Sensory-motor training

Introduction

Balance is an essential function of the locomotor system. It is often ignored but no less important than flexibility, strength, endurance, or aerobic fitness. Balance dysfunction is part of the clinical picture for a variety of conditions such as vestibular disorders, ankle sprain or instability, ataxia, knee osteoarthritis or instability, chronic low back pain, hemiplagia and diabetes. Therefore, rehabilitation should address balance as an important function to be restored in many patients presenting to health care providers.

Why is balance important in musculoskeletal rehabilitation?

- Konradsen demonstrated that delayed reaction time of the peronei contributed to ankle instability (Konradsen & Raven 1990).
- Byl has shown that poor control of anterior to posterior (A to P) body sway on a rocker board as well as poor one leg standing ability differentiated asymptomatic individuals from low back pain (LBP) patients (Byl & Sinnot 1991).
- Delayed hamstring reaction time is correlated with anterior cruciate ligament (ACL) injury (Ihara & Nakayama 1986).
- Balance deficits have been shown to be predictive of future ankle sprains in soccer players (Tropp et al. 1984a).

Proprioception loosely defined means the ability to receive and process sensory input. Sensory information enters the central nervous system (CNS) from exteroceptors of the skin, position and movement detectors of the joints and muscles and is further correlated with information from visual and vestibular centers. This sensory information is formatted and reformatted in subcortical centers and then begins its efferent decent to the periphery where the actual movement is realized.

Neurophysiology of the balanced system

The motor system depends on appropriate input from somatosensory, vestibular, and visual peripheral afferent systems. Without one of these systems, as in blindness, balance and equilibrium are not sacrificed. However, if there is a conflict between two of the systems then a problem will ensue. Classic examples are getting nauseous on a boat when the vestibule notes the motion but the feet and eyes do not. Or, lying on the grass on a breezy day with big, puffy clouds floating by. The skin and vestibule register no movement while the eyes do. Dizziness or nausea may result from such a sensory conflict. The somatosensory afferent system depends on the soles of the feet, the neck, and the lumbar spine for inputs, Neck or back pain has been shown to be related to faulty somatosensory input (Lewit 1988; Byl & Sinnot 1991).

The human body is an inherently unstable system. According to Winter 'Because 2/3 of our body mass is 2/3 of body height above the

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ground we are an inherently unstable system, unless a control system is operating' (1995). In response to a sudden load 'the muscles will respond rapidly to stabilize the body. i.e. they will try to maintain balance and posture' (Wilder et al. 1996).

Different muscles contribute to stance and gait stability. The key stabilizers during quiet stance are the ankle dorsiflexors/plantarflexors. During A to P perturbations of stance or gait it is the hip flexors/ extensors. During medial to lateral perturbations of stance or gait it is the hip abductors/adductors (Winter 1995).

Vestibular dysfunction is known to be related to poor motor development in children. Children with vestibular deficits cannot stand in a darkened room (you need two out of three afferent systems to maintain motor function). Vestibular exercises for the treatment of dizziness have been around awhile. Hammocks and gym balls help train the labyrinth. Tracking exercises for the eyes with the head moving are well accepted.

The visual system can be an interesting area involved in dizziness or neck pain. It has been shown that optokinetic reflexes can be trained (fighter pilots, figure skaters) (Eikemeier et al. 1979). It has been shown that there is often a mapping error of visual fields which results in increased tension in the upper trapezius (Gagey 1987; Martins Da Cunha 1987). Following correction with special prismatic lenses the trigger points dissolve spontaneously.

Clinical aspects

Lewit has studied the relationship between cervico-cranial joint dysfunction and equilibrium problems (Lewit 1988). He has found that a cervical relationship exists which if corrected improves standing postural dysfunctions. Correction involved postisometric relaxation to the sternocleidomastoid muscle, masticatory muscles, or cervicocranial joint. Hautant's test is an essential screening tool for finding the cervical dysfunction and then treating the related muscles or joints (Fig. 1) (Lewit 1999). Gagey has developed a systematic way of studying the connection between the postural system and the balance system (Gagey 1986, 1991, 1996). Differentiating between primary feet, lumbar and cervical disorders is crucial. He has found the Fukuda-Unterberger test to be extremely helpful in identifying when the tonic neck reflexes are involved in a gait problem (Fig. 2) (Gagey 1996).

