Summary

This study examined improvements in static balance and muscle electromyographic (EMG) activity following a four week progressive training program in 16 middle aged females (mean age 46.9 ± 8.7 yrs; height 161.1 ± 6.0 cm; weight 65.4 ± 11.2 kg). Participants trained 3 times per week for 4 weeks, for 50 min per session, progressing base of support, stability, vision, resistance and torque in each of six basic exercises. Pre and post training measures of balance included feet together standing, a tandem stance and a one-leg stand (unsupported leg in the frontal plane) performed with the eyes closed, and a Stork Stand (unsupported leg in the frontal plane) with both eyes open and closed. In each position postural deviations were tallied for each individual while muscle recruitment was determined using root mean squared (RMS) EMG activity for the soleus, biceps femoris, erector spinae, rectus abdominis and internal oblique muscles of the dominant foot side. Balance scores were significantly improved post training in both the Balance Error Score System (p < 0.05) and stork stand positions (p < 0.01). Muscle activity was reduced post-training in all muscles in each condition except the soleus in the tandem position, although not all significantly. Reduced biceps femoris activity suggest that improved core stability allowed participants to move from a hip to an ankle postural control strategy through improved coordination of muscles involved in balance and reduced body sway. The core muscles were able to control body position with less activity post training suggesting improved muscle coordination and efficiency. These results suggest that short term progressive floor to BOSU™ balance training can improve standing balance in middle aged women.
Introduction

Balance can be defined as the ability to maintain the body’s center of gravity (COG) over its base of support (BOS) with minimal sway or maximal steadiness (Emery et al., 2005). Control of balance in upright body position is important for movements necessary not only for operating activities of daily living, but for high level sport activities or prevention of musculoskeletal injuries (Kollmitzer et al., 2000; Saeterbakken and Finland, 2013). To achieve balance or postural stability, the body coordinates four systems: somatosensory, visual, vestibular, and musculoskeletal systems. If balance is perturbed, the body reacts through automatic postural reactions eliciting increased muscle tone while the CNS monitors the sensory inputs to find the most efficient muscle output that will regain balance and provide good stability. The synergy between muscles of the leg and trunk creates stable upright posture. The coordinated arrangement of postural muscle activation employed in response to perturbation exists to simplify control of posture and movement and is referred to as postural synergy (Stemmons and Sahrmann, 1999).

To train balance visual input, size of the base of support, and modifications to the foot support surface are often employed. Current training methods demonstrate the utility of narrowing the base of support (i.e. stand on one foot as opposed to two) (Henry et al., 2001; Saeterbakken and Finland, 2013); closing the eyes reducing visual input (Winter et al., 1998; Lord, 2006; Baumberger et al., 2004); and/or introducing unstable working surfaces (i.e. wobble board, Swiss ball, or BOSU™ balance trainer) to progressively challenge the balance control mechanisms (Cosio-Lima et al., 2003; Silfies et al., 2005).

Researchers and trainers that promote training on unstable surfaces claim that utilizing equipment like the Stability Ball, wobble board and BOSU™ Balance Trainer provides a greater stress to the global and local stabilizing muscles (Anderson et al., 2013; Myer et al., 2005; Norwood et al., 2007; Behm et al., 2010). It has been hypothesized that performing exercise in an unstable environment stresses the synergistic and stabilizing muscles around a joint system for any given movement providing a more specific and functional form of training. Several authors report increased core muscle activation when utilizing unstable surfaces (Behm et al., 2002, 2005; Willardson, 2007; Hibbs et al., 2008), Willardson et al. (2007, 2009) suggesting a direct link between training on unstable surfaces and core training exercises.

While studies have reported improved neuromuscular control of balance using different kinds of instability in injured or aged individuals, the effect of a short term, specific training program performed using transitions in vision, base of support and surface stability have yet to be explored. For that purpose this work examines changes in balance and neural coordination of muscles involved in body control and standing balance following a four week training program focussing on progressive exercise moving from a stable floor condition to instability on the BOSU™ Balance Trainer, from two to one foot stance, and from eyes open to eyes closed conditions. Specific hypotheses include:

1) Balance will improve significantly over the four weeks of progressive training
2) Global muscular electromyographic activity will decrease at the post intervention measurement
3) Biceps femoris activity will decrease as individuals control body sway through core stabilization and ankle postural control strategies.

