EVIDENCE SUPPORTING BALANCE TRAINING IN HEALTHY INDIVIDUALS: A SYSTEMIC REVIEW

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ABSTRACT

DiStefano, LJ, Clark, MA, and Padua, DA. Evidence supporting balance training in healthy individuals: a brief review. *J Strength Cond Res* 23(9): 2718–2731, 2009—Balance is considered a risk factor for several injuries and consequently a focus of many strengthening, injury prevention, and rehabilitation programs. There are several studies that have evaluated the ability of balance training to improve balance ability in a healthy population with no general consensus. We conducted a systematic review to evaluate the body of evidence regarding the effectiveness of balance training on improving various forms of balance ability in a healthy population. Three electronic databases and the reference lists of selected articles were searched. Studies were included that evaluated balance ability before and after healthy subjects performed a multi-session balance training program. Two individuals reviewed all articles and agreed upon the selection criteria. Sixteen articles were selected, abstracted, and reviewed. Means and measures of variability were recorded to calculate effect sizes, and study quality was assessed using the PEDro instrument. There is strong evidence to suggest that balance training can improve static balance ability on stable and unstable surfaces, as well as dynamic balance ability. Elite athletes have the potential to improve static balance on an unstable surface and dynamic balance ability, but a ceiling effect appears to occur with stable balance ability on a stable surface. Balance training programs performed at least 10 minutes per day, 3 days per week, for 4 weeks that incorporate various methods of balance training appear to improve balance ability. Types of balance training included the use of tilt boards, unstable surfaces, and dynamic body movements while maintaining a static stance.

KEY WORDS postural control, dynamic stabilization, injury prevention

INTRODUCTION

Poor balance, or postural control, is associated with injury or falls in many populations and consequently is considered to be a critical component of common motor skills (2,8,18). Balance is generally defined as the ability to maintain the body's center of gravity within its base of support and can be categorized by either static or dynamic balance. Static balance is the ability to sustain the body in static equilibrium or within its base of support (10,24). Dynamic balance is believed to be more challenging because it requires the ability to maintain equilibrium during a transition from a dynamic to a static state (29). Both static and dynamic balance require effective integration of visual, vestibular, and proprioceptive inputs to produce an efferent response to control the body within its base of support (11,14). An interruption or deficit in any part of the sensorimotor system can result in a loss of balance, which can result in injury. Specifically, poor balance may result in lateral ankle sprains (18) and can explain differences between individuals with and without functional ankle instability (29,30,36). Therefore, improving balance is a critical and frequent objective of rehabilitation and injury prevention programs.

Improving balance with training in a healthy population has positive effects with reducing injury. Balance training has decreased the rates of ankle sprains (19,34), as well as overall lower extremity injury rates (25) in several types of athletes. The balance training programs used in these studies vary between using a simple ankle disc to including a balance component in a multifaceted exercise program that consists of strengthening, agility, plyometric, and balance exercises. Despite this evidence suggesting that balance training decreases injuries, it is unknown if improvements in injury rates are actually associated with improvements in balance ability.

There are several studies that have evaluated the effects of balance training on static and dynamic balance abilities, but to our knowledge, there is no clear consensus available from this body of literature to help clinicians and fitness professionals make clinical decisions. Furthermore, the studies that exist have used a variety of different training methods, durations, and outcome measures. This wide range of information can be confusing for a clinician and needs to be consolidated to

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23(9)/2718–2731

Journal of Strength and Conditioning Research

provide clinicians with simple evidence-based guidelines to use with the design of a balance training program. Clinicians and fitness professionals need to understand if there is sufficient evidence to support the use of balance training to improve balance ability and if there are specific variables within a balance training program that influence the effects of the program. Therefore, the purpose of this study was to conduct a systematic review to determine if balance training actually improves balance in a healthy population and evaluate the effects of the program variables. We specifically aimed to answer the following 3 questions: (*a*) Can balance training improve static balance ability on a stable surface? (*b*) Can balance training improve static balance ability on an unstable surface? and (*c*) Can balance training improve dynamic balance ability?

METHODS

Experimental Approach to the Problem

To address the 3 primary research questions of this systematic review, we searched the existing body of literature to select articles that matched specific criteria and then critically evaluated and compared these articles to reach consensus statements for each of the 3 objectives. We performed an electronic literature search of the PubMed (maintained by the National Library of Medicine), CINAHL, and SPORTDiscus databases for articles matching our criteria between January 1988 and January 2008. The databases were searched using variations of the terms listed in Table 1. A total of 310, 202, and 270 articles were selected from PubMed, CINAHL, and SPORTDiscus, respectively, and their titles and abstracts were reviewed to determine if they matched our selection criteria.

Procedures

The selection criteria required the studies to be in English and to primarily evaluate the effects of a balance training program in modifying a balance outcome in healthy subjects. Nine articles from PubMed matched our criteria and were reviewed. The CINAHL database search resulted in 4 additional articles for review, and 1 additional article from SPORTDiscus was reviewed. Finally, we manually reviewed the reference lists from the 14 selected articles for any additional studies that met our criteria and selected 2 final articles giving us a total of 16 articles to review.

TABLE 1. Search terms used for literature review.

Search Terms
Healthy or Athlete or Sport
Evaluate or Outcome
Postural stability or Postural control
Postural sway or Balance or Musculoskeletal equilibrium
Training or Physical education and training
Not cerebrovascular accident or Stroke or Elderly

We extracted specific details from each of the 16 articles to evaluate the body of literature on the ability of balance training programs to improve balance in a healthy population. Each of the 16 articles was reviewed and abstracted for this information including the type and duration of the balance training, whether or not the program was progressive (exercise intensity increased or type of balance activity changed in difficulty over time), and the population studied (Table 2). The data were extracted by one author and verified by the second author.

Statistical Analyses

We used the PEDro scale to evaluate the quality of each study's design and methods. The PEDro scale is a reliable measurement tool that evaluates 11 specific items about study quality (17). These items assess some of the following issues: blinding, subject eligibility criteria, concealment of allocation, randomization, reporting measures of variability, and attrition. The scale ranges from zero to 10 points with the highest score indicating excellent design and methods quality. All 16 articles were scored using the PEDro scale by both authors who were blinded to the other's scores. The authors resolved any discrepancy in score through discussion and came to a conclusion on a PEDro score for every study (Table 2). We also calculated effect sizes from means and *SD*s, when available, before and after the balance training programs (Tables 3–5). Effect sizes greater than 0.7 were considered strong, between 0.41 and 0.7 were moderate, and weak effect sizes were less than 0.4 (3).