Improving balance and speed of contraction is crucial in spinal stabilization because the activation of stabilizers is necessary to control the neutral zone. The goal of sensorimotor exercise is to integrate peripheral function with central programming. Movements that require conscious and willful activation may be monotonous and prematurely fatiguing to the participant. In contrast, movements that are subcortical and reflexive in nature require less concentration, are faster acting and may be eventually automatized. Unexpected perturbations lead to reactive responses. Expected perturbations lead to anticipatory postural adjustments (APAs). Training can lead to the incorporation of APAs into reactive situations. During a jostle from a stance position the

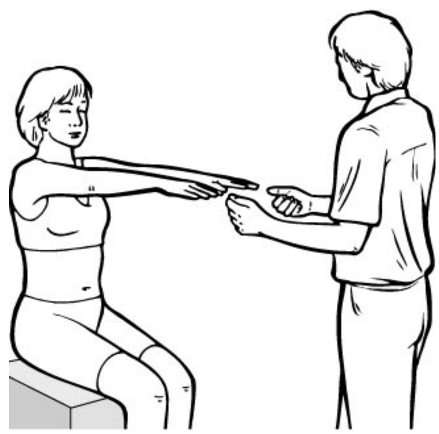

Fig. 1 Hautant's test (Lewit 1999).

- Seated patient with arms forward.
- Eyes are closed and head is turned (extended, or turned and extended).
- Test is + if arms deviate with specific direction of neck movement.

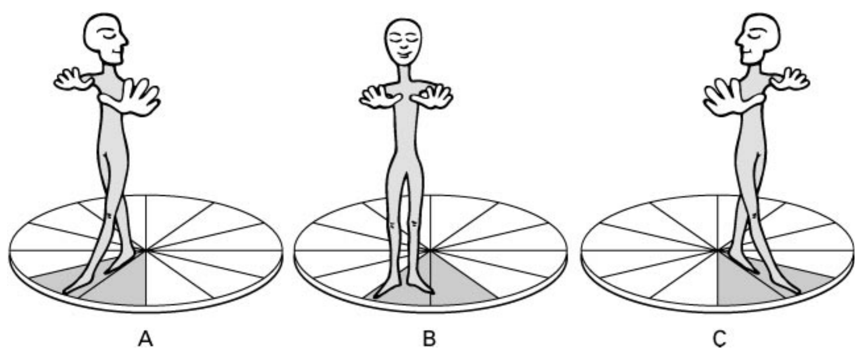

Fig. 2 Normal Fukuda-Unterberger Stepping test (Gagey 1996). (B) Pre-requisite for accurate test is lack of visual or auditory stimuli to orient patient once eyes are closed (e.g. quiet room without strong light source).

- Patient stands with arms reaching forward in a horizontal position.
- Fixes gaze straight ahead.
- Eyes are closed and the patient marches in place with the thighs raised about 45°.
  The place should be medium, about 1.4 Hz. Test is + if legs rotate more than −30° in either direction. (A and C) Test is the same as above except that prior to marching the head is turned to the left (A) or right (C). Test is + if legs rotate ipsilateral to the side of neck rotation or if they rotate contralaterally >30°.

stance leg/hip abductors undergo 'intense' activation. After APA training the load is decreased (McIlroy & Makin 1995).

Balogun et al. showed that balance board training could be a very efficient tool in rehabilitation because it actually produced greater lower extremity strength gains than did a series of isotonic exercises taking far longer (Balogun et al. 1992). Sensory motor therapy with balance sandals has been shown to increase the speed of contraction of key hip stabilizers (Bullock-Saxton et al. 1993, Janda & Va'vrova' 1996).

Poor balance and clinical conditions

One of the most serious clinical conditions related to poor balance is ataxia. This is a condition which effects primarily the elderly and results in frequent falls.

