (Nevitt, Cummings & Hudes, 1991). Specifically, fractures of the hip account for approximately 280,000 fall injuries per year in the U.S. in people older than 65. Two-thirds of these injuries occur in individuals 75 and older (Verfaillie et al., 1997).

Mechanisms of Falling

A fall occurs in the presence of two specific conditions. Maki and McIlroy (1996) state that there must be: 1) a perturbation (destabilizing force), and 2) a failure of the posture control system to compensate for the perturbation. Furthermore, they explain that in a small proportion of cases, a fall results when an internal physiologic perturbation momentarily disrupts the operation of the postural control system by interfering with perfusion of postural centers in the brain or brainstem (e.g., transient ischemic attacks, postural hypotension, cardiac arrhythmias or occlusion of vertebral arteries during neck movement), or by disrupting the sensorimotor systems (e.g., episode of dizziness or vertigo).

Maki and McIlroy (1996) continue their dissection of the mechanism of falling by explaining that there are two forms of external perturbation: mechanical and informational. Mechanical perturbations involve a change in the forces acting on the body that either displaces the center of gravity beyond the base of support (i.e., a push or collision) or prevents the BOS from being aligned beneath the COG (i.e., a slip or trip). Perturbations can be
imposed by the environment (i.e., impact from a swinging door, a jostle from a crowd, standing in a moving vehicle) or may be self-induced, arising during volitional movements, such as walking, rising from a chair, bending over, reaching forward or pushing on a door. Informational perturbations change the nature of the orientation information available from the environment. This may create conflicts among the visual, vestibular and somatosensory input (e.g., moving visual fields that create an illusion of self-motion or carpets that distort proprioceptive information from the foot and ankle), or may change the quality of sensory input (e.g., dim lighting or glare that can interfere with visual input).

**Characteristics of People who Fall**

Individuals who are likely to fall or have a history of falling possess certain attributes. It is possible to identify older persons at risk of falling based on chronic age-associated and disease-related characteristics, acute illness and degree of mobility impairment (King & Tinetti, 1995). Risk factors for major injury or fracture have been identified in prospective cohort studies; however, they are not always consistent with other studies, due to differences in populations studied, risk factors examined and outcomes measured (King & Tinetti, 1996). In one study, for example, the risk of falling was predicted by slow hand-reaction time, decreased grip strength, previous fall with fracture and cognitive impairment (Nevitt, Cummings & Hudes, 1991). In another study, history of stroke or respiratory disorder and recent limitation in activity were used as predictable criteria (O'Loughlin et al., 1993).

In terms of certain physical characteristics, MacRae, Lacourse and Moldavon (1992) identified incidents of falling due to unusually weak hip adductors, knee extensors, knee flexors and ankle dorsiflexors. According to Lipsitz et al. (1991) people who fall tend to be those who take more steps to turn 360 degrees, who cannot rise from a chair without pushing off and who have difficulty determining their body position.

**Fear of Falling**

It has been reported by Tinetti, Richman and Powell (1990) that some elderly persons develop symptoms or behaviors in response to a fall, regardless of physical trauma. Changes in gait cited as risk factors for falling may in fact be stabilizing adaptations related to fear of falling (Maki, 1997). Healthcare providers, family members and elderly persons all have acknowledged that in addition to loss of function due to physical trauma, psychological trauma may result from a self-imposed decline in activity and function not necessitated by physical disabilities or injury (Vellas et al., 1987). The older adult may express an enhanced or increased fear of falling that may result in deleterious emotional, psychological or social changes (Vellas et al., 1997).

Fear of falling also is associated with self-efficacy and confidence with regard to carrying out various ADL. Bandura (1986) refers to self-efficacy as an individual's perception of capabilities within a particular domain of activities. Older people's perception of their degree of ability and, more importantly, what they feel they cannot achieve, is instrumental in regulating their activity level. Depression also may be linked to the activity restriction, social withdrawal and loss of independence that often occur as a result of a fear of falling (Arfken et al., 1994).

