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CURRENT CONCEPTS REVIEW

BALANCE TRAINING FOR THE OLDER ATHLETE

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ABSTRACT

As the older adult population increases in size, the number of older adults participating in sport activities will also likely increase proportionally with a concomitant increase in musculoskeletal injuries. Age-associated functional declines in muscle strength and the sensory systems, in addition to several other issues, contribute to reductions in balance that may increase fall risk There are a variety of ways to evaluate balance and fall-risk, and each older adult should be regularly screened in order to evaluate any changes in the ability to maintain postural stability. Balance training is a useful intervention in rehabilitation of postural stability impairments as well as in training programs for performance enhancement. One scientifically-based approach is Sensorimotor Training (SMT) which can be characterized as a progressive balance training program using labile surfaces to provide adequate and safe challenges to the older athlete's balance. SMT addresses both static and dynamic components of balance as well as the multitude of systems that control balance in order to train effective strategies and elicit automatic postural responses in order to enhance postural stability. The authors believe that SMT should become part of the regular training regimen for the aging athlete. For the sport and orthopedic healthcare professional, an understanding of the physiologic changes that occur with age, the means by which balance can be assessed, and how SMT programs can be developed and implemented is crucial in addressing the growing number of older athletes that they will see.

Key Words: Aging, balance assessment, balance training, postural stability

Level of Evidence: 5

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INTRODUCTION

The American population over the age of 65 will double to 70 million by 2030 and increase to 82 million by 2050.[1] As the number of older adults increases, those regularly participating in sport activities will also likely increase proportionally. Likewise, there will be a rise in the number of musculoskeletal injuries and conditions resulting from the continued sport and recreational activities of these aging athletes for which sports medicine and orthopedic healthcare providers will provide care.

Balance training interventions have recently increased in popularity for their utility in rehabilitation as well as in performance enhancement. While most research on sport-related injuries and performance enhancement is performed on younger individuals, much research is available on age- and inactivity-related changes in the musculoskeletal system. Therefore, clinicians must combine their knowledge of the human systems that participate in controlling balance with their knowledge of physiologic changes associated with aging in order to determine the most appropriate assessments and interventions for aging athletes.

THE SYSTEMS CONTROLLING BALANCE & POSTURAL STABILITY

While "balance" is a commonly used term to describe the ability to maintain an upright position, "postural stability" is a more specific description of human balance. Postural stability can be defined as the ability of an individual to maintain their center of gravity (COG) within the base of support (BOS). Postural stability can be further identified as "static" or "dynamic" postural stability. An example of static postural stability is standing quietly without movement, while dynamic postural stability refers to the ability to maintain posture while performing specific movements, such as reaching forward or walking.

Many complex physiologic and neurological processes control postural stability. The musculoskeletal system and central nervous system (CNS) are the main systems regulating postural stability. While these systems can be delineated anatomically, they must be functionally understood as one "sensorimotor system." The sensorimotor system is recognized as a "looped" system involving afferent (sensory) information from peripheral receptors entering the central nervous system to be processed, and the efferent (motor) information sent back to the musculoskeletal system for action.

Afferent information includes signals from sensory receptors in peripheral joints. These receptors provide information from muscular receptors (muscle spindles and golgi tendon organs), joint capsule and ligamentous mechanoreceptors, and other receptors for touch, pressure, temperature, and pain sensation. Cumulatively, this afferent information is known as "proprioception," a term first defined by Sherrington in 1906 as the sense of position, posture, and movement.[2] More recently, Lephart and Fu[3] defined proprioception as the cumulative afferent input from specialized receptors into the CNS. They further subdivided proprioception into the awareness of joint position (i.e., joint position sense) and discernment of movement (i.e., kinesthesia).

Maintenance of posture relies on proprioceptive input from three important regions: the sole of the foot, the sacroiliac joint, and the cervical spine.[4-6] These three areas have been identified as postural regulators due to their density of mechanoreceptors and influence on movement and postural stability. Clinicians must act to ensure proper positioning and functioning of these regions during exercise and rehabilitation in order to facilitate adequate and appropriate proprioceptive information.

The afferent information is then processed in the CNS at one of three levels: the spinal cord (for reflexive activation); the lower and mid-brain (for automatic activation) or the cortex (for voluntary movements). Information from the sensorimotor system is then combined with information from the eyes and inner ear to coordinate an appropriate stabilizing reaction. Thus, the three main systems controlling balance are the sensorimotor, visual, and vestibular systems.