Ataxia

- Brandt et al. have found that elderly with ataxia can be treated successfully with balance training (Brandt 1981).
- Two weeks of training was shown to lead to significant improvement 9 months later without any home maintenance program.
- Thick foam is used on the floor to deprive the feet of sensory feedback and the eyes are closed, thus forcing the vestibule and somatosensory systems to train hard.
- Similarly, you can train the eyes and feet by leaving the eyes open, but tipping the head back (taking the otoliths out of their functioning range).
- In another 5 week balance program only shorter term results were achieved, thus suggesting for maintenance of results that training may need to continue (Seidler 1997).
- Two different trials of Tai Chi showed that a longer term program improves balance abilities of older adults and that improvement persisted after training stopped (Wolf et al. 1996; Wolfson et al. 1996).

A variety of musculoskeletal conditions from ankle sprain to low back pain have been shown to be correlated with poor balance.

Low back pain

- Balance in low back pain patients has been found to be impaired compared to asymptomatic subjects (Byl & Sinnot 1991; Alexander et al. 1998; Luoto et al. 1996 and 1998; Mientjes & Frank 1999; Takala et al. 1998).
- Sensory motor training has been shown to be more effective than traditional exercise for treating non-specific low back pain (Oostendrop 1988).

Neck pain and cervicobrachial pain syndromes

- Balance has been shown to be disturbed in individuals with neck pain and cervicobrachial pain syndromes (Lewit 1988; Karlberg et al. 1995; McPartland et al. 1997).

Ankle instability and sprain

- Balance training can improve postural sway and single-leg standing balance in patients with functional ankle instability (Bernier & Perrin 1998; Rozzi et al. 1999).
- Six weeks of balance training improved balance and stability in soccer players with functional instability (Tropp & Askling 1984; Gauffin et al. 1998).
- It also prevented future injuries in soccer players with ankle instability (Tropp et al. 1985).
- A 5 week wobbleboard training program has been shown to improve movement discrimination for both ankles in elite rugby league players (Waddington et al. 1999).
- Discrimination of inversion movements is compromised when there is a history of ankle sprain (Waddington et al. 1999).
- Peronei weakness as well as delayed speed of contraction have been shown to correlate with impaired balance (Konradsen & Raven 1990; Tropp 1984b).

Knee instability and osteoarthritis

- A sensory-motor (SM) training program was compared to resistance training in patients with knee instability.
- Those who underwent SM training improved their hamstring reaction time whereas those who did resistance training did not (Ihara & Nakayama 1986).
- Poor balance has been found in individuals with bilateral knee osteoarthritis more so than in an age-matched control group (Wegener et al. 1997).
- Poor balance has also been identified in ACL deficient knees (O'Connel et al. 1998).
- In a prospective, controlled study it has been shown that soccer players who undergo balance training can prevent ACL injuries (Carrafa et al. 1996). The trained group included 600 players while the control group consisted of 300 players.

Evaluation

Balance can be assessed with the single-leg stance test (Janda &

Va'vrova' 1996; Bohannon et al. 1984). The single-leg stance test is performed with the hip flexed to 45° and the knee flexed to 90° so that the knee is in front of the standing leg and the foot behind the standing leg (Liebenson & Oslance 1996). Single-leg stance may assess function in two ways:

1. Assess proprioception — patient is instructed to stand on one leg with their eyes open. The patient is then instructed to close their eyes and maintain the stance. The patient should be able to maintain this single leg standing for at least 10 seconds, without their foot lifting up or shifting or opening their eyes. closing the eyes removes a significant sensory input and requires that the patient have adequate awareness and kinesthetic responses to maintain balance (Fig. 3).
2. Assess gluteus medius — as the patient is instructed to shift from two-leg to one-leg standing, the pelvis should remain relatively level and not shift greater than one inch towards the weightbearing side within the first 20 seconds of single-leg standing. The position is held for 20 seconds and the following errors should be looked for : >1 inch side shift; pelvic unleveling.

The one leg standing test can be quantified (Bohannon et al. 1984). Perform by raising one foot without touching it to the support leg. Begin with the eyes open and practise once or twice on each side. Then with gaze fixed straight ahead have the patient close his/her eyes and maintain balance up to 30 seconds. Failure occurs if the foot touches the leg on the support leg, hopping occurs, the foot touches the floor, or the arms touch something for support. The patient should be given a 2–4 chances to reach a peak performance (Table 1).