Fear related to falling can manifest itself in artificial corrections in posture and gait. Spirduso, Franco & MacRae (2005) state that

<p>| Table 19.2 |</p>
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<th>Client Information to Obtain from Medical Professionals</th>
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<tr>
<td>1) What health condition related to gait and balance does the client currently have?</td>
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<td>2) What medications does the client take and how do they affect gait and balance?</td>
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<tr>
<td>3) Has the client ever fallen?</td>
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<td>4) Does the client have any prosthetic joints or limbs?</td>
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<tr>
<td>5) What limitations are placed on the client’s ability to participate in gait and balance training?</td>
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<tr>
<td>6) Has this person seen a physical therapist?</td>
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<td>7) Should this person see a physical therapist?</td>
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due to an exaggerated fear of falling backward, the elderly may bias their posture so that if a fall occurs, they fall forward and break the fall with their arms. This flexed posture places a higher muscular load at the hips and knees, and shifts the base of support to the front of the feet over the toes. The main gait changes found to be associated with a fear of falling are increased double-support time and reduced stride length and velocity (Winter et al., 1990). Maki (1997) explains that the increase in double-support time is thought to increase gait stability by reducing the amount of time spent balancing on one leg. The slowing of the gait may have the benefit of allowing more time to react to obstacles or other changes in environment. It also may improve the probability of successful balance recovery in the event of loss of balance that results from reduced momentum of the body. The decreased stride length may promote stability by minimizing the forward excursion of the center of mass beyond the base of support provided by the stance foot.

Assessment of Gait and Balance

One of the key factors in the assessment of gait and balance is the progression of information gathering that takes place prior to any physical-performance tests. For every individual, there are a myriad of potential roadblocks that must first be identified (Welch, 2005). Because of the multifactorial nature of gait and balance disorders, it is necessary to acquire both a complete medical history and consent from a primary-care physician. A clear diagnosis, precise medications, contraindications and information on whether the individual is prone to falling all should be obtained from the client’s physician.

The Pre-exercise Interview

The pre-exercise interview is a simple, non-threatening way to acquire valuable information regarding an individual’s history of physical activity. Likewise, present activities, goals and objectives, and likes and dislikes can be determined during the interview. Discussions of interests, hobbies, work regimen (professional as well as personal), involvement in the community, etc., can shed light on what an individual perceives they can successfully accomplish.

Begin the interview with a simple statement regarding the individual’s ADL: Tell me about a typical week in your life (Welch, 2005). Follow with questions more specific to the work objective. For example, if a client included gardening within her typical week, you can assume she has the mobility to move about the yard successfully. However, to further scrutinize the information, a follow-up line of inquiry might be: 1) How often do you work in the garden? 2) How long do you spend in the garden at one time? 3) What kinds of foliage do you plant? 4) Do you ever get light-headed, dizzy or nauseated or have trouble with balance when standing after you’ve been planting? 5) What types of things do you lift when you’re in the garden? 6) Have you ever stumbled or fallen?

Since mobility level can vary greatly in the elderly, answers to these types of questions based on other ADL scenarios can provide additional insight into your selection of the most

<p>| Table 19.3 |</p>
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<th>Typical Activity Guidelines</th>
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<tr>
<td><strong>n</strong> Total-body transitions: Support transitional movements, such as getting in and out of the car, bed, bath, chair and toilet, with personal assistance, or encourage the use of stabilizing objects, such as bars, walkers and quad canes.</td>
</tr>
<tr>
<td><strong>n</strong> Ambulatory transitions: Provide assistance when moving from one floor surface to another (e.g., carpet to hard floor, carpet to throw rug), and when stepping onto raised thresholds and stairs, or into narrow hallways.</td>
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<tr>
<td><strong>n</strong> Pathway obstacles: Remove all obstacles from walking areas, including throw rugs, ottomans, pillows, toys,</td>
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appropriate assessment tools. Information also may be elicited through questioning on why the individual stopped their usual activities, what aspects of the activity made them nervous or fearful, and what aspects of their performance had deteriorated (Berg & Norman, 1996). Similarly, a description of a typical day in the life of a person who relies on a walker for safe ambulation generates information that would suggest a more basic assessment protocol. The point, however, is to identify the present level of mobility the individual possesses prior to engaging in physical activity.