RESULTS

Overall, the primary method of balance training in the 16 articles meeting the inclusion criteria incorporated the use of tilt boards (1,6,12,13,16,33) or other unstable surfaces (4,7,9,28,31,32). For the purposes of this review, tilt boards will be inclusive of ankle discs, tilt boards, and wobble boards because they all require individuals to move the board in specified directions while balancing. The tilt boards are different from unstable surfaces because unstable surface training requires subjects to maintain a static stance while standing on an unstable surface compared with moving the surface while balancing. Other methods of balance training included the use of unstable exercise sandals (20), dynamic body movements while balancing (27), and integrating balance training into a multifaceted exercise program (22,26). Studies assessed balance in 1 of 3 ways: static balance ability while standing on a firm surface, static balance ability while standing on an unstable surface, and dynamic balance ability that required the subjects to stabilize themselves in a static stance after or while moving. Measures of balance ability ranged from center of pressure excursions to the time a subject could maintain stability.

TABLE 2. Overview of balance training interventions to improve balance.*

Study [PEDro score]	Design	Population	Balance training	Progression	Duration
Rasool and George (2007) [7]	RCT	Adult males	Static and dynamic exercises on floor or gym mat with different visual conditions (eyes open/closed) and contralateral limb and trunk motions	Surface, visual, and body conditions progressed	Session duration not provided; 5 $\text{d}\cdot\text{wk}^{-1}$ for 4 wks
Gioftsidou et al. (2006) [6]	RCT	Adolescent male soccer players	Balance boards, mini trampoline, instrumented platform	No	20 $\text{min}\cdot\text{session}^{-1}$; 3 $\text{d}\cdot\text{wk}^{-1}$ for 12 wks
Kovacs et al. (2004) [7]	RCT	Adult female figure skaters (competitive)	Single-leg stance, wobble board, trampoline	Visual (eyes closed/open) and surface (floor, wobble board, waffle, mini trampoline) conditions progressed	20–25 $\text{min}\cdot\text{session}^{-1}$; 3 $\text{d}\cdot\text{wk}^{-1}$ for 4 wks
Hoffman and Payne (1995) [5]	RCT	Adolescent males and females	Ankle disc	Ankle disc levels progressed	10 $\text{min}\cdot\text{session}^{-1}$; 3 $\text{d}\cdot\text{wk}^{-1}$ for 10 wks
Emery et al. (2005) [6]	RCT	Adolescent males and females	Wobble board	Double-leg balance progressed to single-leg balance; increased duration of eyes closed exercises; increased level of wobble board instability after 4 weeks	20 $\text{min}\cdot\text{session}^{-1}$; 7$\text{d}\cdot\text{wk}^{-1}$ for 6 wks
Sforza et al. (2003) [6]	RCT	Adult males	Tilting platform	No	15 $\text{min}\cdot\text{session}^{-1}$; 3 $\text{d}\cdot\text{wk}^{-1}$ for 4 wks
Cox et al. (1993) [5]	RCT	Adult males and females	Eyes closed, single-leg balance; group 1: hard surface; group 2: foam surface	Amount of knee flexion increased after week 2	5 $\text{min}\cdot\text{session}^{-1}$; 3 $\text{d}\cdot\text{wk}^{-1}$ for 4 wks
Puls and Gribble (2007) [3]	RCT	Adult males and females	Single-leg stance with elastic band kicks using nondominant leg	Eye condition and band resistance changed as weeks progressed	14 $\text{min}\cdot\text{session}^{-1}$; group 1: 3 $\text{d}\cdot\text{wk}^{-1}$; group 2: 5 $\text{d}\cdot\text{wk}^{-1}$ for 6 wks
Balogun et al. (1992) [5]	RCT	Adult males	Wobble board (“back and forth”)	Time for training sessions increased	10–25 $\text{min}\cdot\text{session}^{-1}$; 3 $\text{d}\cdot\text{wk}^{-1}$ for 6 wks
France et al. (1992) [6]	RCT	Adults males and females	Instrumented inflated platform	Surface pressure level decreased	10–15 $\text{min}\cdot\text{session}^{-1}$; 3 $\text{d}\cdot\text{wk}^{-1}$ for 6 wks
Rothermel et al. (2004) [5]	RCT	Adult males and females	Unstable surfaces (foam pads) in various visual conditions (eyes open/closed) and with different hand positions (arms out, on hips)	Surface and hand position progressed	10 $\text{min}\cdot\text{session}^{-1}$; 3 $\text{d}\cdot\text{wk}^{-1}$ for 4 wks

Holm et al. (2004) [1]	One group pretest-posttest	Adult female handball athletes (competitive)	Wobble board, balance mat, floor exercises	Double-leg progressed to single-leg exercises and perturbations were added	15 min·session^{-1}; 3 d·wk^{-1} for 5–7 wks
Michell et al. (2006) [5]	RCT	Adult males and females	Achilles stretching, short foot contractions, high knee walking, lateral side steps, forward/backward walking, lunges, squats. Group 1 used exercise sandals (unstable surface) for all exercises; group 2 did not use sandals	No	Session duration not provided; 3 d·wk^{-1} for 8 wks
Myer et al. (2006) [4]	RCT	Adolescent females	Unstable surfaces, dynamic balance with trunk and lower extremity movement, resistance, agility, speed exercises. Control group: performed same exercises except no balance exercises	Exercise intensity progressed, single-limb exercises were added, exercises were made more complex, unstable surfaces and perturbations were added	90 min·session^{-1}; 3 d·wk^{-1} for 7 wks
Rozzi et al. (1999) [4]	One group pretest-posttest	Adult males and females	Single-leg stance, tilting, and circles on an unstable instrumented platform	No	Session duration not provided; 3 d·wk^{-1} for 4 wks
Paterno et al. (2004) [1]	One group pretest-posttest	Adolescent females	Dynamic balance exercises: stick landings after jumps, unstable surface balance	Duration, volume, and intensity of exercises increased; single-limb exercises increased, and exercises progressed in complexity	90 min·session^{-1}; 3 d·wk^{-1} for 6 wks

*RCT = randomized control trial.