Once processed in the CNS, efferent information is sent to peripheral muscles. These efferent signals travel through alpha and gamma motor neurons to coordinate motor responses through both facilitory and inhibitory signals. These signals are sent to motor units (groups of muscle fibers innervated together) to either "contract" or "relax." The proper coordination of these signals between agonists and antagonists is the key to coordinated movement.

Humans use specific balance and righting reactions to maintain upright posture. The responses to changes in balance and posture are innate, automatic, and predictable in normal adults. These "automatic postural responses" (APR) are motor strategies that have been identified in response to specific directions of postural sway to maintain upright posture. Researchers have classified automatic activation of muscles in normal individuals through electromyography in response to anterior and posterior postural perturbations.[7,8] These APR precede voluntary movement and are not modified by conscious effort.[9]

Balance reactions can then be combined into higher level "strategies" to maintain postural stability in response to larger perturbations. These strategies include the ankle, hip, and step strategies. Horak and Nashner[7] reported that when small challenges were applied to the base of support, the ankle musculature was dominant in maintaining postural stability. When larger challenges were applied however, the hip joint became active to reposition the center of gravity over the base of support. Finally, if individuals could not maintain their center of gravity over their base of support in response to a challenge to postural stability, they took a step to move their base of support under the center of gravity.

BALANCE CHANGES WITH AGING

Although there is relatively little information available on balance and the older athlete compared to the sedentary older adult, there is evidence to support the fact that many of the same changes in systems controlling balance occur in active and inactive older adults, albeit to a lesser extent in athletes. For example, muscular strength is an important factor involved in maintaining balance since all body movements are produced via contraction of skeletal muscles. Muscles are particularly important in allowing the body to maintain postural stability since they work to keep the center of gravity within the base of support. Unfortunately, a reduction in muscle strength is a major component of normal aging, even in active older adults. With over a century of competition for Olympic gold medals, record-setting performances have improved by 20% to 90% in various strength events, while the age of the record holders has remained unchanged between 16 years and 31 years.[10] Data from the United States Weightlifting Federation[11] indicate that world records in competitive strength events decrease with increasingly older age-groups. These observations provide evidence that losses in muscle strength are not solely caused by the decrease in physical activity commonly associated with the aging process. Therefore, it is very possible that age-associated strength losses are due, in part, to various intrinsic age-related changes in muscle composition.

Quetelet and Cathcart et al.[12] recognized nearly 80 years ago that declines in strength accompany aging. Due to the relative ease in assessment, training response, and involvement in typical activities, the quadriceps muscle group has received the most attention with respect to age-associated changes in strength. Cross-sectional studies have shown that maximal quadriceps muscle strength is reached during the third or fourth decade of life.[13,14] Larsson et al.[15] studied 114 male subjects between the ages of 11 and 70 years with low daily physical activity and found that maximal isometric and dynamic strength of the quadriceps increased up to the age of 30 years, stayed constant up to the age of 50 years, and decreased thereafter with increasing age. Reductions in strength between the ages of 50 years and 70 years ranged from 24% to 36%. The age-related decline persisted when strength was expressed per unit body mass or fat-free mass. Age-related strength losses are also present in women. In a comparison of 20 year-old and 80 year-old women, knee extensor strength was 22% to 44% lower in the older women.[16]

Strength deficits are associated with the risk for falling in older adults.[17-19] Although many activities of daily living require minimal levels of strength, performing house work, shopping, using public transportation, carrying groceries, climbing stairs, and standing from a chair are only a few examples of activities that may be impossible to perform when strength is compromised.[20,21] Aniansson and colleagues[20] reported that 23% of senior adults aged 75 to 84 years had difficulty walking, while 55% had trouble crouching, kneeling, and stooping. Bassey et al.[22] have reported that several functional performances including chair-rising power and walking speed are correlated with leg strength. Greater postural sway and slower gait speeds have also been reported in individuals who sustained multiple falls.[23-25] Furthermore, many occupations require higher levels of strength and this poses a further problem as many individuals over traditional retirement age attempt to continue working. Once retirement occurs, the ability to continue favorite pursuits (e.g., participate in recreational and social activities, travel) is adversely affected by losses in strength.[26]