Table 1 Normative data for single-leg standing balance test — eyes closed (Bohannon 1984)

Age (years)	Eyes closed (seconds)
20–49	24.2–28.8
50–59	21.0
60–69	10.2
70–79	4.3

The bodies reaction to an unexpected perturbation is important to evaluate. Wilder et al. showed that muscles exhibit a slow reaction time, decreased peak output, and increased after discharges when a load is unexpectedly altered (1996). Whereas Wilder et al. used high-tech computerized laboratory equipment, a simple way to evaluate an individual's response to an unexpected perturbation has been shown by Janda (1988). The test involves gently, but unexpectedly pushing the standing patients sacrum forward. This unexpected perturbation results in a forward displacement of the patients torso. The depth of the forward displacement, the latency (time period) before equilibrium is restored, and the number of oscillations that occur all contribute to the clinicians subjective appreciation of the patients stability response.

Sensorimotor therapy

Janda's approach begins from the ground up with careful attention to formation of an actively shortened longitudinal arch of the foot without flexion of the toes (Bullock-Saxton et al. 1993; Janda, Va'vrova' 1990, 1996). This is called the short foot and is based on the work of Freeman et al. (1965) (Fig. 4). Freeman demonstrated that a 'short foot' position would increase proprioceptive outflow. Patient's often have difficulty consciously producing the 'short foot' and thus a

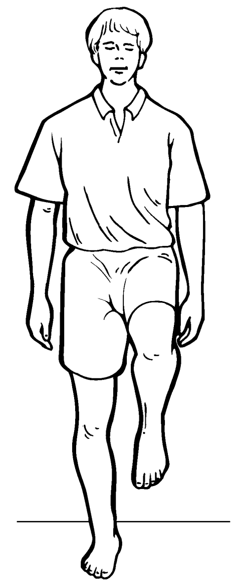

Fig. 3 Single-leg standing balance test.

number of alternatives to formation of the 'short foot' have been suggested. Turning the knees out without moving the feet is an easy 'trick' that lifts the arch. Lewit recommends gripping with the toes to activate the deep arch muscles (Lewit 1999). Exercises proceed from sitting to standing and from stable to labile surfaces. The 'short foot' position is maintained throughout most of the exercises.

An excellent beginning balance exercise is simply to stand on one leg in a doorway for 30 seconds (Fig. 3). This can be progressed to eyes closed. The patient should be encouraged to avoid reaching out and if they can't last the full 30 seconds to do a few repetitions until 30 seconds is achieved cumulatively. This exercise should be performed twice a day.

In standing, various leaning movements are introduced and explored. A single step taken forward with a forward lean (i.e. lunge) and held there emphasizes alignment, coordination and balance. The same is done with a single backwards step with the torso aligned upright and the ischia