TABLE 3. Results of studies evaluating the effectiveness of balance training programs on static balance ability on stable surface.*†

Study	Group or limb tested	Balance test	Dependent variable	Significant improvement	% change	Effect size
Rothermel et al. (2004)	Traditional group: trained limb	Single-limb stance	COP excursion velocity	Yes	21.6	4.00
	Trained limb	Single-limb stance: eyes closed	COP excursion velocity	Yes	21.9	2.30
	Untrained limb	Single-limb stance	COP excursion velocity	Yes	21.1	4.00
	Untrained limb	Single-limb stance: eyes closed	COP excursion velocity	No	9.5	2.00
	Foot positioning group: trained limb	Single-limb stance	COP excursion velocity	No	−2.9	−0.50
	Trained limb	Single-limb stance: eyes closed	COP excursion velocity	No	10.4	1.00
	Untrained limb	Single-limb stance	COP excursion velocity	No	2.9	0.50
	Untrained limb	Single-limb stance: eyes closed	COP excursion velocity	No	−4.2	−0.80
Balogun et al. (1992)	Intervention	Single-limb stance	Balance time	Yes	85.5	0.80
		Single-limb stance: eyes closed	Balance time	Yes	20.8	0.35
Emery et al. (2005)	Intervention	Single-limb stance: eyes closed	Balance time	Yes	69.9	2.59
Hoffman and Payne (1995)	Intervention	Single-limb stance	A/P postural sway	Yes	16.1	0.43
		Single-limb stance	A/P COP excursion	Yes	12.7	0.37
Michell et al. (2006)	Exercise sandal group	Single-limb stance	A/P COP excursion	Yes	45.6	1.09
	No sandal group	Single-limb stance	A/P COP excursion	No ($p = 0.47$)	−5.8	−0.17
	Exercise sandal group	Single-limb stance	M/L COP excursion	Yes	35.2	1.19
	No sandal group	Single-limb stance	M/L COP excursion	Yes	6.4	0.17
Puls and Gribble (2007)	3 $d \cdot wk^{-1}$ training	Single-limb stance	COP excursion velocity	No		N/A
	5 $d \cdot wk^{-1}$ training	Single-limb stance	COP excursion velocity	No		N/A
	Control	Single-limb stance	COP excursion velocity	No		N/A
Cox et al. (1993)	Intervention	Single-limb stance	Sway index	No ($p = 0.11$)		N/A
Kovacs et al. (2004)	Intervention	Single-limb stance	COP path length	No	5.4	0.37
Kovacs et al. (2004)	Intervention	Single-limb stance: eyes closed	COP path length	No	5.6	0.21

*Significant changes ($p < 0.05$); positive % change indicates program improved balance; negative % change indicates program decreased balance.

†N/A = means and measures of variability were not provided; COP = center of pressure; A/P = anterior/posterior; M/L= medial/lateral.

Can Balance Training Improve Static Balance Ability on a Stable Surface?

Static balance ability on a stable surface was evaluated using several measures including center of pressure excursions, center of pressure velocity, and balance time (1,5). A total of 8 articles assessed static balance ability on a stable surface and the mean PEDro score of 6.75. Five (1,5,12,20,31) of these 8 articles demonstrated improvements in static balance ability, whereas 3 studies (4,16,27) did not. Balance training for these articles included the use of exercise sandals (20), elastic bands with dynamic movements (27), tilting boards (1,5,12,16), and unstable surfaces (4,16,31). A summary of each article's findings, which includes percent changes and effect sizes because of the balance training program along with 95% confidence intervals (when available), is presented in Table 3.

Two studies evaluated subjects' abilities to balance for a period on a stable surface, and both observed successful improvements in balance time because of balance training. Balogun et al. (1) investigated the effects of a 3 times per week 6-week progressive balance training program on static balance ability in healthy men between the ages of 18 and 24 years old (PEDro = 6). All subjects performed a timed static single-limb balance assessment with their eyes open and closed, before and after the program. The authors reported high between-day reliability with this assessment [intraclass coefficient (ICC) = 0.95 (type of ICC is not reported)]. Subjects were randomly assigned to either a control ($n = 14$) or an experimental group ($n = 16$). The subjects in the experimental group reportedly "rocked back and forth" on a tilt board to complete the training. The

TABLE 4. Results of studies investigating the effectiveness of balance training programs on improving static balance ability on unstable surfaces.*†

Study	Group or limb tested	Balance test	Dependent variable	Significant improvement	% change	Effect size
Emery et al. (2005)	Intervention	Static single-limb balance with eyes closed on unstable surface	Balance time	Yes	54.5	3.00
Holm et al. (2004)	Intervention	Single-limb static balance test on movable platform	Balance index	No ($p = 0.52$)	−5.8	−0.15
Kovacs et al. (2004)	Intervention	Single-limb stance on skate	COP path length	Yes	18.1	0.92
Sforza et al. (2003)	Intervention	Double-limb stance on tilting platform	Angular velocity	Yes	27.5	1.41
		Double-limb stance on tilting platform	Oscillation area	Yes	50.2	1.28
Paterno et al. (2004)	Right leg	Single-limb stance on unstable platform	A/P stability index	Yes	25.0	0.90
	Left leg	Single-limb stance on unstable platform	A/P stability index	Yes	23.1	0.75
	Right leg	Single-limb stance on unstable platform	M/L stability index	No ($p = 0.65$)	5.0	0.11
	Left Leg	Single-limb stance on unstable platform	M/L stability index	No ($p = 0.65$)	0.0	0.00
France et al. (1992)	Intervention	Static double-limb balance on unstable surface	Surface pressure level	Yes	44.4	1.33
		Static left limb balance on unstable surface	Surface pressure level	No	40.0	1.14
		Static right limb balance on unstable surface	Surface pressure level	Yes	50.0	1.67
Rozzi et al. (1999)	Trained	Single-limb balance on instrumented platform (level 2)	Stability index	Yes	42.3	0.68
	Trained	Single-limb balance on instrumented platform (level 6)	Stability index	Yes	32.8	0.67
Gioftsidou et al. (2006)	Before training group	Single-limb balance on instrumented platform	Stability index	Yes	35.1	0.75
		Single-limb balance on M/L unstable board	Balance time	Yes	242.9	1.79
		Single-limb balance on A/P unstable board	Balance time	Yes	573.1	1.94
		Single-limb balance on unstable board	Balance time	Yes	79.1	1.89
	After training group	Single-limb balance on instrumented platform	Stability index	Yes	32.9	0.92
		Single-limb balance on M/L unstable board	Balance time	Yes	364.3	1.67
		Single-limb balance on A/P unstable board	Balance time	Yes	586.2	1.77
		Single-limb balance on unstable board	Balance time	Yes	70.5	2.07

*Significant changes ($p < 0.05$); positive % change indicates program improved balance; negative % change indicates program decreased balance.