Several reasons may exist to explain why older people with less muscle strength tend to fall more often than younger matched counterparts. Deficits in leg strength are related to diminished gait velocity, stride length, and balance performance.[2,27-29] These deficits have been linked to an increased risk of falling.[30,31] In addition, hip extensor power is significantly related to the ability to rise from a chair, climb stairs and walk.[22] Improvements in quadriceps femoris and hip extensor muscle strength result in improvements in gait speed and stair climbing.[32] Another contributing factor may be that compromises in leg strength in aged muscle limit the ability to quickly correct a temporary loss of balance.[26] Increasing strength may offset some of the contraction speed-associated deficits observed in older adults, and further modify other factors (e.g., postural control, proprioceptive input, range of motion, joint destruction, fear) that would reduce the risk for fallsing.[31,33,34] Furthermore, skeletal muscle may protect bone against impact and prevent subsequent fracture even in the presence of decreased bone mass.[35] It is important to note that more active adults exhibit a smaller decline in muscle strength.[28]

In addition to muscle changes associated with aging, several diseases interfere with balance by affecting the sensory, neurological, cognitive and musculoskeletal functions of the elderly. For example, neurologic pathologies such as stroke with hemiparesis, Parkinson's disease, dementia, seizures, peripheral neuropathies and vestibular dysfunction can predispose older adults to falls. Musculoskeletal disorders, including arthritic conditions that weaken muscles or bones and joints, affect postural stability.[36] When a joint such as the knee or ankle develops arthritis (or has been replaced), its surrounding muscles often suffer from impaired coordination and position awareness, resulting in poor balance and an increased risk of falling. In addition, metabolic conditions of hypothyroidism, hypoglycemia, and diabetes, also increase the risk for falls.

A common cardiovascular risk factor is orthostasis or a reduction in the systolic blood pressure of at least 20 mmHg when transitioning from a laying/seated position to a standing position. Orthostasis results in an inadequate blood flow to the brain, producing dizziness that can cause a fall. Blood loss or fluid volume depletion resulting from exercise, diarrhea, gastrointestinal bleeding, or dehydration can contribute to the occurrence of orthostasis.[37] In addition, myocardial infarction, dysrhythmias and cough syncope in chronic lung disease can also trigger hypotensive episodes that lead to falls.

Polypharmacy, or the use of four or more prescription medications, is a common cause of falls.[38] Many of the most commonly prescribed drugs for older people can contribute to falls. The use of drugs such as sedative hypnotics, anxiolytics, antidepressants and tranquilizers, can cause confusion and sedation that have been identified as contributors to falls. In addition, antihypertensive drugs and cardiac medications often produce postural hypotension and fatigue.[39] Tinetti and Speechley[37] have proposed a direct relationship between the number of drugs an older person takes and the frequency of falls.

THE PATHOPHYSIOLOGY OF FUNCTIONAL JOINT INSTABILITY

Joint stability results from both static (structural) and dynamic (functional) mechanisms. Static stability is provided by anatomical structures such as joint capsules, ligaments, and articular structure. Dynamic stability is provided by the joint musculature, acting as functional secondary restraints to excessive joint movement. Muscles act reflexively to stabilize joints.[40] This dynamic stability relies heavily on the afferent information from joint receptors and muscle receptors and the efferent information resulting from CNS processing.

Articular receptors contribute significantly to postural reflexes, joint stabilization, and motor control.[5,41,42] A reflex loop exists between a joint's mechanoreceptors and the muscles surrounding the joint.[43,44] This reflex loop maintains dynamic joint stability via gamma motor neurons, therefore demonstrating that muscles and mechanoreceptors influence each other.[41,42,45] This stability is regulated through feedback and feed forward mechanisms. Feedback regulates motor control through reflex loops between the mechanoreceptors and muscle spindles, while feed forward mechanisms plan movement based on experience. An example of the importance of the feed forward mechanism is the activation of the transversus abdominis muscle prior to movement of the extremities, regardless of direction and speed of movement.[46,47]

Functional instability of joints can be defined as a repetitive loss of joint stabilization ("microinstability," "chronic subluxation") occurring during functional activities. The term "Functional Instability" (FI) was first used by Freeman and colleagues[48] to describe the condition where patients with chronic ankle sprains demonstrated a normal clinical exam of the structural components, but experienced repeated injury. The researchers suggested that FI was caused by the loss of afferent information from damaged proprioceptors in the ankle joint ligaments and capsule, and termed this "deafferentation."