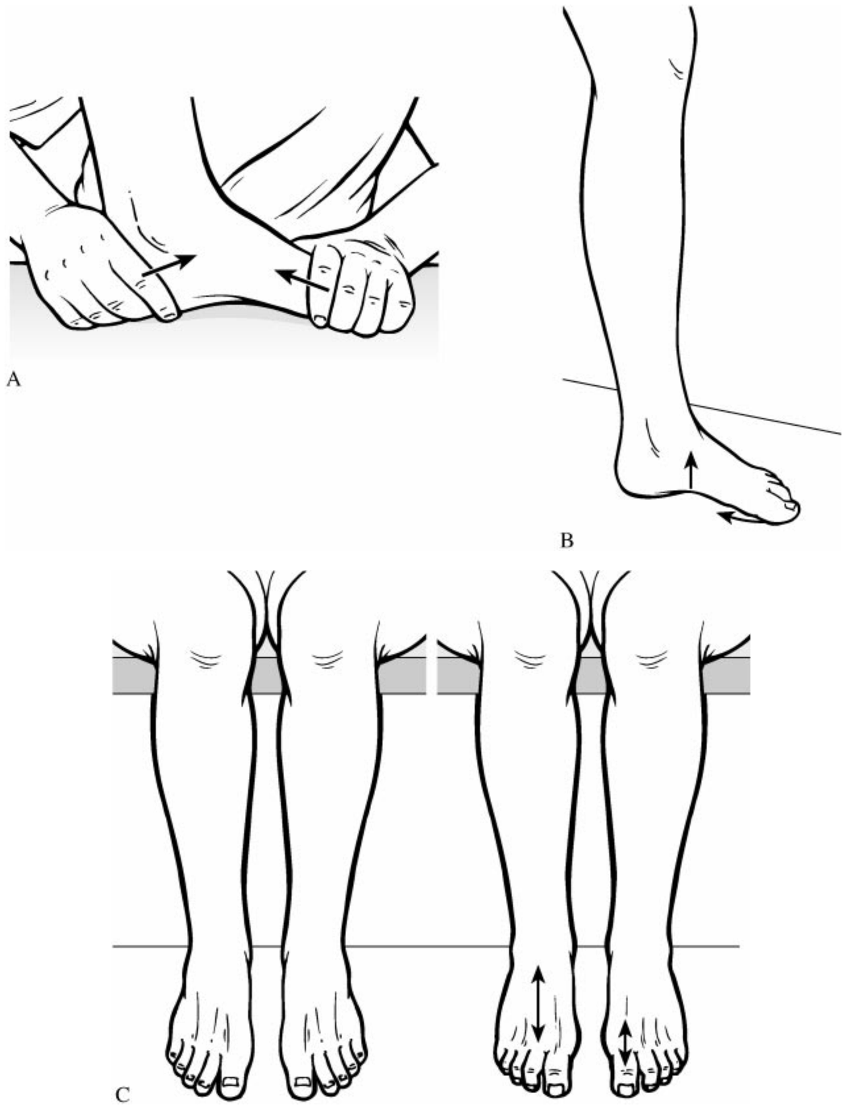

Fig. 4 Proper foot position for balance training. (A) Passive modeling the 'small foot'. (B) Active modeling the 'small foot'. (C) Gripping of the toes after Lewit 1999.

over the heels. These fundamental movements emphasize balance during postural challenges that simulate activities of daily living. Lunges can be performed slowly 6–12 times, once/day.

In order to elicit fast, reflexive responses the patient is 'pushed' quickly but gently about the torso and shoulders. This challenges the patient to remain upright and respond to sudden changes in their center of gravity. In such a way the patient develops a 'reflex' APA strategy. These pushes are performed in two-leg and in single-leg standing with the eyes open. Closing the eyes while performing these exercises focuses the participant's awareness on kinesthetic sense and is more challenging to perform.

Each push creates a quick loss and re-establishment of balance. Sudden changes in the center of gravity requires fast reflex responses to maintain balance and to protect joints from the untoward effects of uncoordinated and delayed muscle contraction. Such reflex pushing can be performed for anywhere from 30–90 seconds.

To further challenge reflexive righting movements, the subject is placed on a labile surface, i.e. the rocker board.[1] The rocker board is unstable in one plane only. The patient stands on the board in various directions in order to control the plane of instability. Again, the exercises proceed from two-leg standing to single-leg standing, and pushes are utilized to elicit a fast response. Arm movements overhead, catching a ball, head turning, reflex pushing, etc are clever and fun ways to vary the center of gravity and make the program interesting (Janda, Va'vrova' 1990, 1996). Balance board training should last between 5 and 30 min/day.

Mixing stable and labile surfaces are more advanced skills. Stepping from floor to board, on two legs, on a single leg, mixing surfaces from rocker to wobble, etc are ways to vary the terrain. One is limited only by one's imagination and the needs of the patient: a competitive athlete will require more challenging sensory-motor training than a sedentary office worker.

Janda has devised a unique pair of balance sandals[2] consisting of a rigid sole configured to support the longitudinal arch and metatarsal heads as in the 'small foot' (Bullock-Saxton et al. 1993; Janda, Va'vrova 1990, 1996). On the bottom of the sole, a rigid hemisphere about the size of a tennis ball is fixed at the midway point. This essentially creates a pair of mini wobbleboards to carefully walk upon. The goal is to walk very slowly, taking tiny steps initiated by lifting the knees up. The patient should practise stepping in place, while near a wall for support. Progressions include

[1]A rocker board build to Pr. Janda's specification is available in the United States from the Gym Ball Store www.gymball.com, (800) 393-7255 or O.P.T.P. (800) 367-7393.