†N/A = Means and measures of variability were not provided.

duration of each training session progressed from 10 minutes during the first 2 weeks to 25 minutes during the last 2 weeks of training. The authors concluded that the program resulted in balance improvements, as measured by balance time, between the second and fourth weeks of training but improvements appeared to plateau after the fourth week. Based on the effect sizes and percent improvements, the balance training program had a strong effect on single-limb balance with the eyes open but only a weak effect on balancing with the eyes closed. Several limitations exist with this study because the balance training program description was vague and compliance of the program was not discussed. Although limitations are present, this study was an initial step toward demonstrating that static balance can improve after a few weeks of training.

Similar to the study by Balogun et al., Emery et al. (5) also demonstrated large improvements in balance time after subjects trained using a tilt board (PEDro = 7). Physically active high school–aged subjects (14–19 years old) were randomly assigned to either the control program with no training ($n = 30$ men and 30 women) or a progressive balance training program ($n = 30$ men and 30 women), which consisted of wobble board exercises and was performed daily at home for 6 weeks. Compliance was evaluated through

TABLE 5. Results of studies investigating the effectiveness of balance training programs on improving dynamic balance ability.*†

Study	Group or limb tested	Balance test	Dependent variable	Significant improvement	% change	Effect size
Kovacs et al. (2004)	N/A	Single-leg landing: eyes open	COP path length	No	8.0	0.39
		Single-leg landing: eyes closed	COP path length	Yes	24.8	0.90
Rasool and George (2007)	Trained limb	SEBT	Reach distance	Yes	20.5	3.00
	Untrained limb	SEBT	Reach distance	Yes	10.1	1.50
Myer et al. (2006)	Balance	Single-leg landing	M/LCOP variability	Yes	4.9	0.20
	Plyometric	Single-leg landing	M/LCOP variability	Yes	5.6	0.40
	Balance	Single-leg landing	A/P COP variability	No		N/A
	Plyometric	Single-leg landing	A/P COP variability	No		N/A
Holm et al. (2004)	Intervention	Double-leg stance on moving platform to directed targets using KAT 2000	Balance index	Yes	15.6	0.64

*Significant changes ($p < 0.05$); positive % change indicates program improved balance; negative % change indicates program decreased balance.

†SEBT = star excursion balance test; A/P = anterior/posterior; M/L = medial/lateral; N/A = means and measures of variability were not provided.

subject's self-reports. The authors concluded that the balance training program resulted in improvements in timed static balance on a stable surface [test-retest reliability ICC = 0.70 (type of ICC was not reported)] with a strong effect, whereas no improvements were observed with the control group. Although not a statistically significant finding, the authors noted that subjects who attended more training sessions appeared to have greater improvements [mean improvement: 25.8 seconds (95% CI, 16.4–35.1)] compared with subjects who attended less sessions [mean improvement: 6.1 seconds (95% CI, −8.4 to 20.7)]. A limitation of this study is that specifics about the training program were not included.

Two of the successful studies that evaluated static balance ability on a stable surface assessed changes with center of pressure excursion measures (12,20). Compared with the 6-week program in Balogun et al. (1), Hoffman and Payne (12) evaluated a slightly longer progressive balance training program that required 3 days per week of training for 10 weeks (PEDro = 7) using a tilt board. Similar to Emery et al. (5), the subject population consisted of healthy high school–aged (14–18 years old) subjects who were randomly assigned to either a control (*n* = 6 men and 8 women) or experimental group (*n* = 10 men and 4 women). A force plate measured postural sway with a sampling frequency of 50 Hz, but no measures of reliability for this assessment were reported. Hoffman and Payne showed weak to moderate improvements in single-leg stance postural sway in both anteroposterior and mediolateral directions in the experimental group compared with the control group. The biggest limitations with this study are that compliance and supervision of the program were not described and the groups were not balanced for sex.

Instead of using tilt boards for balance training, Michell et al. (20) required healthy physically active subjects (18–23 years old) to use a relatively new piece of rehabilitation equipment, exercise sandals, during an 8-week balance training program (PEDro = 6). Exercise sandals involve balancing in a sandal with a hemisphere ball under the sandal's midsole. Subjects were randomly assigned to a sandal (*n* = 8 men and 8 women) or no sandal group (*n* = 8 men and 8 women). Both the sandal and no sandal groups performed a balance training program consisting of functional exercises and static stretching that was performed 3 times a week under supervision. Examples of the functional exercises included high knee walking, lateral sidesteps, lunging, squats, and forward and backward walking in a defensive stance. A force plate measured anterior–posterior (A/P) and medial–lateral (M/L) center of pressure excursions during a static stance with a sampling frequency of 180 Hz. The authors reported good reliability and precision for A/P (ICC(2,3) = 0.79; *SEM*, 0.11 cm) and M/L (ICC(2,3) = 0.75; *SEM*, 0.07 cm) measures. The authors reported a test main effect of M/L postural stability. This finding suggests that subjects were able to improve their M/L postural stability, as measured through center of pressure excursions, regardless of whether or not the subjects used exercise sandals during the balance training program. However, the sandal group's training resulted in strong effect sizes, whereas the no sandal group only demonstrated a weak effect size. Furthermore, the sandal group improved A/P stability, whereas the group that performed the exercises without the exercise sandals did not improve. Therefore, adding an unstable surface to functional dynamic exercise may cause an additional benefit to balance training. A limitation to this study is the lack of a pure control group.