Afferent joint information has been shown to influence muscle tone, most likely due to the reflex loops between the joint mechanoreceptors and muscle spindles surrounding the joint. Most noted is the reflex inhibition of the quadriceps muscle in the presence of knee effusion as demonstrated in several research studies.[49-52] Researchers have also identified delayed firing of stabilizing muscles in patients with chronic instability in the low back,[53] ankle,[54,55] and knee.[56] Functional instability often results in repetitive injury and overuse syndromes. Patients typically present with normal clinical evaluation, but experience symptoms of "giving way" during activity. This condition typically occurs in the ankle, knee, and shoulder joints, but may also be present in patients with chronic low back and neck pain. Clinical research has demonstrated a relationship between chronic joint instability and poor postural stability, indicating a possible CNS component to chronic joint instability and many studies have identified deficits in postural stability in subjects with joint instability, including the ankle, knee, low back, and neck.[57-67]

When discussing joint stability, it is important to note that the most significant contribution of muscle is not strength, but the unconscious reaction and speed of contraction for reflexive stabilization. Only 25% maximum voluntary isometric contraction (MVIC) is required to provide joint stiffness;[68] thus, strengthening exercises alone may not be the most appropriate intervention for rehabilitating functional joint instability.

ASSESSMENT OF BALANCE IMPAIRMENT

Recently, a variety of assessment tools focusing on balance performance have been developed and validated. These tools are designed to predict outcomes and to provide objective measurement of balance for screening, baseline status, changes over time and the effects of interventions. Both static and dynamic balance can be assessed using sophisticated methods such as computerized force-platform posturography.

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.[69] The applied force and force-moment signals are used to electronically calculate an individual's center of pressure. Increased postural sway, both in 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 standing 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 in Balance (CTSIB) is one test of postural sway that is designed to measure the influence of sensory input on balance.[70] 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. Two additional conditions for the test include use of a "dome" or other means to distort the accuracy of the visual input on both flat surface and on foam. 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 ten seconds of data collection. A trial is considered unsuccessful if the participant takes a step or is unable to balance for the coordinates determined on the force platform, Microsoft 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 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 declines in dynamic balance are observed much earlier.[71] Dynamic balance tests stress the balance control systems and therefore greater losses in balance are typically seen during these types of tests.[72] Often, dynamic tests are performed in combination with static balance tests.

Although computerized posturography is an excellent technique for the assessment of balance, many rehabilitation clinics do not have access to such equipment. In lieu of these methods, several tools are available to allow the rehabilitation professional to evaluate the patients who have fallen and accurately identify risk factors. One such test of static balance is the One-Leg Balance Test which is performed by having the patient stand unassisted on one leg for five seconds.[73] The participant stands on the preferred foot while resting the hands at waist level and then raises the other foot approximately ten centimeters off the floor. Balance is scored by the number of seconds for which the foot is kept raised or until balance is lost. A stopwatch is used to time the test. Dynamic balance can be evaluated using the Functional Reach Test.[74] Functional reach is defined as 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 "zero" centimeter 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. The tester or a designated spotter 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.

Another test that is easy to administer and that has been shown to be valid in identifying those at risk for falls is the Timed Up – and – Go Test (TUG).[75] This test evaluates physical mobility (gait speed and agility) and dynamic balance. The test begins with the participant fully seated in a standard armchair (seat height of approximately 46 cm [18.4 in.]). The subject is allowed to push off the sides or arms of the chair to aid in getting up from the chair. The subject can also use any walking aid (e.g., cane or walker) during the test if the patient normally uses one. On the signal "go," the individual stands from the chair as quickly as possible, walks around a cone placed three meters (ten feet) in front of the chair, and returns to a seated position. The participant is told 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. The subject can be allowed to walk through the test for practice. A stopwatch is used to record the time from the signal "go" until the patient returns to a seated position. The participant is observed and any apparent balance or gait problems should be noted. If it takes the individual longer than 30 seconds then that patient has a high risk of falls and requires assistance.