[2]Balance sandals are available from O.P.T.P. (800) 367-7393.

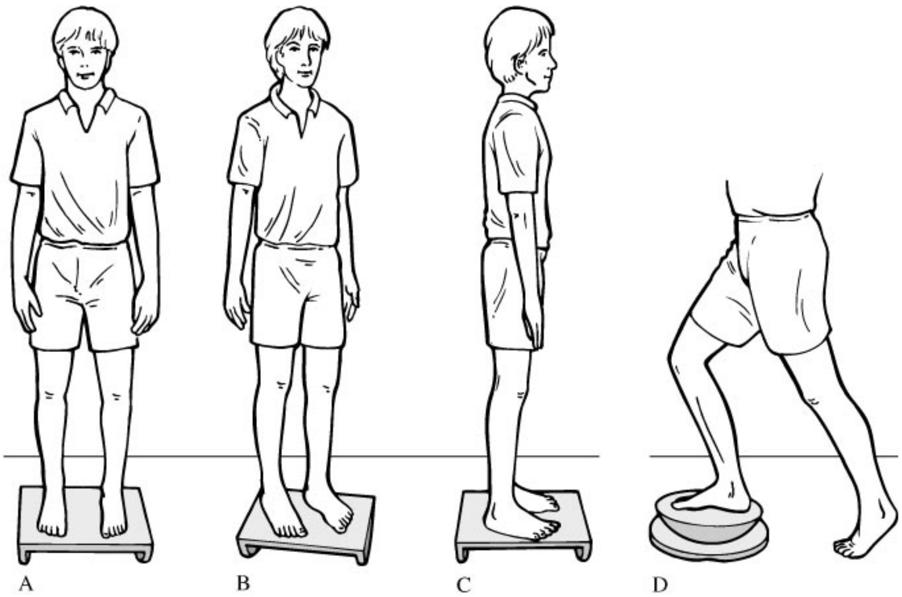

Fig. 5 Basic balance training options. (A) Sagittal plane rocker board. (B) Oblique plane rocker board. (C) Frontal plane rocker board. (D) Wobble board single leg.

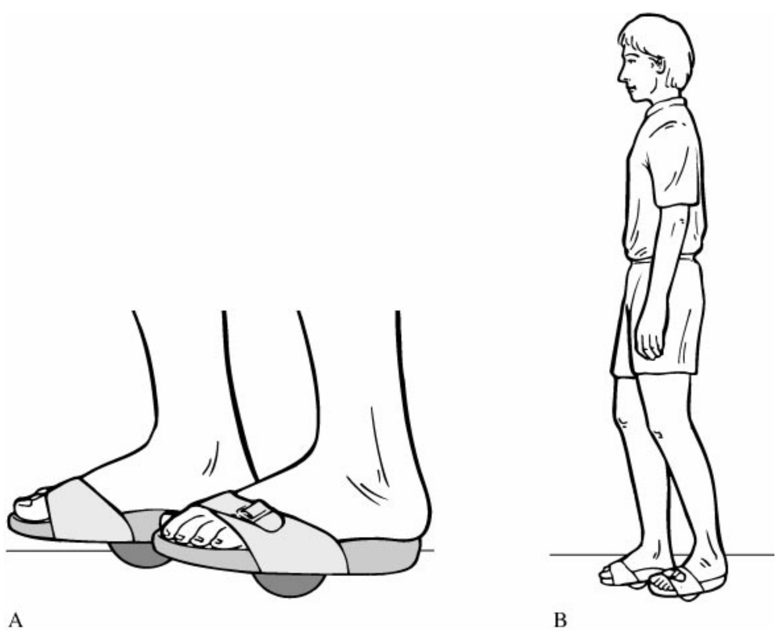

Fig. 6 Balance sandals.

taking small steps forward, backwards and sideways. At all times the 'small foot' should be maintained and the sandals platform should be kept as level as possible. In one study, after 2 weeks of prescribed exercise the speed of contraction of the gluteus maximus and medius were increased by as much as 180% to 200% and remained so as much as 6 weeks post exercise without further reinforcement (Bullock-Saxton et al. 1993). The patient should attempt to practise with the balance sandals 5 min/session — three times/day.

