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Training to Reduce Postural Sway and Increase Functional Reach in the Elderly

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Poor balance is one of the most common risk factors for falling, a common cause of work-related injury and death. To evaluate the effects of a 10-week intervention program on balance in older adults, 12 participants aged 61–77 years (age $= 70.4 \pm 5.4$ years; mean $\pm$ SD) completed an exercise program (60 min, 2 days $\cdot$ week^{-1} for 10 weeks) performed while laying/sitting on large air-filled exercise balls (Thera-Band®). Several postural sway composite scores (determined while standing with feet apart and semitandem, eyes open and closed) improved ($p \leq 0.05$) including medial–lateral amplitude and speed of sway (reduced by ~9%), and instantaneous speed (reduced by ~13%). Reductions in XY area approached ($p = 0.06$) statistical significance and anterior–posterior amplitude and speed of sway did not change. Functional reach also improved (20.3%). These results suggest that challenging the physiological systems involved in balance control while on the nonstable support surface of the exercise balls improves both static and dynamic balance in older adults and may reduce the risk for falling.

KEY WORDS: aging; exercise; balance; fall prevention; postural stability; functional reach.

INTRODUCTION

Falls are a common cause of injury and death both on and off the job. Falls are the third leading cause of work-related deaths, accounting for over 10% of all work-related fatalities. Within the construction industry, falls account for 32% of all work-related deaths. Furthermore, approximately 16% of nonfatal occupational injuries in private industry involving days away from work result from falling on the same floor level (10.7%) or to a lower level (5.5%) (1).

The incidence of falls becomes more common with advancing age. Approximately 45% of adults over the age of 65 years will experience at least one fall per year and many of these individuals will fall repeatedly (2). Furthermore, increasing age is correlated with

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Table I. Unintentional-Injury Deaths (UID) Attributable to Falls, United States, 1997

Age group	Population (thousands)	Total UID	UID due to falls	% UID due to falls
20–29	36,296	12,905	316	2.4
30–39	43,361	13,798	495	3.6
40–49	39,841	13,128	766	5.8
50–59	26,912	8,158	722	8.9
60–69	19,837	7,266	1,179	16.2
70–79	15,839	10,529	2,913	27.7
80–89	7,144	11,981	5,557	46.4
90–99	1,385	4,761	3,085	64.8
100 and over	54	274	189	69.0

Note. From *Injury Facts*™*, 2000 edition,* 2000, pp. 28–29.

a greater number and severity of falls (3). Falls are the second most common cause of death resulting from unintentional injuries, second to those accounted for by motor vehicles, for those aged 55–79 years (1). For those aged 80 and beyond, falls are the primary cause of death from unintentional injuries, accounting for more than half of all fatal injuries (Table I).

The number of older adults is expected to double by the year 2030 and coinciding with this growth will be an increase in the size of older segments within the workforce. This change in both general and occupational demographics will require the accommodation of older adults to reduce their risk for suffering falls both on and off the job.

Fractures occur in 5% of all falls (4) and approximately 210,000 hip fractures, mostly in older adults, occur annually in the United States (5). Currently this amounts to an estimated 10–20 billion dollars per year in health care costs and by 2030 the cost associated with hip fractures alone is predicted to exceed 240 billion dollars annually (6). Although the presence of osteoporosis often contributes to a fracture once an older adult falls, osteoporosis is seldom the cause of the fall. In many cases, falls are caused by a loss of balance (7,8). Therefore, one of the most commonly identified risk factors for falling and thus, subsequent injury, is impaired balance.

Balance is the ability to maintain the body's position over its base of support. The center of gravity of the body shifts continuously even during quiet upright standing. Postural sway is the corrective body movement resulting from the control of body position and is determined by measuring the location and amount of change that occurs in the position of the vertical force vector projected onto a horizontal plane. Traditionally, postural stability has been measured by determining the degree of motion of the center of pressure at the surface of support through force platform technology (9,10). Postural sway is usually measured during quiet, upright standing and thus reflects the body's effort to maintain balance in that posture, with increased sway indicating greater effort and thus poorer balance. Advancing age is associated with increased postural sway (11) and individuals who have sustained multiple falls demonstrate greater postural sway than age-matched peers (12,13).