An individual's physical function can also be assessed using a performance-based test such as the Tinetti

Performance Oriented Mobility Assessment.[37] This test requires the participant to stand from a chair, step forward and then stand with the feet as close together as possible while the examiner nudges the patient by pushing lightly on the sternum. The subject is then asked to stand with the eyes closed, open eyes and turn 360 degrees, walk 25 feet at a normal speed, turn and walk back to the chair at a faster speed and then sit down. The test, which can be conducted in less than three minutes, is scored from zero to 28 points with balance and gait subscores. Scores of less than 20 points are associated with a fivefold increase in risk for falls.[37] Results are generally very reliable and provide valuable information for detecting gait and balance problems that can be addressed with specific therapy. The participant's performance of these activities is then evaluated to identify any balance impairments and assess the risk for falls.

DESIGNING AND IMPLEMENTING A BALANCE TRAINING PROGRAM

Sensorimotor Training

Balance training is a useful intervention in rehabilitation of postural stability impairments as well as in training programs for performance enhancement. While balance training generally means exercise on unstable surfaces, a more specific program has been developed by Dr. Vladimir Janda, a pioneer in identifying and treating chronic musculoskeletal pain related to sensorimotor dysfunction.[76] Janda's program is aptly named, "Sensorimotor Training" (SMT). Sensorimotor Training can be characterized as a progressive balance training program using labile surfaces to elicit automatic postural stabilization.[77] Exercises and devices for balance training should not be implemented randomly or haphazardly. While research on resistance training shows that progressive increase in resistance intensity leads to increases in strength, specific research on the dose and progression of balance training is still lacking. However, it is possible to infer the amount of challenge to the BOS or COG in maintaining postural stability as "intensity levels" during balance training; therefore, the more difficult to maintain balance, the higher the intensity of the balance exercises. It is important to remember the goal of each balance exercise is to perform with appropriate postural stabilization. The goal is not simply to "balance" on an unstable surface. Too often, clinicians impart excessive challenge to patients performing balance exercises, who in turn develop various compensatory and potentially harmful sensorimotor strategies. Proper dosage and progression of balance training is important to improve postural stability with appropriate motor strategies.

The intensity of a balance exercise can be manipulated through the systems controlling balance: the sensorimotor, visual and vestibular systems. This addresses the SAID (Specific Adaptations to Imposed Demands) principle, where systems adapt specifically to the demands placed upon them.

The sensorimotor system is first challenged by manipulating the BOS and the COG. The BOS is challenged by decreasing the size of the base of support (such as going from two- leg to one-leg standing), or by adding a labile surface (Figure 1). Labile surfaces, such as foam pads, balance boards, balance sandals and exercise balls have been shown to increase muscle activation and speed of contraction

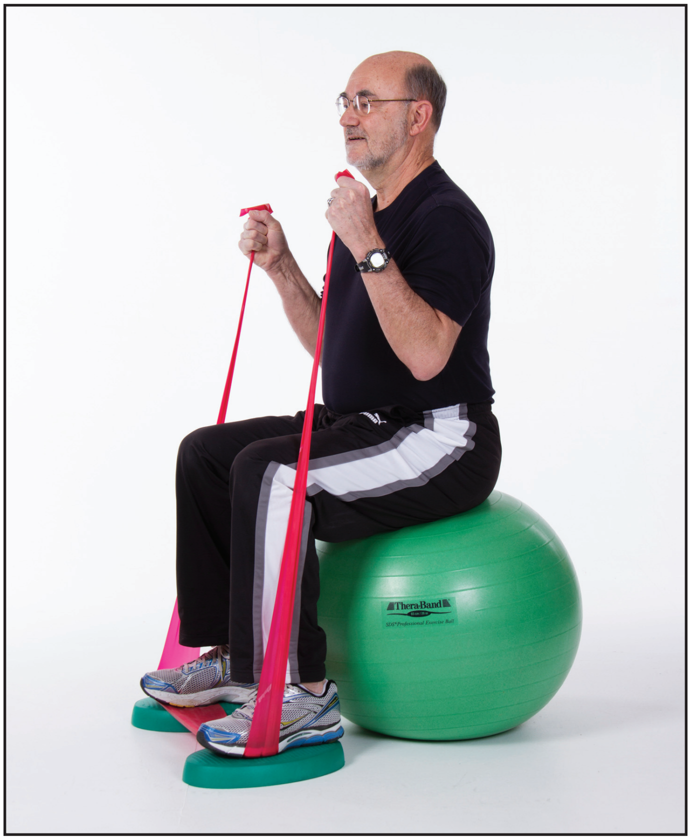

Figure 1. *Labile surfaces - foam pads and exercise ball.*

compared to stable surfaces.[45,56,78,79] Thus, labile surfaces activate the postural mechanisms (i.e., APR) vital to maintaining postural stability. The COG is then challenged by adding weight shifts, perturbations or movement of the extremities (including resistance training).