**Functional Assessment of Balance**

In general, dynamic balance measures that assess the ability to maintain equilibrium in response to either self-motivated or external perturbation are superior to static tasks (Duncan et al., 1990). The following are assessment tools that address a wide variety of abilities. Each of the tests is adequate in determining functional ability. Though there is some degree of subjectivity, the tests are quantifiable so that measurements can be taken after a training period to identify improvement. Normative data are available to allow for comparison (Rikli & Jones, 1999).

Table 19.4 describes a field interpretation of the Functional Reach protocol (Duncan et al., 1990). In Table 19.5, Tinetti, Williams and Mayewski (1986) offer an evaluation of balance that incorporates a series of challenges and a corresponding scoring system. Table 19.6 displays a measure of balance that was developed from a series of eight independent studies, collectively known as the FICSIT (Frailty and Injuries: Cooperative Studies of Intervention Techniques) (Buchner et al., 1993; Rossiter-Fornoff et al., 1995). Berg and Norman (1996) state that these tests were designed to examine the effect of diverse interventions in older adults with various ability, including active healthy individuals living in the community and disabled nursing home residents. Figure 19.3 is a test of stepping on and off objects of varying height (Williams & Greene, 1995). In addition to the timed component of this test, there are what the authors refer to as notable characteristics. These are subjective evaluations that can further help to determine real-life function, issues of fear and areas of body weakness.

Table 19.7 is a series of dynamic balance tests that I developed to test the ability of establishing and maintaining rhythm or cadence, specifically without the use of a metronome. The SpeciFit Rhythm Series Tests challenge dynamic balance while simultaneously testing the anticipatory timing component. Successful completion of the maneuver suggests the ability to rhythmically correct for an anticipated weight shift.

**Functional Assessment of Gait**

Similar to maintaining balance in a standing position, gait involves the maintenance of upright posture and control over the projection of the center of gravity (Berg & Norman, 1996). Judge, Ounpuu and Davis (1996) explain that for an older person to feel safe while walking, periods of single-leg support cannot be perceived as dangerous. Stability while walking, during both single- and double-leg support, is enhanced by the ability to control the muscle movements at all lower-extremity joints. Furthermore, smooth progression and stability during walking are possible through power generation and absorption at all lower-extremity joints.

The first assessment of gait (see Figure 19.2) is to establish the individual’s stride and step length, and step width. Have the individual walk on a dry surface immediately after placing the feet in a wet area. Measure distance according to foot patterns. Further assess gait with the evaluation by Tinetti, Williams and Mayewski (1986) (Table 19.8). Gait speed is another test that is easy to perform. Have the individual walk as fast as possible for a specified distance, (6, 10 or 12 meters). Williams and Greene (1995) add a series of variations to the straight-line gait-speed evaluation. Figures 19.4, 19.5 and 19.6 display those variations.

**Gait and Balance Training**

There is mounting evidence that exercise training (strength, aerobic and balance exercise) can improve performance in individuals who demonstrate moderate gait and balance deficits. Likewise, research involving the very frail suggests exercise may delay fur-
In a study to test the effectiveness of a home-based exercise program, Campbell et al. (1997) concluded that strength and balance retraining exercises improved physical function and were effective in reducing falls in 116 women aged 80 years and older. Likewise, Shumway-Cook et al. (1997) reported that multidimensional exercise improved balance and mobility function in 105 community-dwelling older adults with a history of two or more falls within six months. Sherrington and Lord (1997) discuss specificity as the focal point to skill acquisition, muscle strengthening and postural control, which makes it vital to selecting appropriate physical training strategies. Nugent, Schurr and Adams (1994) were successful in improving the gait in a group of stroke patients by utilizing a specific leg extensor exercise. Additionally, Chandler and Headley (1998) concluded that while lower-extremity strength gain is associated with chair-rise performance, gait speed and stair climbing, there is no association with improved balance or endurance.