Methods

Eighteen middle aged females participated in repeated measurements of pre and post training balance using standing posture with two feet together (2 feet), a Tandem Stance with one foot in front of the other (Tandem), 1 leg standing on the non dominant (1 Leg) with the eyes closed, and a Stork Stand with both eyes open (SS EO) and eyes closed (SS EC). Muscle recruitment was determined using root mean squared (RMS) EMG activity in internal oblique (IO), rectus abdominis (RA), erector spinae (ES), biceps femoris (BF) and soleus (SO) muscles. Subjects were recruited as volunteers from university faculty and staff. Each performed an orientation to the study and the tests and measures at least three days prior to testing at which time subjects were screened for health issues that would limit participation using a Physical Activity Readiness Questionnaire (PAR-Q). Each participant provided written informed consent prior to participating in the study which was approved by the institution’s research ethics board.

Training procedures

Participants trained 3 times per week for 4 weeks, for 50 min per session. Training included a progression from floor to BOSU unstable surface, eyes open to eyes closed conditions, static to dynamic exercise, from two to one foot, and progressed to include offcentred forces (torque). The training focus was defined using variations of 6 specific exercises (Table 1). All exercises were progressed in relation to improvement in both static and dynamic balance:
<table>
<thead>
<tr>
<th>Exercise</th>
<th>Stable/unstable</th>
<th>Static/dynamic</th>
<th>Eyes open/closed</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 leg standing</td>
<td>Standing on the floor/BOSU</td>
<td>Standing/standing with arm movement</td>
<td>Standing with eyes open/closed</td>
<td>Standing on the floor/BOSU with catching a medicine ball</td>
</tr>
<tr>
<td>Squat</td>
<td>Squat on the floor/BOSU</td>
<td>Static squat/dynamic squat</td>
<td>Squat on the floor with eyes open/closed</td>
<td>Squat on the BOSU with medicine ball</td>
</tr>
<tr>
<td>Squat with partner</td>
<td>Squat “hand to hand contact” on the floor/BOSU</td>
<td>Squat “hand to hand contact” static on the floor/BOSU and during a dynamic squat</td>
<td>Static “hand to hand contact” squat on the floor/BOSU with eyes open/closed</td>
<td>Lateral bound on the BOSU with medicine ball catch</td>
</tr>
<tr>
<td>Lateral Bound</td>
<td>2 feete1 foot lateral bound on the floor/BOSU</td>
<td>Lateral bound/bound with partner destabilization</td>
<td>Lateral bound on the floor/BOSU eyes open/closed</td>
<td>Lateral bound on the BOSU/BOSU with medicine ball hold</td>
</tr>
<tr>
<td>Kneeling on BOSU</td>
<td>Kneeling on BOSU</td>
<td>Kneeling on BOSU/kneeling with arm movement</td>
<td>Kneeling eyes open/closed</td>
<td>Kneeling with medicine ball holding and partner destabilization</td>
</tr>
<tr>
<td>Torque</td>
<td>Torque on the floor/BOSU with medicine ball throw/catch</td>
<td>Dynamic torque with medicine ball throw/catch</td>
<td>Torque on the floor eyes open/closed with medicine ball and partner</td>
<td>Torque on BOSU with partner destabilization</td>
</tr>
</tbody>
</table>

Week 1 and 2 were performed using the floor and BOSU with the eyes open with no external load; week 3 and 4 increased the exercise’s difficulty by introducing a medicine ball and the eyes closed condition (Table 1). The total number of exercises per session increased weekly from 6 in week one to 12 in week 4. Similarly, the number of repetitions per set increased from 8 in week one to 14 in week 4. Each variable increased by 2 each week. In all sessions participants were asked to focus on “core” muscle activation to stabilize the body.

### Balance testing procedures

Static balance was assessed using components of the BESS e Balance Error Score System (Riemann et al., 1999). This test is a quick and practical balance evaluation method demonstrated to be safe and efficient in previous studies (Susco et al., 2004; Valovich et al., 2003) and as a clinical evaluation of balance that usually has moderate to good reliability (Bell, 2011). While BESS has a learning effect in healthy and neurological patients (concussion specially) (Mulligan et al., 2013), all participants performed the BESS 2 times during their orientation to the study, and practiced once on the day of data collection prior to testing. The BESS is normally performed barefoot on a firm surface by holding 3 different positions for 20 s each one in both eyes open and eyes closed conditions. This study utilized only the eyes closed condition, and added the stork stand as one of the measures in both eyes open and eyes closed conditions (see Table 2). While completing the BESS participants held each position with hands on the iliac crests while trying to maintain optimal stability without body movement. During each test three investigators observed each subject and assigned the value “1” for every balance fault; the median value was used when there was a discrepancy, and the final score was obtained by counting the total number of errors in all positions, and by summing them separately for the eyes open and closed condition. The following body movements were considered an “error”:

- lifting hands from the iliac crest (one or both)
- opening eyes (only in eyes closed condition)
- stepping, stumbling or falling
- remaining out of the position for more than 5 s
- moving the hip through more than 300° of abduction or flexion
- lifting forefoot or heel

During each testing session (pre and post), subjects were re-introduced to each test and were able to practice each test position prior to testing.

### Surface electromyography

Surface EMG recording locations were measured from five muscle groups (Anderson et al., 2013; Behm et al., 2002; Cram et al., 1998); Rectus Abdominus (muscle bellies lateral to the umbilicus), Internal Obliques (2.5 cm medial from the anterior superior iliac spine), Erector Spinae (2 cm lateral to L5-S1), Bicep Femoris (mid-belly of the long head), Soleus (mid-point between medial malleolus and medial condyle of the tibia). Each EMG site was shaved, cleansed with alcohol, and abraded with inter-electrode distances of approximately 2.5 cm positioned parallel to
Surface EMG activity was recorded using Grass Model 10A amplifiers with a digital interface. Electrical activity was recorded using 17 silver-silver chloride disposable electrodes applied to the skin’s surface (16 EMG electrodes and a ground). Electrode impedances were maintained below kOhm. Filter settings were 10 Hz for the low filter and 1000 Hz for the high filter. The recording epoch was five seconds at a sample rate of 2000 Hz. All data were digitized using a National Instruments AT-MIO-16F-5 A-D card and stored on a CD. The data were smoothed using a 10-point moving average and root mean squares (RMS) were calculated for time-series using a Microsoft EXCEL spreadsheet.

### Statistical analysis

Results for the BESS and Stork Stand were analysed separately using repeated measures analyses of variance to examine the global muscle RMS EMG activity. SPSS v13 was used to perform a 2 (time) x 5 (muscle) x 3 (position) analysis of variance (ANOVA) with repeated measures to evaluate the effects across the BESS test, and a 2 (time) x 5 (muscle) x 2 (position) analysis of variance (ANOVA) with repeated measures to evaluate the effects across the Stork Stand. Differences in muscle recruitment in the biceps femoris (hip strategy) and soleus (ankle strategy) were examined using a 1 (muscle) x 2 (time) x 3 (position) repeated measures ANOVA for the BESS, and 1 (muscle) x 2 (time) x 2 (position) for the stork stand. When differences were detected by ANOVA pairwise comparisons were performed adjusted for multiple comparison through use of Bonferroni correction. Paired T Tests were used to analyse positional errors in BESS and global RMS activity (separately for BESS and Stork Stand) in pre-post training comparisons. The level of significance was set at $p < 0.05$.

<table>
<thead>
<tr>
<th>BESS position</th>
<th>Eyes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double leg stance</td>
<td>Closed</td>
<td>Standing both feet in contact with the floor and each other</td>
</tr>
<tr>
<td>Tandem stance</td>
<td>Closed</td>
<td>Standing with the heel of the dominant foot (front foot) touching the toe of the non dominant foot (back foot)</td>
</tr>
<tr>
<td>One leg stance</td>
<td>Closed</td>
<td>Single leg standing (non dominant leg) while maintaining 90° of knee flexion with the dominant leg, thighs parallel</td>
</tr>
<tr>
<td>Stork stand</td>
<td>Open and closed</td>
<td>Single leg standing (dominant leg) while maintaining contact between medial knee and contralateral plantar surface of the foot</td>
</tr>
</tbody>
</table>

1000 Hz for the high filter. The recording epoch was five seconds at a sample rate of 2000 Hz. All data were digitized using a National Instruments AT-MIO-16F-5 A-D card and stored on a CD. The data were smoothed using a 10-point moving average and root mean squares (RMS) were calculated for time-series using a Microsoft EXCEL spreadsheet.
Results

Eighteen apparently healthy females (mean age 46.9 ± 8.7 yrs; height 161.1 ± 6.0 cm; weight 65.4 ± 11.2 kg) with no known balance issues participated in the present study with pre and post training measures of balance and muscle activity during static posture balance positions, and included activities with the eyes open and closed. Only participants who attended 80% of the sessions were included in the statistical analysis, with 16 participants completing at least 10 of the 12 workout sessions and included in this analysis. The two participants excluded from the study continued for the four weeks but cited work time pressures as their reason for low attendance (7 and 9 of 12 sessions) at training sessions.