Next, the visual and vestibular systems can be challenged by closing the eyes or turning the head, respectively. Rogers et al.[77] identified a progression of labile surfaces with and without eyes closed. Subjects demonstrated progressive increase of postural instability using foam pads, air-filled disks and wobble boards with eyes open (progressing between 74% and 172%). Postural sway was significantly increased (between 340% and 1000%) when subjects closed their eyes while standing on the device. Because of the higher increases in postural sway with eyes closed, the researchers recommended introducing labile surfaces with eyes open through the progression before adding additional challenge of the visual system.

Posture is the most important consideration when performing SMT. Before training the sensorimotor system, afferent input must be optimized from the three key joints mentioned previously regulating posture. The first postural key point is the foot.[5] Proprioceptive exercises are best performed without shoes (barefoot is best) to ensure the maximum amount of appropriate afferent information entering the sensorimotor system.

The remaining afferent joints in postural stability are the sacroiliac joint6 and cervical spine4 due to their high densities of mechanoreceptors. These regions should be first actively stabilized in a "neutral" position during exercise. It is important that any dysfunction of the sacroiliac joint or cervical spine be addressed prior to initiating SMT because of their role in proprioception.

The older athlete should progress through three stages of SMT: Static, Dynamic and Functional. Within each stage, individuals progress through exercises in (1) different postures, (2) progressive BOS and (3) challenges to the COG. Each exercise should elicit automatic and reflexive muscular stabilization, challenging the patient to maintain postural control under a variety of situations.

Static Phase of Sensiomotor Training

In the static phase, emphasis is placed on developing a stable pelvis and core from which to build movement in subsequent phases. Without a stable base at the pelvis, extremity movement will be compensated elsewhere in the kinetic chain. This is the principle of "proximal stability for distal mobility." Vary the BOS by progressing from a firm surface to a foam surface, and then progress to the balance boards. These progressive challenges to the BOS gradually increase postural sway.[77] During the static phase, the older athlete is challenged to maintain their COG using passive weight shifts or challenges to their COG. These weight shifts and perturbations are used to elicit reflexive and automatic postural reactions[80] and can be performed manually or with elastic resistance bands (Figure 2).

Dynamic Phase of Sensiomotor Training

Once the older athlete exhibits the ability to maintain postural stability under a variety of BOS in the static stage, the clinician may progress the challenges of their COG in the dynamic phase. The individual begins "building" on the stable pelvis by performing movements of the upper and lower extremity, gradually adding resistance to the movements. One of the most effective exercises to elicit automaticmuscular contractions of the leg is the "T-Band Kicks" (Figure 3). Several studies have demonstrated reflexive activation of muscles in the stance leg while kicking an elastic band with the other leg.[81-83]

Functional Phase of Sensiomotor Training

The final stage of SMT is functional progression of postures with extremity movement on various BOS. These include walking, squats, lunges, steps, jumps, and running. Advanced SMT activities combine many different challenges to postural stability. For example, patients may perform a lunge onto a wobble board with a concurrent anterior weight shift using an elastic band (Figure 4). In addition, sport-specific exercises that incorporate extremity movement can be performed for activities such as golf, tennis, and bowling (Figure 5).