### Table 19.4
**Functional Reach**

1. Secure a yardstick to a wall horizontally at right acromion height.
2. The subject stands next to the wall with their right acromion aligned at beginning of yardstick.
3. With the subject’s feet approximately shoulder-width apart, trace foot position to ensure identical foot placement for each trial.
4. Have the subject extend their right arm parallel to the yardstick with a clenched fist. Position one is measured at the third metacarpal.
5. Ask the subject to reach forward as far as possible without losing their balance or taking a step (which represents position two), and again record the placement of the third metacarpal.
6. Do not allow the subject’s upper extremity to contact the wall during this maneuver. If the subject touches the wall or takes a step during testing, repeat the trials.
7. Do not make any attempt to control the subject’s method of reach.
8. Functional reach is defined as the mean difference between positions one and two after three trials.
9. Guard or spot subjects during the testing procedure to avoid loss of balance.

### Table 19.5
**Tinetti Balance Evaluation**

<table>
<thead>
<tr>
<th>Sitting Balance</th>
<th>Leans or slides in chair*</th>
<th>Steady, safe</th>
</tr>
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<tbody>
<tr>
<td>Rising</td>
<td>Unable without help</td>
<td>=0</td>
</tr>
<tr>
<td></td>
<td>Able but uses arm to help</td>
<td>=1</td>
</tr>
<tr>
<td></td>
<td>Able without use of arms</td>
<td>=2</td>
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<thead>
<tr>
<th>Attempts to rise</th>
<th>Unsteady (staggers, moves feet, marked trunk sway)</th>
<th>Steady but uses walker or cane, or grabs other objects for support</th>
<th>Steady without walker, cane or other support</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>=0</td>
<td>=1</td>
<td>=2</td>
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<tr>
<th>Immediate standing balance (first 5 sec.)</th>
<th>Unsteady (staggers, moves feet, marked trunk sway)</th>
<th>Steady but wide stance (medial heels more than 5 in. apart)</th>
<th>Narrow stance without support</th>
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<tr>
<td></td>
<td>=0</td>
<td>=1</td>
<td>=2</td>
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<tr>
<th>Standing balance</th>
<th>Unsteady (staggers, moves feet, marked trunk sway)</th>
<th>Steady but wide stance (medial heels more than 5 in. apart)</th>
<th>Narrow stance without support</th>
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<td>=0</td>
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<tr>
<th>Nudged (subject with feet close together; examiner pushes lightly on subject’s sternum with palm of hand)</th>
<th>Begins to fall</th>
<th>Staggers, grabs, but catches self</th>
<th>Steady</th>
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<td>=0</td>
<td>=1</td>
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<tr>
<th>Eyes closed with feet close together</th>
<th>Unsteady</th>
<th>Steady</th>
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<td></td>
<td>=0</td>
<td>=1</td>
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<tr>
<th>Turning 360 degrees</th>
<th>Discontinuous steps</th>
<th>Continuous steps</th>
<th>Unsteady (grabs, staggers)</th>
<th>Steady</th>
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<tr>
<td></td>
<td>=0</td>
<td>=1</td>
<td>=0</td>
<td>=1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sitting down</th>
<th>Unsafe (misjudged distance, falls into chair)</th>
<th>Uses arms or not a smooth motion</th>
<th>Safe, smooth motion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>=0</td>
<td>=1</td>
<td>=2</td>
</tr>
</tbody>
</table>

*Subject is seated in hard armless chair.
Maximum Balance Score is 16.
The role of specificity training was further supported by the research of Verfaillie et al. (1997). They stated that older individuals can make significant gains in muscular strength and gait speed through resistance training, but that resistance training alone will not sufficiently improve balance and other gait parameters to significantly reduce risk factors for falls. Furthermore, to maximize the likelihood of reducing these risk factors, balance and gait training should be included with resistance training programs for the elderly.

Balance-training Techniques

To train clients for better balance, first determine the appropriate level of challenge. It is always wise to err on the conservative side by selecting an exercise for which the level of confidence is high for both the trainer and trainee.