Balance positional errors

The mean number of positional errors during the BESS and stork stand decreased in each position with the exception of the BESS two feet with eyes closed (see Table 3). During the BESS positions, the sum of positional errors for all participants combined decreased from 67 pre-training to 44 post training (t = 1.74; p < 0.05) moving from “broadly normal” to “above average”. During the stork stand the sum of positional errors for all participants combined decreased from 100 pre training to 59 post training (t = 2.97; p < 0.01).

BESS muscle activity

The Repeated Measures ANOVA (2 x 5 x 3) demonstrated a significant main effect for test conditions (F = 6.91; p < 0.01), between muscles (F = 39.40; p < 0.00) and importantly, time (pre and post-training) (F = 5.28; p < 0.00), with significant Test x Muscle (F = 4.72; p < 0.00). The test x Time (F = 3.09; p < 0.06) interaction approached significance. Mean muscle RMS reductions for each test are reported in Table 4, and for each test in Fig. 1.

Surface electromyographical RMS decreased for all muscles in all positions with exception of the soleus during the Tandem position, even if not significantly (p > 0.05). Global RMS activity (EMG in Tandem, 1 leg and 2 Feet together) decreased significantly in both the rectus abdominis and biceps femoris (p < 0.01) when comparing pre- and post-training. A one way ANOVA for the biceps femoris found muscle activity to be lower in post training compared to pre training (9.09 vs 13.87; F = 4.81, p < 0.04) and the 1 Leg position showed higher muscle activity compared to Tandem positions, independently for time (F = 7.17; p < 0.00); no differences were detected in Time x Test interactions (F = 2.61; p < 0.09).

A one way ANOVA for soleus found a significant main effect (F = 5.62; p < 0.01) with EMG activity significantly lower in the 2 Foot position compared to tandem and 1 leg (respectively p < 0.00 and p < 0.04); EMG in all positions decreased in post training compared to pre training, even if not significantly for the time factor and time x test interaction (p > 0.05).

Stork stand muscle activity

The Repeated Measures ANOVA (2 x 5 x 2) demonstrated a significant main effect for test conditions (F = 21.80; p < 0.00), between muscles (F = 19.61; p < 0.00) and time (pre and post-training) (F = 8.76; p < 0.01), with significant Test x Muscle (F = 3.89; p < 0.00) interactions. In both the eyes open and eyes closed stork stand positions, during the eyes closed condition muscle EMG activity were higher for each muscle (see Fig. 2). Similarly, the muscle EMG activity was reduced in each muscle post training in each condition even if significant only in the biceps femoris and soleus for EC (p < 0.05; Table 5). Global RMS activity (EMG in Stork Stand EO and EC together) decreased significantly in all muscle (p < 0.05) with exception of OI (p > 0.05) for pre-post training comparison.

A one way ANOVA for biceps femoris evidenced significance for test (F = 37.159; p < 0.00), time (F = 11.56; p < 0.00) and time x test interaction (F = 7.52; p < 0.01). EMG activity was lower in post training compared to pre training in EC (20.82 vs 36.19; p < 0.00) and EO (7.99 vs 11.17; p < 0.07) with significance only in the EC condition; EMG activity was significantly higher in EC compared to EO in both pre and post training conditions (p < 0.00).

A one way ANOVA for soleus evidenced significance for test factor (F = 57.315; p < 0.00), time x test interaction (F = 5.34; p < 0.03) while the time factor (F = 3.65;
Table 4  EMG values for all muscles in BESS positions pre and post-training. RA: Rectus Abdominis; IO: Internal Oblique; ES: Erector Spinae; BF: Biceps Femoris; S: Soleus. *Significantly different in pre-post comparison (p < 0.05).