Dynamic balance is the ability to anticipate changes in balance and coordinate muscle activity to maintain stability. Dynamic balance is often determined by functional reach, or the maximum distance one can reach beyond arm's length while maintaining a fixed base of support (14). Functional reach also decreases with age (11), placing the older adult at an increased risk for falling when reaching for objects with outstretched arms. For workers aged 65–74 years, more than 13% have difficulty reaching overhead and more than 7% are completely unable to perform this task. Furthermore, 30.9% of workers aged 65–69 and 37.8% of those aged 70–74 have difficulty performing tasks that involve dynamic balance such as stooping and crouching (15).

During both static and dynamic balance, posture is controlled by the detection of disturbances to the center of gravity and the initiation of appropriate responses to return the body to a stable position. This is a complex process controlled to a large extent by the visual, somatosensory, and vestibular systems. In addition, the muscular system contributes to balance control since all body movements are produced via contraction of skeletal muscles. With increasing age, there is a decrease in sensory function (16,17) and a decrease in muscle strength (18). Slobounov *et al.* (19) measured postural sway in older adults and found that postural sway, with eyes open and closed, increased with age, but was affected to a much greater extent when visual cues were removed. Hasan *et al.* (20) investigated changes in postural sway in older women during eyes open double stance, eyes open single stance, eyes closed double stance, and eyes closed single stance. The velocity of sway increased when the visual cues were removed and when the feet were positioned to reduce the size of the base. Therefore, a reduced base of support (e.g., when the feet are in the semitandem, tandem, or unilateral positions as occurs during walking) may increase the risk for suffering a fall, especially in dimly illuminated conditions that compromise visual sensation.

Typical strategies to improve balance and mobility include assistive devices (e.g., canes, walkers) and general exercise programs. The literature is equivocal regarding the effects of exercise programs on balance. For example, Binder *et al.* (21) reported that frail elderly improved balance after participating in exercises for 8 weeks. Hopkins *et al.* (22) found improvements in balance after completion of a 12-week program of aerobic dance. However, others have found no improvement of balance in older adults following exercise programs (23–25).

It has been recommended that exercise programs be customized to target the physiological systems involved in balance control, specifically the visual, vestibular, somatosensory, motor, and musculoskeletal systems. One challenge in developing such programs is identifying safe and effective modalities that can be used to enhance balance. The popularity of large air-inflated balls as an exercise modality for use by people of all ages in fitness and rehabilitation settings has been increasing during the recent past. A variety of exercises can be performed while laying or sitting on the balls. These balls are purported to enhance balance by strengthening ancillary muscles and stimulating the sensory systems. However, very little is known about the effects of this exercise modality on balance in older adults. The purpose of this study was to determine if these balls could be used to enhance balance in a group of older adults.

METHOD

Twelve participants (5 men, 12 women) aged 61–77 years (mean $= 70.4 \pm 5.4$ years) were recruited from the Wichita State University, Center for Physical Activity and Aging. Participants had no history, signs or symptoms of any disabilities or neuromuscular illness that could preclude participation in the study. Screening was accomplished by a medical/health history questionnaire administered prior to the study. All procedures were approved by the University's Human Subjects Review Board and all participants signed an informed consent document.

Exercise training was performed as a group activity for 60 min, 2 days · week^{-1} for 10 weeks, and consisted of stretching, strengthening, and balance exercises. The training sessions were lead by a professional exercise instructor. Stretching exercises consisted of full-body range-of-motion exercises performed at the beginning and end of each session. Strengthening exercises included upper and lower body resistance exercises using dumbbells and 6-in. wide elastic bands (Thera-Band®). Balance exercises involved a multitude of exercises where the participants placed themselves in the prone, supine, or sitting position on 55-cm-diameter air-filled balls (Thera-Band™) and moved their body with the eyes open and closed over the ball's shifting base of support.