The study by Rothermel et al. was the final study to demonstrate positive changes in static balance ability on a stable surface (31) (PEDro = 6). Rothermel et al. investigated the effects of a minimally time-intensive balance training program on postural control improvements, measured by center of pressure excursion velocity, during single-leg stance. A force plate measured center of pressure excursion velocity with a sampling frequency of 50 Hz. The authors did not report any measures of reliability. Subjects were healthy adults and were assigned to a control group ($n = 15$), a traditional balance training group ($n = 15$), or a balance training group ($n = 15$) that performed a foot positioning technique during all exercises. The foot positioning technique required subjects to maintain a short foot posture, which involves actively elevating the medial longitudinal arch without lifting the rearfoot or forefoot from the ground. This position had been hypothesized to improve balance ability by increasing cutaneous stimulation and decreasing foot motion. Subjects in the foot positioning technique group and the traditional group completed a progressive balance training program using a foam pad. The program required 10 minutes of training, 3 times per week for 4 weeks. The traditional balance training program effectively improved postural control in both the trained and the untrained limbs compared with the control group. However, the foot-positioning group did not improve significantly. Despite failing to see a statistically significant improvement, moderate to large effect sizes were demonstrated by the foot-positioning group for the trained limb in the eyes closed position and the untrained limb when the eyes were open. These effect sizes suggest that with additional subjects, the foot-positioning group may actually have resulted in statistically significant improvements. A limitation of this study is that the number of men and women in each group were not provided.

Although the previous studies suggest that static balance on a stable surface can be improved, 3 studies showed otherwise because they failed to see any improvement (4,16,27). Kovacs et al. (16) compared the effects of a 4-week neuromuscular training program to a basic exercise program with no balance exercises on postural control improvements in experienced elite female adolescent and adult figure skaters (12–28 years old) (PEDro = 8). Subjects were randomly assigned into either the neuromuscular training program ($n = 22$) or the basic exercise program (n-23). The neuromuscular training program required 20–25 minutes to complete, 3 times per week and consisted of progressive single-limb stance, wobble board, and trampoline balance exercises, whereas the basic program included lower extremity stretching and strengthening exercises and required 10–15 minutes to perform. A force plate measured center of pressure path length (cm) and area (cm^2), as well as *SD* of center of pressure along the vertical and horizontal axes at a sampling frequency of 100 Hz. The center of pressure assessments occurred during a static single-limb stance with their eyes open and closed while barefoot. The authors described moderate to excellent reliability with this assessment technique from previous research but did not report values. No significant differences were observed between groups or periods, but the neuromuscular program did demonstrate weak to moderate effect sizes during both the eyes open and closed conditions. Therefore, additional subjects may have led to statistical significance during these 2 conditions. Unfortunately, neither confidence intervals nor p values were reported. These findings may be confounded by a ceiling effect since elite athletes were trained and assessed. These subjects may already be proficient with this simple task, leaving minimal room for improvement.

Cox et al. (4) also evaluated the ability to improve balance measured through center of pressure excursions during a static single-limb stance on a stable surface (PEDro = 7). Healthy recreationally active adult subjects (18–36 years old) were randomly assigned to a control group ($n = 9$), a hard surface training group ($n = 9$), or a foam surface training group ($n = 9$). Subject demographics per group were not provided. The control group did not perform any type of exercise, whereas subjects in both training groups completed static balance training for 4 weeks. The hard surface training group balanced on a stable surface, whereas the foam surface training group balanced on a foam surface. The Chattecx Dynamic Balance System measured center of pressure displacements to calculate a sway index that was used to evaluate improvements. Reliability with this measurement is reported using an unpublished study, and exact values were not stated. No improvements for either training group were observed; however, the p value was low (0.11), and 9 subjects per group may have prevented statistical significance from being observed with a 3-way analysis of variance. The authors do not report if the programs were supervised or any measure of compliance with the program. Compared with the other studies discussed, this study used a relatively short program requiring only 5 minutes per day, 3 days per week for 4 weeks. Other studies have used a training duration of only 4 weeks, but these programs require more than 5 minutes per day, so it is possible that the training program's effects were limited by overall duration of training. Further changes may have been observed if the subjects had completed the program for a longer period. The authors did not provide measures of variability, so it was not possible to calculate or evaluate the effect sizes associated with this study.

Puls and Gribble (27) compared two 6-week ankle rehabilitation programs and a control program on center of pressure excursion velocity in healthy recreational athletes (18–26 years old) (PEDro = 7). Subjects were randomly assigned to either a control group ($n = 3$ men and 6 women), or 1 of 2 training groups. A force plate measured center of pressure excursion velocity at a sampling frequency of 60 Hz, but no mention of reliability is provided. The 2 rehabilitation programs consisted of progressive thera-band kicks while maintaining single-leg balance and differed by the number of training sessions completed per week. One group performed the training 3 days per week ($n = 1$ man and 8 women), whereas the other group completed the exercises 5 days per week ($n = 3$ men and 7 women). No improvements were observed between the 3 programs. Compliance and supervision of the training program were not described, so it is unknown if these factors influenced the results of this study. The interesting point from this study is that duration of training per week does not appear to be a vital component of a balance training program; however, this was the only study to make this comparison, and no significant improvements were observed, so these results should be considered preliminary. The biggest limitation of this study is the lack of reported means, measures of variability, and statistical results to evaluate the group by time interaction. With a relatively low sample size (9 subjects per group) and the inability to evaluate effect sizes, the conclusions of this study are limited.

The results of these articles lead to mixed findings on whether or not static balance on a stable surface can be improved consistently. On closer inspection of the differences between the studies, it appears that the study population, the difficulty, and the duration of the training program may influence the outcomes of a balance training program. Static balance ability on a stable surface was significantly improved when recreational athletes complete a balance training program involving tilt boards (1,5,12) and exercise sandals (20) or on unstable surfaces (31) when the program is completed for a sufficient duration. The programs that were successful observed improvements in center of pressure excursion variables and the time the subject could maintain balance. All successful programs were performed for 10 minutes, at least 3 days per week for 4 weeks and involved healthy recreationally active adults or adolescents. In contrast to the successful studies, the 3 studies that did not demonstrate significant improvements used elite athletes (16), a short 5 minute training program (4), or involved a balance training program that required subjects to stand on a stable surface while performing contralateral elastic band kicks (27).

Can Balance Training Improve Static Balance Ability on an Unstable Surface?