<table>
<thead>
<tr>
<th></th>
<th>RA</th>
<th>IO</th>
<th>ES</th>
<th>BF</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>2 feet</td>
<td>5.05</td>
<td>4.16</td>
<td>7.01</td>
<td>6.89</td>
<td>7.45</td>
</tr>
<tr>
<td>SD</td>
<td>2.42</td>
<td>1.23</td>
<td>7.46</td>
<td>7.56</td>
<td>6.26</td>
</tr>
<tr>
<td>Tandem</td>
<td>5.32</td>
<td>4.33</td>
<td>9.35</td>
<td>7.80</td>
<td>10.32</td>
</tr>
<tr>
<td>SD</td>
<td>2.65</td>
<td>1.26</td>
<td>7.05</td>
<td>5.75</td>
<td>8.09</td>
</tr>
<tr>
<td>1 leg</td>
<td>5.66</td>
<td>4.46</td>
<td>12.92</td>
<td>8.46</td>
<td>14.33</td>
</tr>
<tr>
<td>SD</td>
<td>2.78</td>
<td>1.12</td>
<td>15.38</td>
<td>5.70</td>
<td>10.59</td>
</tr>
<tr>
<td>Global muscle RMS</td>
<td>5.34</td>
<td>4.31*</td>
<td>9.76</td>
<td>7.71</td>
<td>10.69</td>
</tr>
</tbody>
</table>

Figure 1  BESS position muscle comparison pre-post training. 2 FT: 2 Feet Standing; TAN: Tandem Position; 1 LEG: 1 Leg Standing; RA: Rectus Abdominis; IO: Internal Oblique; ES: Erector Spinae; BF: Biceps Femoris; S: Soleus.

Figure 2  Stork stand muscle comparison pre-post training. SS EO: Stork Stand Eyes Open; SS EC: Stork Stand Eyes Closed; RA: Rectus Abdominis; IO: Internal Oblique; ES: Erector Spinae; BF: Biceps Femoris; S: Soleus.
Table 5  EMG values for all muscles in stork stand positions pre and post-training. RA: Rectus Abdominis; IO: Internal Oblique; ES: Erector Spinae; BF: Biceps Femoris; S: Soleus. *Significantly different in pre-post comparison (p < 0.05). y Significantly different pre-post comparison (p < 0.05). z Significantly different EC e EO comparison (p < 0.05).

<table>
<thead>
<tr>
<th></th>
<th>RA</th>
<th>IO</th>
<th>ES</th>
<th>BF</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>SD</td>
<td>2.73</td>
<td>1.11</td>
<td>19.08</td>
<td>6.13</td>
<td>6.92</td>
</tr>
<tr>
<td>Stork stand EC</td>
<td>8.86</td>
<td>5.43</td>
<td>30.71</td>
<td>22.28</td>
<td>20.28</td>
</tr>
<tr>
<td>SD</td>
<td>5.93</td>
<td>1.71</td>
<td>60.45</td>
<td>34.53</td>
<td>12.45</td>
</tr>
<tr>
<td>Global muscle RMS</td>
<td>7.08</td>
<td>4.91*</td>
<td>21.31</td>
<td>14.42</td>
<td>14.98</td>
</tr>
<tr>
<td>SD</td>
<td>4.76</td>
<td>1.47</td>
<td>44.79</td>
<td>25.30</td>
<td>10.80</td>
</tr>
</tbody>
</table>

p ≤ 0.07 approached significance. EMG activity was lower post training compared to pre training in EC (40.49 vs 51.30; p ≤ 0.04) and EO (24.73 vs 26.31; p > 0.05) with significance only in EC; EMG was significantly higher in EC compared to EO in both pre and post training conditions (p ≤ 0.00).