A patient with decreased balance ability should be progressed through a balance training program which stays at a fairly challenging level so that it does not become boring. The office and home routines will often vary. In the office, 'reflex pushing' and more advanced balance apparatus can be used. At home, once a patient learns to perform the 'small foot' or gripping exercise and can stand for 30 seconds on one leg with their eyes closed they are ready for a home tool such as the rocker board or balance sandals.

Conclusion

Sensory motor training is a valuable form of active care. It is simple, fun and effective. It can be used for a variety of conditions both musculoskeletal and neurologic. Compared to resistance training it shows promise as being at least as effective and perhaps more efficient. It requires minimal cost to utilize in the clinical setting and home training balance equipment is also inexpensive ($25 – $50). This form of therapy should form a fundamental pillar in rehabilitation alongside training aimed at strength, endurance, cardio-vascular fitness and flexibility.

REFERENCES

Alexander KM, Kinney LaPier TL 1998 Differences in static balance and weight distribution between normal subjects and subjects with unilateral low back pain. Journal of Orthopaedic Sports Physical Therapy 28: 378–383

Balogun JA, Adesinasi CO, Marzouk DK 1992 The effects of a wobble board exercise training program on static balance performance and strength of lower extremity muscles. Physiotherapy Canada 44: 23–30

Bernier JN, Perrin DH 1998 Effect of coordination training on proprioception of the functionally unstable ankle.