One-legged balance
Support is optional. Switch legs after 10 to 15 seconds; repeat for three to five sets.
Level 1
• Subject stands on one leg.
Level 2
• Subject stands on one leg on a mini-trampoline.
Level 3
• Subject stands on one leg on a mini-trampoline and gently rebounds without breaking contact with the trampoline bed.
Level 4
• Subject stands on one leg and attempts to balance on a wobble board.
Level 5
• Standing on one leg, the subject intentionally rocks the board laterally. Repeat for anterior/posterior.
Level 6
• Divide the mini-trampoline with a line and have the subject hop over it laterally. Repeat for anterior/posterior.

Two-legged balance
Support is optional. Each work bout should last 15 to 30 seconds, followed by a rest period of the same length. Repeat for three to five sets.

Table 19.6
The FICSIT
1. Feet close together, unsupported, eyes open
2. Semi-tandem, eyes open; heel of one foot placed to the side of the first toe of the opposite foot
3. Full-tandem, eyes open; heel of one foot directly in front of the other foot
4. Standing on one leg, eyes open

This four-item scale tests the subject for 10 seconds. Record the best of three timed trials. Add additional challenge by repeating the four items while blindfolded.

Figure 19.3
Stepping On and Off Objects
Gait and Balance

Table 19.7
The Rhythm (Cadence) Test

1. This test requires a proprioception board, also known as a wobble board. The board generally is about 12 inches in diameter with two 1-inch knobs or balls fastened to the bottom that allow it to tip anteriorly/posteriorly and laterally.

2. To test laterally, the subject stands on the board in ready position with body weight shifted to one side. On “go,” the subject begins to shift body weight side to side, attempting to sustain the movement in a rhythmic motion. The subject may hold on to a support device; this would be noted as a process characteristic. Speed is not important and, in fact, should be discouraged. A slow cadence at about one sequence (a sequence equals a right and left touch) per second is recommended as a target.

3. Calculate the subject’s score by counting the touches of one side of the board that are made in a rhythmic sequence, up to 20 touches, and take the best of three trials.

4. Test anterior/posterior rhythm by turning the board 90 degrees and repeating steps one through three.

5. Repeat steps one through four for the single-leg test.

Table 19.8
Tinetti Gait Evaluation

<table>
<thead>
<tr>
<th>Item</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation of gait after told to “go”*</td>
<td></td>
</tr>
<tr>
<td>Any hesitancy or multiple attempts to start</td>
<td>0</td>
</tr>
<tr>
<td>No hesitancy</td>
<td>1</td>
</tr>
<tr>
<td>Step length and height</td>
<td></td>
</tr>
<tr>
<td>a) Right swing foot</td>
<td></td>
</tr>
<tr>
<td>Does not pass left stance foot</td>
<td>0</td>
</tr>
<tr>
<td>Passes left stance foot with step</td>
<td>1</td>
</tr>
<tr>
<td>Right foot does not clear floor completely with step</td>
<td>0</td>
</tr>
<tr>
<td>Right foot completely clears floor</td>
<td>1</td>
</tr>
<tr>
<td>b) Left swing foot</td>
<td></td>
</tr>
<tr>
<td>Does not pass right stance foot</td>
<td>0</td>
</tr>
<tr>
<td>Passes right stance foot with step</td>
<td>1</td>
</tr>
<tr>
<td>Left foot does not clear floor completely with step</td>
<td>0</td>
</tr>
<tr>
<td>Left foot completely clears floor</td>
<td>1</td>
</tr>
<tr>
<td>Step symmetry</td>
<td></td>
</tr>
<tr>
<td>Right and left step length not equal (estimate)</td>
<td>0</td>
</tr>
<tr>
<td>Right and left step appear equal</td>
<td>1</td>
</tr>
<tr>
<td>Step continuity</td>
<td></td>
</tr>
<tr>
<td>Stopping or discontinuity between steps</td>
<td>0</td>
</tr>
<tr>
<td>Steps appear continuous</td>
<td>1</td>
</tr>
<tr>
<td>Path**</td>
<td></td>
</tr>
<tr>
<td>Marked deviation</td>
<td>0</td>
</tr>
<tr>
<td>Mild/moderate deviation or uses walking aid</td>
<td>1</td>
</tr>
<tr>
<td>Straight without walking aid</td>
<td>2</td>
</tr>
<tr>
<td>Trunk</td>
<td></td>
</tr>
<tr>
<td>Marked sway or uses walking aid</td>
<td>0</td>
</tr>
<tr>
<td>No sway but flexion of knees or back, or spreads arms while walking</td>
<td>1</td>
</tr>
<tr>
<td>No sway, no flexion, no use of arms and no use of walking aid</td>
<td>2</td>
</tr>
<tr>
<td>Walk stance</td>
<td></td>
</tr>
<tr>
<td>Heels apart</td>
<td>0</td>
</tr>
<tr>
<td>Heels almost touching while walking</td>
<td>1</td>
</tr>
</tbody>
</table>