Standing balance was determined using a force platform (#K80401, Bertec Corp.). The force components consisted of the medial–lateral (F_x), anterior–posterior (F_y), and vertical (F_z) axes. The moment components consisted of moment in the $x(M_x)$, $y(M_y)$, and $z(M_z)$ directions. All components were measured in metric units. The signals collected from the platform were amplified through a six-channel amplifier. The pressure signals were relayed into the computer using a digital converter (A/D board PX116XE0) and recorded with LabVIEW software.

Standing balance measures were made while participants stood with the feet apart (feet parallel, toes even, 3-in. gap between feet) (FA) and semitandem (feet parallel, dominant foot placed diagonally in front of the other with the heel in line with the other toe) (ST). Each stance was performed with either the eyes open (EO) or eyes closed (EC). Therefore, the four testing conditions consisted of FA/EO, FA/EC, ST/EO, and ST/EC.

The force platform was marked to maintain consistency in foot placement. For each stance, the participants stood in bare feet with their eyes at the horizon and their arms at the sides in a neutral position. An anthropometric kit (Siber Hegner & Co.) was used to measure the standing height (cm), foot length (cm), and width (cm) of each participant. The length of the base of support was defined as foot length in the FA conditions and twice the foot length in the ST conditions. The width of the base was defined for both FA and ST conditions as the width of both feet plus the distance between the feet.

Each condition was performed for 10 s in random order and repeated three times. The data were collected with a sample frequency of 50 Hz. The LabVIEW software recorded all 500 data points (in X and Y coordinates). Microsoft Excel was used to calculate anterior–posterior (A–P) amplitude (% of length of base), medial–lateral (M–L) amplitude (% of width of base), A–P speed (% of length of base · s^{-1}), M–L speed (% of width of base · s^{-1}), XY area (mm^2), maximum instantaneous speed (mm · s^{-1}), and mean instantaneous speed (mm · s^{-1}) (26,27). A composite score was determined for each of these balance parameters (A–P amplitude, M–L amplitude, A–P speed, M–L speed, XY area, maximum instantaneous speed, and mean instantaneous speed). The best performance of the three trials for each of the conditions was used to calculate the composite score for each parameter by averaging these four values. The composite score is a measure that represents overall postural stability as measured during each of the static balance conditions. Therefore, the composite score is an indication of an individual's ability to maintain posture and prevent a loss of balance while standing with the feet in different positions with and without visual sensation.

Functional reach was determined using the PEAK Performance System (PEAK Performance Systems, Inc., Englewood, CO) which digitizes the movement of reflectors attached

Table II. Descriptive Statistics for Participants

	Mean	Standard deviation
Age (year)	70.4	5.4
Height (cm)	167.83	8.35
Weight (kg)	166.83	33.06
Foot length (cm)	25.86	1.95
Foot width (cm)	9.60	0.72

to the body. The system was calibrated using a standard scaling rod. A reflective marker was placed on the wrist of the outstretched arm (closest to the filming camera) and the participants were asked to reach forward with the arms held together and parallel to the floor until they had to take a step. Functional reach was the difference between arm's length and maximal forward reach (measured in millimeters) while maintaining a fixed base of support (until a heel was raised from the floor). This was repeated four times and the best measure was used for analysis.

Paired t tests were used to determine the effect of the training program on postural stability composite scores and functional reach. All statistical analyses were conducted using JMP IN (SAS Institute, Cary, NC) for Windows software. The level of significance was set a priori at the $p \leq 0.05$ for all statistical analyses.

RESULTS

Descriptive characteristics and anthropometric measures of the participants are given in Table II.