Journal of Orthopaedic Sports Physical Therapy 27: 264–275
Bohannon RW, Larkin PA, Cook AC, Gear J, Singer J 1984/Decrease in timed balance test scores with aging. Physical Therapy 64: 1067–1070
Brandt T, Krafczyk S, Malsbendend I 1981 Postural imbalance with head extension: improvement by training as a model for ataxia therapy. Annals of New York Academy of Science 636–649
Bullock-Saxton JE, Janda V, Bullock MI 1993 Reflex activation of gluteal muscles in walking. Spine 18: 704–708
Byl NN, Sinnot PL 1991 Variations in balance and body sway in middle aged adults: Subjects with healthy backs compared with subjects with low-back dysfunction. Spine 16: 325–330
Carrafa A, Cerulli G, Projectti M, Aisa G, Rizzo A 1996 Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training. Knee Surgery Sports Traumatology Arthroscopy 4: 19–21
Eikemeier KD, Schmidt N, Reicke N, Melzig HD 1979 Balance training of the equilibrium organ and it's effect of flight strategy. NASA Conference Publication 2085, Part II (377–388)
Freeman MAR, Dean MRE, Hanham IWF 1965 The etiology and prevention of functional instability of the foot. Journal of Bone and Joint Surgery (Br) 47B: 678–685
Gagey PM 1986 Postural disorders among workers on building sites. In: Bles W, Brandt T (eds). Disorders of Posture and Gait. Elsevier Science, UK
Gagey PM 1987 L'occulomotricite endo-entreee du systeme postural. Aggressologie 28: 899–903
Gagey PM 1991 Non-vestibular dizzyness and static posturography. Acta Oto-rhino-laryngologica Belgium 45: 335–339
Gagey PM 1996 Postural Disorders of the Body Axis. In: Liebenson C (ed). Spinal Rehabilitation: A Manual of Active Care Procedures. Williams and Wilkins, Baltimore
Gauffin H, Tropp H, Odenrick P 1988 Effect of ankle disk training on postural control in patients with functional instability of the ankle joint. International Journal of Sports Medicine 9: 141–144
Ihara H, Nakayama A 1986 Dynamic joint control training for knee ligament injuries. American Journal of Sports Medicine 14: 309–313
Janda V 1988 Seminar at the Los Angeles College of Chiropractic, Whitier, CA
Janda V, Va'vrova' M 1996 Sensory Motor Stimulation. In: Liebenson C (ed). Spinal Rehabilitation: A Manual of Active Care Procedures. Williams and Wilkins, Baltimore
Janda V, Va'vrova' M 1990 Sensory Motor Stimulation: A video. Presented by JE Bullock-Saxton. Brisbane, Australia, Body Control Systems.
Karlberg M, Perrsson L, Magnuson M 1995 Reduced postural control in patients with chronic cervicobrachial pain syndrome. Gait and Posture 3: 241–249
Kondrasen L. Raven JB 1990 Ankle instability caused by prolonged peroneal reaction time. Acta Orthopaedica Scandinavia 61: 388–390
Lewit K 1988 Disturbed balance due to lesions of the cranio-cervical junction. Journal of Orthopaedic Medicine 3: 58–61
Lewit K 1999 Manipulative therapy in rehabilitation of the motor system. 3rd edition. Butterworths, London
Liebenson C, Oslance J 1996 Outcome assessment in the small private practice. In: Liebenson C (ed). Spinal Rehabilitation: A Manual of Active Care Procedures. Williams and Wilkins, Baltimore
Luoto S, Taimela S, Hurri H et al. 1996 Psychomotor speed and postural control in chronic low back pain patients. Spine 21: 2621–2627
Luoto S, Aalto H, Taimela S, Hurri H, Pyykko I, Alaranta H 1998 One-footed and externally disturbed two-footed postural control in patients with chronic low back pain and healthy control subjects. Spine 23: 2081–2090
Martins Da Cunha H 1987 Le syndrome de deficience posturale. Aggressologie 28: 941–943
Mcllroy WE, Maki BE 1995 Adaptive changes to compensatory stepping responses. Gait and Posture 3: 43–50
McPartland JM, Brodeur RR, Hallgren RC 1997 Chronic neck pain, standing balance, and suboccipital muscle atrophy — a pilot study. Journal of Manipulative and Physiologic Therapeutics 20: 24–29
Mientjes MIV, Frank JS 1999 Balance in chronic low back pain patients compared to healthy people under various conditions in upright standing. Clinical Biomechanics 14: 710–716
O'Connell M, George K, Stock D 1998 Postural sway and balance testing: a comparison of normal and anterior cruciate ligament deficient kness. Gait and Posture 8: 136–142
Oostendrop RAB 1988 A preliminary report on the use of the propriosensory facilitating method versus the Williams method in the treatment of patients with non-specific low back pain. Manual Medicine 3: 106–109
Rozzi SL, Lephart SM, Sterner R, Kuligowski L 1999 Balance training for persons with functional unstable ankles. Journal of Orthopaedic Sports Physical Therapy 29: 478–486
Seidler R, Martin PE 1997 The effects of short term balance training on the postural control of older adults. Gait and Posture 6: 224–236
Takala EP, Korhonen I, Viikari-Juntura E 1998 Postural sway and stepping response among working population. Reproducibility, long-term stability, and associations with symptoms of the low back. Clinical Biomechanics 12: 429–437
Tropp H, Askling C 1984a Effects of ankle disk training on muscular strength and postural control. American Journal of Sports Medicine 85: 259–261
Tropp H, Ekstrand J, Gillquist J 1984b Stabilometry in functional instability of the ankle and its value in predicting injury. Medicine and Science in Sports and Exercise 16: 64–66
Tropp H, Ekstrand J, Gillquist J 1984b Factors affecting stabilometry recordings of single limb stance. American Journal of Sports Medicine 12: 185–188
Tropp H, Askling C, Gillquist J 1995 Prevention of ankle sprains. American Journal of Sports Medicine 4: 259–262
Waddington G, Adams R, Jones A 1999 Wobble board (ankle disc) training effects on the discrimination of inversion movements. Australian Journal of Physiology 45: 95–101
Wegener L, Kisner C, Nichols D 1997 Static and dynamic balance responses in persons with bilateral knee osteoarthritis. Journal of Orthopaedic Sports Physical Therapy 25: 13–18
Wilder DG, Aleksiev AR, Magnusson ML et al. 1996 Muscular response to sudden load. Spine 21: 2628–2639
Winter DA 1995 Human balance and posture control during standing and walking. Clinical Biomechanics 3: 193–214
Wolf SL, Barnhart HX, Kutner NG et al. 1996 Reducing frailty and falls in older persons: An investigation of Tai Chi and computerized balance training. JAGS 44: 489–497
Wolfson L, Whipple R, Derbe C et al. 1996 Balance and strength training in older adults: Intervention gains and Tai Chi maintenance. JAGS 44: 498–506