Sensiomotor training exercises are performed either to fatigue or for a certain amount of time. Rather than prescribe a specified number of repetitions, have the older athlete perform the exercise under

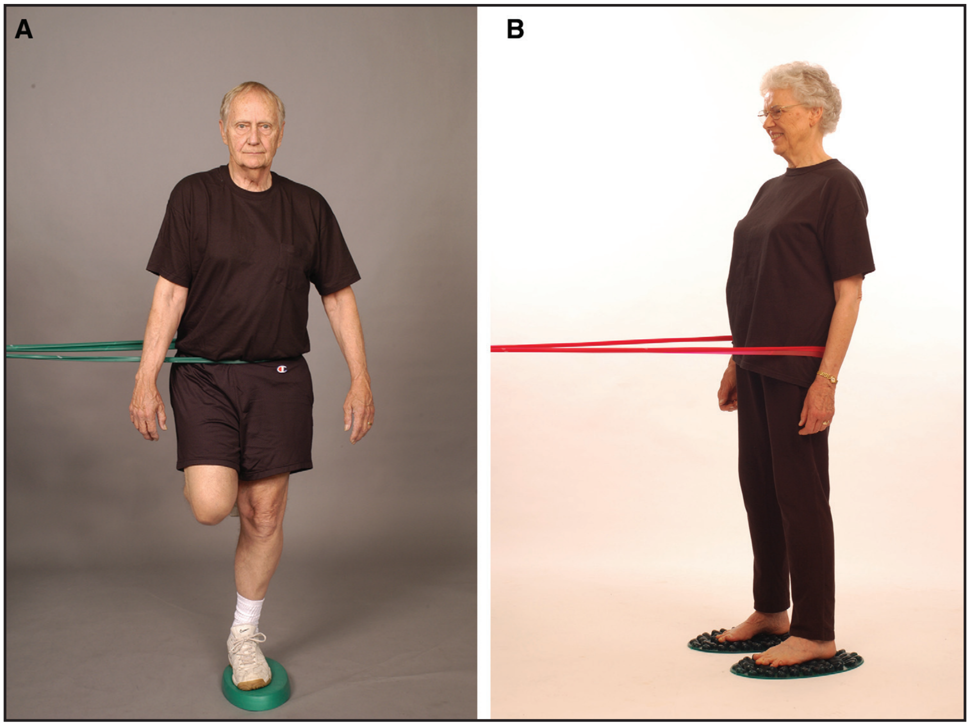

Figure 2. *a) Medial and b) anterior weight shift with elastic bands.*

Figure 3. *T-Band Kicks.*

Figure 4. *Reaching for an object on the floor.*

direct supervision to the point of fatigue. The goal of SMT is to increase muscle reaction and tissue endurance rather than total joint strength. Instead of focusing on strength, the focus is placed on restoring the automatic reflexive stabilization for dynamic restraint. At the first sign of fatigue, the initial burn-

Figure 5. *Sport-specific activities for golf (a-c), tennis (d-e), and bowling (f-g).*

ing sensation or any compensated movement, the exercise should be stopped to avoid further compensatory movements that may promote dysfunction. Therefore, quality is more important than quantity when performing SMT.

Sensiomotor Training Outcomes

Balance training alone can produce strength gains similar to resistance training.[84] German researchers compared the strength gains of a group of individuals training with conventional weight machines with group training with SMT techniques. The researchers noted equal improvement in strength in both groups, but also noted an improvement in postural stability (100% more than the strength training group), as well as restoration of normal muscle balance in the lower extremity.[84] Therefore, SMT may be considered a more efficient mode of training.

A 12-week program utilizing foam pads and strength-training exercises using elastic bands was also performed in a community senior center.[85] 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. To enhance muscular strength, participants performed a series of exercises using elastic bands while sitting in chairs. Significant improvements were observed for the limits of stability in the directions that are most associated with fall-related hip fractures, namely the right, left, and back directions. In addition, lower body strength improved by 20%. No changes were observed in any of the balance or strength variables for the control group.[85]

SMT improves proprioception, strength, and postural stability in a variety of lower extremity conditions, including ankle instability[59,86,87] and anterior cruciate ligament (ACL)/knee instability.[56,78,88-90] In fact, SMT has been shown to be more effective than traditional rehabilitation at improving function and muscle reaction in ACL reconstruction rehabilitation.[78,88] Finally, training with balance boards and foam surfaces decrease the risk of ACL and other sports injuries.[91-96]

SUMMARY

Sensorimotor training is a scientifically-based progression of balance training that specifically targets the systems controlling postural stability. Sports and orthopedic physical therapists will have to continue to combine their knowledge of sports medicine in younger athletes with their knowledge of the aging body as research yields new information on balance training in the aging athlete.

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