Several of the postural sway composite scores improved as a result of training (Table III). Both amplitude and speed of sway in the M–L direction were reduced significantly ($p \leq 0.05$) after the training program. Each of the M–L composite scores improved by approximately 9%. However, amplitude and speed of sway in the A–P direction did not change. Maximum instantaneous speed and mean instantaneous speed were reduced significantly ($p \leq 0.05$) with scores for both measures improving by approximately 13%. Furthermore the change in XY area approached ($p = 0.06$) statistical significance. In terms of dynamic balance, functional reach (Table IV) increased significantly ($p \leq 0.05$) from 333 mm before training to 401 mm after training, a 20.3% increase.

Table III. Comparison of Postural Sway Composite Scores

Measure	Before	After	% Change	p value
A–P amplitude (% of length of base)	1.18	1.20	1.0	0.5939
M–L amplitude (% of width of base)	1.82	1.66	−9.0	0.0329*
A–P speed (% of length of bases^{-1})	47.78	48.52	1.5	0.6417
M–L speed (% of width of bases^{-1})	73.52	66.38	−9.7	0.0214*
XY area (mm^2)	636.79	512.71	−19.5	0.0617
Maximum instantaneous speed (mm s^{-1})	135.36	118.12	−12.7	0.0015*
Mean instantaneous speed (mm s^{-1})	31.52	27.33	−13.3	<0.0001*

*$p \leq 0.05$.

Table IV. Comparison of Functional Reach

Measure	Before	After	% Change	p value
Functional reach (mm)	333.0	400.7	20.3	0.0496*

$^{*}p \leq 0.05$.

DISCUSSION

These results suggest that exercise programs that incorporate the use of exercise balls can produce improved postural sway and functional reach in older adults. These improvements may reduce the risk of falling in older adults, both at home and in the workplace. Improvements observed during this study were approximately 9% for speed and amplitude of sway in the M–L directions, approximately 13% in maximum and mean instantaneous speeds, and over 20% in functional reach. The observed improvements in the postural stability composite scores suggest that balance was improved under a variety of conditions (i.e., reduced visual sensation and base of support) that typically compromise static balance. In addition, the improvements in functional reach suggest that the risk for falling while leaning or reaching for objects was reduced in these older adults.

Several different exercise modes and modalities designed to improve balance have been studied and the results are equivocal. Binder *et al.* (21) have reported that frail elderly people showed improved balance after participating in group exercises for 8 weeks. Hopkins *et al.* (22) found a 12% increase in balance time after completion of a 12-week program of aerobic dance. However, Brown and Holloszy (23) found no significant improvement of balance or gait in 60–71-year-old participants following a general physical activity program. Likewise, Jirovec (25) reported no significant gains in balance when 15 nursing home residents were given a month of assisted walking. Other exercise interventions have produced small or negligible reductions of sway in older adults (28,29).

Combined programs, especially those emphasizing multisensory training and balance-specific activities may be more effective in improving balance than general exercise programs or those consisting of only aerobic, strength, or flexibility exercises. Telian *et al.* (30) reported that vestibular habitation therapy was effective in increasing stability for participants standing on one leg while shaking the head or closing the eyes. Brandt *et al.* (31) reported that a training program based on the manipulation of sensory inputs significantly improved postural stability. Tanaka *et al.* (10) found that a training program designed to improve both sensory and motor function is effective in the improvement of balance among older adults.

It is possible that multisensory training which manipulates the three sensory systems under stable and nonstable support surfaces may be the most effective means to improve balance in older adults. The use of exercise balls may improve both static and dynamic balance in older adults because this type of training challenges the visual, vestibular, and somatosensory systems while on a nonstable support surface. In addition, strength and flexibility exercises can be performed while participating in this type of training.

The use of balance balls is a relatively inexpensive, safe, and simple means to improve balance. The development and promotion of exercise programs that can be done independently or guided by an exercise instructor in a group setting may be a means to attenuate losses in balance and reduce the risk of falling among older adults. Further studies are needed to identify optimal duration, frequency, and intensity of balance-specific training. As with other modes of exercise, it is expected that longer duration, greater frequency, and higher intensity (placing the participants at or near their limits of stability) would deliver better results. Further studies that compare the effects of different training modes are needed to determine the most effective approach to enhance balance in older adults.

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