There were 8 studies (5,7,9,13,16,26,32,33) that evaluated the ability to improve static balance ability on an unstable surface using 7 different measures of stability. The 7 measures included center of pressure excursion (16), oscillation area and velocity (33), balance time (5,9), stability index (13,32), degrees of sway (9), and surface pressure level (7). Seven (5,7,9,16,26,32,33) of the 8 studies demonstrated improvement in these measures, whereas only 1 study (13) failed to see balance improvements. The average PEDro score was a 5.75 in this group of articles, and a summary of findings is presented in Table 4.

As previously described, Kovacs et al. (16) studied the effects of a neuromuscular training program and a basic exercise program in elite figure skaters. Although this study did not observe any statistically significant improvements in static balance ability on a stable surface, the neuromuscular training program resulted in significant improvements in static balance ability on an unstable surface. The unstable surface in this study was the subjects' figure skate, and improvements were observed by decreased center of pressure excursions. These findings further suggest that the previous failure to see changes during the simple stable surface assessment may have been because of a ceiling effect. Improvements appear possible when the elite athletes performed a more challenging task by balancing on the unstable surface.

Sforza et al. (33) compared balance training ($n = 7$) with no training ($n = 6$) on improving postural control using a tilting platform in healthy men (19–33 years old) (PEDro = 7). Movement of the platform was evaluated with a 3-dimensional motion analysis system at 100 Hz. No measures of reliability with this assessment were provided. The program used was very simple, was not progressive, and required only 15 minutes, 3 times per week for 4 weeks. The authors concluded that the training improved balance ability because the training group decreased the oscillation area and angular velocity during a 30-second double-limb stance on the platform after completing the program. The improvements because of the program accounted for a 25–50% change, resulting in strong effect sizes. The ability to generalize these findings is limited because only 13 men participated in this study, but it is impressive that the results obtained occurred from such a small sample size. In addition, subjects were evaluated on the same platform used for the training program, so it is unknown if the improvements would transfer to a different task or surface.

Emery et al. (5) and Gioftsidou et al. (9) both evaluated the effects of a balance training program on improving the time an adolescent could maintain single-limb balance on an unstable surface (wobble board). Emery et al. demonstrated that healthy adolescents who complete a balance training program using tilt boards can effectively increase their balance time on an unstable surface. Gioftsidou et al. (9) performed a unique study comparing the effects of a single-leg balance training program performed either before or after soccer training sessions in adolescent male soccer players (15–17 years old) (PEDro = 8). The program consisted of balance exercises performed on the Biodex platform, mini trampoline, and balance boards. Both groups (before training or after training) performed the program for 20 minutes, 3 days per week for 12 weeks. Balance time was assessed using 3 different balance boards. The boards restricted movement in the anteroposterior direction, the mediolateral direction, or did not involve any restrictions. Subjects also performed a single-limb stance test on a Biodex platform (Biodex Stability System, Biodex Medical Systems, Shirley, NY, USA), which calculated an instability index. No mention of reliability with either measure was provided. The balance training program resulted in greater postural control during single-limb stance on the boards in both treatment groups ($n = 13$ per group) with no changes in the control group ($n = 13$). Both training groups also improved their balance assessment scores on the platforms, resulting in strong effect sizes; however, subjects who performed the training after practice sustained larger amounts of improvement compared with the group who completed the training before practice. Therefore, the balance training program in this study improved balance, and it appears that greater benefits occur when the training takes place after soccer training sessions.

Instrumented balance training equipment that is able to provide feedback has also been studied. France et al. (7) investigated the effects of double-leg and single-leg balance training on improving static balance in healthy adults between the ages of 20 and 46 (PEDro = 6). Subjects were from 6 service centers (approximately $n = 8$ each) and were randomly assigned within each center to either the control ($n = 23$) or balance training group ($n = 23$). Both groups had an equal number of male and female subjects. Balance training occurred on an air-inflated platform (Breg Kinesthetic Ability Training, Breg Inc., Carlsbad, CA, USA) 3 times per week for 6 weeks and consisted of level balancing, squats, and multidirectional motions using the platform. To assess balance, a proficiency level was determined while the subjects stood on the air-inflated platform and the level of pressure was elevated until the subject could not maintain the pressure constant. The authors did not report any reliability information regarding this method. The authors concluded that the balance training improved double- and single-leg static balance while the subjects balanced on the unstable platform. However, the control group was evaluated 3 times, whereas the training group was assessed 7 times, resulting in a possible learning effect in the balance training group. The authors also describe a balance improvement plateau occurring after week 3 with the training program. This finding stresses the need for further balance training program progressions.

Rozzi et al. (32) evaluated the effects of a 4-week balance training program in subjects with functional ankle instability ($n = 8$ men and 5 women) and stable ankles ($n = 7$ men and 6 women) (PEDro = 5). All subjects were from a university setting and between the ages of 18 and 24. The program was performed 3 times per week and involved static single-limb stance and dynamic single-limb tilting and rotation exercises using the Biodex Stability System. The Biodex Stability System was also used to assess balance in both limbs by calculating a stability index based on the subject's ability to control the platform's angle of tilt (variance of platform displacement). The authors described reliability values (ICC) between 0.6 and 0.95 for all testing procedures from previously published research but do not report the type of ICC. Both groups improved their balance after the program, and although improvements were observed in both the trained and untrained limbs, the untrained limb demonstrated only weak to moderate effect sizes. Compliance and supervision of the program were not reported.

Balance exercises can be performed in isolation or in combination with other types of exercises. Paterno et al. (26) investigated the effects of a neuromuscular training program that included progressive balance, plyometric, and resistance training exercises on changing postural stability in female high school athletes ($n = 41$) (PEDro = 2). The program used required 90 minutes of training, 3 times per week for 6 weeks. Balance was assessed on a Biodex Stability System using stabilometry to assess anteroposterior, mediolateral, and total stabilities. Between-session reliability data were reported from other published research demonstrating ICC (type of ICC unknown) values between 0.72 and 0.81. Both limbs improved anteroposterior postural stability after the program, but mediolateral stability was not affected during a single-leg stance on an unstable stability system. The results of this study are promising because balance did improve from a comprehensive neuromuscular training program; however no control group was used in this study, so it is unknown whether improvements are directly related to the program or other activities.