*Subject stands with examiner, walks down hallway or across room, first at their usual pace, then back at rapid but safe pace (using usual walking aid such as a cane or walker).

**Estimate path in relation to floor tiles. Observe excursion of one foot over about 10 feet of the course.

Maximum Gait Score is 12.

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Gait and Balance Training

Strength-training Techniques

**Lower-extremity Strength (squats)**
Support device is optional.

**Level 1**
- Subject sits in a chair, then stands and sits repeatedly for three to five repetitions.
- Recover and repeat for two to three sets.

**Level 2**
- Repeat level-1 sequence without back support.

**Level 3**
- Repeat level-1 sequence with a peanut-shaped physio-roll ball.

**Level 4**
- Repeat level-1 sequence with a stability ball.

Lower-extremity Strength (heel lifts)

**Level 1**
- Subject faces a wall at arm’s length away.
- With arms outstretched and body leaning slightly against the wall, the subject raises their heels and transfers total body weight to the balls of the feet for three to five repetitions.
- Recover and repeat for two to three sets.

**Level 2**
- Repeat level-1 sequence and increase to five to seven repetitions.

**Level 3**
- Repeat level-1 sequence holding two- to five-pound dumbbells in each hand.

**Level 4**
- Repeat level-3 sequence and increase to five to seven repetitions.

1. On signal the subject walks as fast as possible through a curved pathway measuring 10 feet long and 2 feet wide.
2. Record the time; the score is the average of three trials.

Process Characteristics
- Steps are continuous.
- Arms swing while walking.
- Subject does not stop or slow down at curves.
- Length of right and left steps is equal.

**Figure 19.4**
Body Agility with Wide Curve

**Figure 19.5**
Body Agility with Two Changes of Direction
Gait and Balance

Level 2
• Repeat level-1 sequence and increase to five to seven repetitions.

Level 3
• Repeat level-1 sequence and increase to seven to ten repetitions.

Level 4
• Repeat level-1 sequence using only one leg and continue progress as detailed in levels 2 and 3.

Pelvic Girdle Stabilization and Hip Strength
(multi-hip machine)
Level 1
• Subject performs hip flexion, hip extension, hip adduction and hip abduction.
• Use lightest possible weight to surpass learning curve.
• Increase number of repetitions over a 12-week period from three to five, to five to seven, to seven to 10.
• Do not allow individuals with hip replacements to cross the midline of the body when adducting.
• Levels 2 and higher should be based on each individual.

Gait-training Techniques

Treadmill
The treadmill is one of the most beneficial training devices available for gait training. All variables can be manipulated and controlled to keep the individual safe at all times. Cardiovascular benefits also may be realized.

Recommendations:
• Subjects probably will experience a lack of stability in the early stages of treadmill work. Holding the handrails helps alleviate this problem.
• As soon as possible, encourage the individual to let go of the handrails. Progress to this by encouraging the client to hold on with one hand for 10 seconds, then return to two hands.
• Monitor activity with a wireless heart monitor, modified rate of perceived exertion (RPE) scale and weak link index (WLI) scale.
• At the conclusion of treadmill activity, have the subject hold handrails for 30 seconds with the treadmill stopped. Have the subject continue to hold the handrails when stepping off the machine.