The study by Holm et al. (13) is the only study that did not observe improvements in static balance on an unstable surface after the completion of a balance training program (PEDro = 3). A progressive neuromuscular injury prevention program was implemented to 35 female adult (20–26 years old) handball athletes. Subjects performed the program, which consisted of wobble board and balance mat exercises, 3 days per week for 5–7 weeks. Balance was assessed using the KAT platform (OEM Medical, Carlsbad, CA) during a static single-leg stance when the platform could move. A balance index representing the displacement of the platform was used for analyses. No mention of reliability with testing procedures is reported. No changes in static balance, as measured by the platform using a stability index, were observed. Limitations of this study are that compliance with the program was not reported and no control group was used. Similar to the study by Kovacs et al, one possible reason these authors did not observe improvements in static balance is that the population was elite athletes, so it is plausible that the static assessment was too easy for them, resulting in a ceiling effect.

Seven of the 8 articles improved static balance ability on an unstable surface using 7 different dependent variables (5,8,9,16,26,32,33). Therefore, the type of balance variable assessed does not appear to influence the ability to see balance improvements. The most apparent difference between the 7 successful studies and study by Holm et al. (13), who did not demonstrate improvements, was the subject population. Elite adult handball athletes performed the balance training program in Holm et al. compared with primarily recreational athletes in the other studies. Although elite athletes were used in the study by Kovacs et al. (16) as well, the type of unstable surface differed between Kovacs et al. and Holm et al. and may have attributed to the difference in findings. The unstable surface in Kovacs et al. was a figure skate, whereas Holm et al. assessed balance on an unstable platform. The figure skate may be more difficult than the unstable platform, which would remove the ceiling effect possibly present in Holm et al. Overall, it appears that balance on an unstable surface can be improved using a variety of unstable surfaces, tilt boards, or balancing after landing from a jump.

Can Balance Training Improve Dynamic Balance Ability?

Dynamic balance ability was defined as the ability to transition from a dynamic state to a static state or to maintain stability while performing dynamic motions. Four studies (13,16,21,28) measured dynamic balance ability, which were included in this review with an average PEDro score of 6. The tasks for dynamic balance ability included the ability to acquire stability after landing from a jump (16,21), performing contralateral leg movements while maintaining static stance (28), and making a tilt board move in specified directions while balancing in a single-limb stance (13). All 4 studies observed significant improvements using these dynamic balance assessment tasks. A summary of the results of these studies is presented in Table 5.

Myer et al. (21) and Kovacs et al. (16) both observed balance ability while subjects jumped and landed on a single limb. Kovacs et al. concluded that the neuromuscular training program was more effective with improving center of pressure excursions than the basic exercise program in elite figure skaters when the subjects jumped down from a box and maintained single-limb stance with their eyes closed. Similar to Paterno et al. (26), Myer et al. (21) incorporated balance exercises into a multifaceted neuromuscular injury prevention program. High school female volleyball athletes ($n = 19$) participated in this study and were randomly assigned into either a plyometric or balance training group. Both groups performed supervised agility, resistance training, speed training, and their respective group program 90 minutes, 3 days per week for a total of 8 weeks. The balance training program consisted of stability exercises on different surfaces and single-leg stance exercises with additional body or lower extremity perturbations. The plyometric group did not perform any dynamic balance exercises. Center of pressure excursions in the M/L and A/P directions were measured through a portable force platform. The authors reference another study to demonstrate reliability with this technique but do not report specific values or type of reliability measurement. The results indicated that both groups significantly decreased their mediolateral center of pressure excursion during a single-leg hop and balance task, which is opposite to the findings of Paterno et al. where only anteroposterior improvements were observed. The authors hypothesize that the difference in balance assessment tasks may have contributed to these contrasting findings because Paterno et al. studied balance during a single-leg stance on an unstable surface versus a dynamic landing task in the present study. Regardless, the findings of Myer et al. further support the notion that balance training within a multifaceted program can improve balance ability. However, it is possible that the improvements occurred as a result of concurrent sport participation or a learning effect because no pure control group was used. Furthermore, the plyometric group acquired the same improvements as the balance group

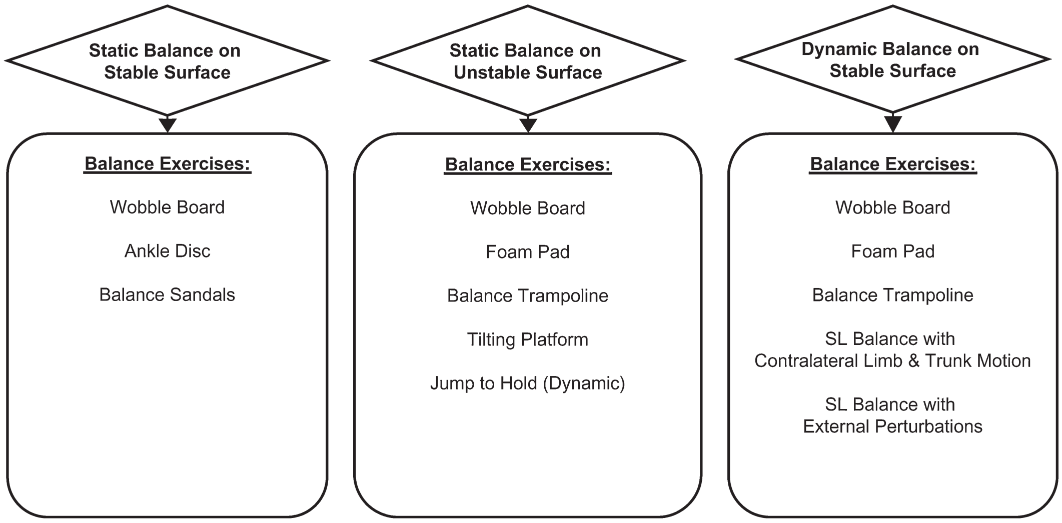

Figure 1. Basic exercise guideline for improving various types of balance ability.

without performing any specific type of balance training. A small sample size in each group may have limited the results of this study, and future research needs to further investigate dynamic balance changes because of a multifaceted neuromuscular training program.

Holm et al. (13) and Rasool and George (28) studied balance ability that required the subjects to maintain single-limb stability while moving the ipsilateral or contralateral limb. Rasool and GK evaluated the effects of a progressive single-leg dynamic balance training program on dynamic balance improvements using the star excursion balance test (SEBT) in 30 healthy men (PEDro = 8). Subjects were randomly assigned to either a training or control group. The SEBT requires individuals to balance on one limb while moving the other limb in various directions and was reported to be a reliable technique. The authors describe the SEBT as a reliable measure citing previous research but do not report specific values or type of reliability measurement. The balance training program was performed 5 days per week for 4 weeks and progressed from stable to unstable surfaces, incorporated eyes open and eyes closed conditions, and involved contralimb and trunk movements. Dynamic balance was improved on the trained leg after 2 and 4 weeks of training. Similar to the findings of Rothermel et al. (31), these authors also concluded that crossover effects occurred because dynamic balance improvements with a strong effect size were observed in the untrained leg as well.

Although Holm et al. (13) did not observe improvements in static balance ability on an unstable surface, dynamic balance improvements were observed in the elite handball athletes after 8 weeks and 12 months of the program with moderate effect sizes. The authors concluded that the program was successful with improving dynamic balance, but there was no control group, so it is unknown whether changes were because of the program or continued handball participation.

According to the results of these 4 studies, dynamic balance ability can be improved after a balance training program. Four different types of dynamic balance assessments were used in this group of articles, so the exact type of assessment does not appear to affect the ability to see improvements. Compared with the other articles in this review, this group of articles evaluating dynamic balance ability appears to use challenging balance training programs and should be considered as a potential reason for unanimous successful findings. The study by Holm et al. (13) is the only study to use unstable surface training as the primary balance training modality as the others relied on integrated training, dynamic body movements, or a combination of various balance exercises.

DISCUSSION

Our systematic review provides strong evidence that balance training can improve static and dynamic balance. This conclusion was determined from consistent findings of multiple studies with strong designs. Thirteen (1,4,5,7,9,12,16,20,27,28,33) of the 16 articles performed a randomized controlled trial design to assess balance improvements. Sixteen articles were reviewed and abstracted with 14 of them demonstrating balance improvements after their training program. The 2 studies that did not observe balance improvements did not report exact means or detailed descriptions of their programs and both studies assessed static balance, which is an outcome that may be too easy for healthy subjects to show improvement (4,27). An easy balance measure may create a ceiling effect that prevents improvements from being observed because the subjects perform the task with minimal error before the intervention. This ceiling effect during a static limb stance was demonstrated by both the Kovacs et al. (16) and Holm et al. (13) studies, in which dynamic balance improvements were found despite no changes in static balance being present. Both of these authors supported the theory that a static assessment may not provide sufficient improvement ability with healthy and athletic subjects. Therefore, it is recommended that future studies use more demanding assessments of postural control to evaluate changes in balance from a training program with a healthy population.

Balance training has been incorporated into many injury prevention programs with healthy populations (5,15,23,25,35). However, there is speculation that perhaps balance improvements are not possible with a functional healthy population. The results of this review do not support this anecdotal theory because all of the studies implemented a balance training program to a healthy population and the majority found dramatic balance improvements. Furthermore, 2 studies used elite athletes and still observed improvements (13,16).

The findings of this review suggest that the type of balance training does not influence the ability to gain balance improvements. Training methods included dynamic exercises with lower extremity and trunk perturbations, balancing with instrumented stability systems, multifaceted training (strengthening, plyometric, agility, and balance exercises), and single-leg stance on unstable platforms (wobble boards and ankle discs). Basic progressions were also frequently embedded into training programs and included stages transferring from eyes open to eyes closed, double-leg stance to single-leg stance, and firm stable surface to soft or unstable surface. More dynamic progressions that were at times used include throwing a ball, kicking with an elastic band on the nondominant limb, or moving the body to cause changes in the location of the center of mass. There is a possibility that challenging the sensorimotor system by either producing other body movements or requiring stabilization on an unstable surface produces the same effects. Michell et al. (20) demonstrated this possibility by showing balance improvements because of dynamic body movements that were enhanced by training with an unstable surface. However, these comparisons deserve further study.

In addition to multiple types of training used, no consensus exists on the duration of these training programs. The results of this review lead to the conclusion that the period for an intervention is not a vital factor. The minimum training period used that led to balance improvements was 10 minutes, 3 days per week for 4 weeks, whereas the longest training duration was 3 days of training per week for 12 weeks. From an efficiency standpoint, it appears that 4 weeks of balance training is sufficient for improving both static and dynamic balances.

An important finding of this systematic review is that none of the balance training programs appear to result in negative changes in balance ability. All of the effect sizes and percentage change scores demonstrate improvements in balance ability regardless of the specific balance training program or assessment employed. Even though a few of the studies did not demonstrate significant improvements in balance ability, there is no evidence to suggest that balance training programs cause harm.

Despite almost unanimous evidence for supporting the use of balance training to improve balance ability, several limitations were commonly observed and should be a focus of future research. Only a few studies included measures to monitor compliance and supervise the actual training program. Though, the successful findings indicate that this limitation most likely did not influence the final results but should be a consideration in future work especially if a control group is not included. The issue of a pure randomized control group is also an important aspect of a randomized trial for evaluating the effectiveness of an intervention program. Evidence supporting balance training will be enhanced if randomization of groups occurs in the future. Finally, although it is often impossible to blind subjects in a balance training program to their experimental group, it is possible to blind evaluators measuring a subjective item, such as balance time, and should be encouraged in future studies.

PRACTICAL APPLICATIONS

These findings suggest that balance can be improved in a healthy population and therefore should be incorporated in future rehabilitation and injury prevention programs. Figure 1 illustrates the type of training modalities that effectively improved static balance on a stable surface, static balance on an unstable surface, or dynamic balance ability and can be used to assist the design of a balance training intervention. Any type of balance training program in any type of athlete can improve static balance ability on an unstable surface and dynamic balance ability. However, individuals should take into consideration when designing programs that the ability to improve static balance ability on a stable surface appears to be directly related to the initial level of balance ability and the duration and the difficulty of the balance training program. Most of the programs in this review incorporated exercise progressions that began the individual in a comfortable environment and progressed to more challenging tasks. These progressions included starting with double-leg exercises with eyes open on a stable surface and progressing to single-leg exercises with eyes closed on an unstable surface with eventual progressions to dynamic balance activities. Programs that are performed at least 3 times per week for 4 weeks and include some type of progressive dynamic balance training appear to have the best results.

ACKNOWLEDGMENTS

We would like to acknowledge the National Academy of Sports Medicine for helping to fund this review.

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