Spotting
It is imperative that close spotting techniques be practiced when working with an individual affected by problems of gait and balance. All testing and exercise protocols for gait and balance should not be carried out unless you are experienced in effective spotting. Some individuals will need more attention than others. However, the fact that they have a gait and/or balance disorder suggests they might need assistance without warning, regardless of their level of function.
The spotting techniques utilized may vary from person to person, depending on their individual health issues. Sometimes a hand on the back at the waist will suffice because it reminds the client that you are there. Others may require support provided by holding a hand or arm. Some individuals may feel invalidated by their need for you to provide assistance in order for them to complete the evaluation. However, safety is more important and spotting can easily be noted in the process characteristics.

Communication also is an effective spotting technique. Frequent, reassuring comments can help alleviate apprehension and motivate the individual to new levels. Creating positive yet accurate perceptions of the work accomplished may even stimulate the individual's own self-efficacy.

**Guidelines from the Physician**

For gait and balance disorders, guidelines from a physician and/or physical therapist must be specific to the etiology and are, therefore, too difficult to place in a categorical list. A cane or walker, which does nothing to further gait and balance training, would most likely be prescribed. See Table 19.2 for information to obtain from the client's physician.

**Conclusion**

Gait and balance training is a vital link to maintaining autonomy for many individuals. It is not difficult to see that a loss of mobility would curtail even the simplest ADL. The problem, however, is that disorders of gait and balance are multifactorial. A variety of diseases can lead to gait and balance anomalies as can frailty, medication, fear or any combination thereof. Nevertheless, training the components of gait and balance will always be a prudent endeavor. This is because physical conditioning brings positive physiological changes to the individual even if gait and balance are only affected minimally. Therefore, it is wise to become knowledgeable in gait and balance program design in order to provide a more complete wellness offering to a rapidly growing population.

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**The Weak-link Index (Welch, 2005)**

The weak-link index (WLI) is a subjective evaluation based on the same zero-to-10 scale used in the revised rating of perceived exertion (RPE) scale (Borg, 1998). The weak-link index is valuable because it directly addresses the issue of pain in specific body areas during an assessment or work session. For instance, a person on the treadmill may be walking at a comfortable pace but begin to experience slight discomfort in the left knee. This could be unimportant, or it could be a precursor to a more serious injury. Unless you ask, you may never know until it's too late. Your inquiry should be specific to any level of pain or discomfort in a particular area of the body, not general fatigue. The pain may be good reason for curtailing the activity even though the individual reports a low RPE value. Perceived exertion and perceived pain are different sensations and can be clearly delineated with the addition of the WLI scale. You are responsible for the well-being of your clients. If you do not monitor areas of discomfort, you will not be able to truly evaluate an individual's performance, and you will not be able to design the most effective exercise program.

Ask the following questions approximately every one to two minutes: 1) Is there any part of your body where you feel discomfort? 2) If so, where is the pain and how would you rate it on a scale from zero to 10 if zero means no discomfort at all and 10 indicates maximal pain? The individual should not be allowed to continue if the discomfort level is above two or three. Be sure to note when the test or work bout ended. Wait 24 to 48 hours, applying ice for 15 to 20 minutes every two to four hours, then ask the client if the pain is still present. It may have subsided after discontinuing the exercise, yet may return later in the form of soreness and/or point tenderness in the affected area. If pain is still present, wait another 24 hours. If the client is still experiencing pain, referral to a physician would be appropriate.

If the pain does not return, attempt the exercise again at a reduced intensity (e.g., slower pace, less elevation, more gradual ascent). Do not exceed the length of the previous test in which discomfort was first discovered, regardless of whether the client experiences pain. Curtail the exercise at or before the previous work duration and note the successful parameters (i.e., time, distance, pace, elevation). Repeat this work four to six times before increasing the workload.
References


Suggested Reading