Discussion

This study examined the effects of a 4 week targeted neuromuscular training program for the improvement of balance and neuromuscular control of standing postures in middle aged females. Improvements in balance have been reported in various populations following a 6-8 week training program incorporating the Swiss Ball (Sekendiz et al., 2010), uniaxial or multiaxial unstable surfaces (Eisen et al., 2010), resistance training incorporating unstable surfaces (Sparkes and Behm, 2010; Schilling et al., 2009), core stability (Aggarwal et al., 2010) and progressive neuromuscular training (Filipa et al., 2010). The pre- sent results extend the past literature demonstrating the ability of a short, four-week targeted training program to increase balance in middle aged women (as documented by reduced positional errors during the BESS) through the manipulation of training variables that included base of support, stability, vision, resistance and torque. DiStefano et al. (2009) demonstrated a short term training programs (4 weeks) was effective in improving static and dynamic balance in stable or unstable conditions. While there were no significant decreases in muscles EMG recorded activity between pre and post training in the present study, muscle activation was reduced in all muscles during each of the BESS positions (with the exception of the soleus muscle in the Tandem position), and during both the eyes open and eyes closed Stork Stand. Reduced EMG activity was hypothesized with increased coordination of neural control patterns and reduced co-activation of muscles. Anderson and Behm (2005) report that muscle tension at only 30e40% of maximal voluntary contraction can be effective in stabilizing the core with proper training and muscle activation patterns. Intensive training of motor skills may require the neural effort required to perform a task, with the automation of the motor response moving neural activation from higher (cortical) to lower brain centres (basal ganglia and cerebellum) (Schubert et al., 2008). These authors report a reduced corticospinal excitability during the trained task after 4 weeks of training as a result of increased motor efficiency and automatic movement control, supporting the notion that improved motor efficiency may underlie the reduced EMG activity found in the present study post training. Training in the present study included a progression from floor based activities to activities performed on the BOSU ball dome (unstable surface), utilized progressive change in visual input through using eyes open to eyes closed conditions, purposefully manipulated the base of support from two to one foot in each of the stable and unstable conditions, moved from static to dynamic exercise, and progressed resistance with the inclusion of off centred forces (torque). The training focus was defined using variations of specific whole body activities. With reduced muscular activity to maintain balance and posture post training (in all but the soleus in the Tandem position), the present study supports the notion that activities that stress the neuro- muscular coordination of whole body movement are efficient in increasing balance (Myer et al., 2005; Hibbs et al., 2008; Willardson, 2007; Filipa et al., 2010). The single Leg BESS position and Stork Stand were most challenging, and support the results of Saeterbakken and Finnland (2013) who found single leg standing (with reduced base of support) and unilateral exercises (introducing torque) to best in- crease superficial core muscle activation.

Training on unstable surfaces, exposing individuals to altered sensory input, is reported to increase muscular stress (Anderson et al., 2013) and may lead to gains in stability, proprioceptor activity, sway control, and improved core stability through neuro-adaptive mechanisms (Aggarwal et al., 2010; Schilling et al., 2009; McNeill, 2010). Anderson et al. (2013) recently demonstrated that as the level of instability increased during a push-up protocol, there was a greater amount of muscle activation for the core stabilizers, prime movers and lower body stabilizers. Similar results were found by Norwood et al. (2007) during a bench press, with significant in- creases in EMG with increasing instability of both the upper and lower body, and both. While muscular activity pa- tterns present differently with variation in postural perturbation (Henry et al., 2001; Winter et al., 1998), muscle force output is significantly greater for the majority of muscles when they are trained under unstable conditions through enhanced motor unit recruitment (Behm et al., 2002). Importantly, as stated previously, Schubert et al. (2008) found reduced motor cortical in fluence during the trained tasks following balance training on unstable surfaces with both eyes open and eyes closed activities. Shifting to the lower level of CNS neuromuscular control allowed for increased the rate of force development, and would allow for a more rapid response to perturbations in the balance system. These findings are consistent with the position that unstable surfaces in conjunction with standard exercises can be used to improve the motor coordination and control which may be beneficial to improving the performance of standing balance activities (Kaj et al., 2010), and are supported by the results of the present study. When the sensory systems are systematically manipulated (closing the eyes or adding vibration), body sway is affected (Winter et al., 1998). When participants close their eyes, body sway increases by 20%-70% (Lord, 2006). The interaction between visual, vestibular and proprioceptive information is crucial for maintaining appropriate biomechanical alignment (Lepers et al., 1997), and should be considered
important training variables. For example, during the stork stand in the present study the global muscle activity was higher during the eyes closed condition in both pre and post training conditions, and the training effect demonstrates larger reductions in global muscle activity in the eyes closed condition.

Successful completion of activities of daily living occur as a result of adapting postural strategies for different standing positions to maintain equilibrium (Henry et al., 2001; Henry et al., 2001) found that altering the foot position (affecting the available base of support) resulted in changes in the stiffness of the musculoskeletal system. Results of the present study reinforce previous results, and suggest that manipulation of base of support may modify the neural control of equilibrium Training programs to modify the balance strategy used, and the degree of muscle activation required, should include manipulation of base of support. Further, the effect of modifying base of support may be exemplified when there are modifications in vision from eyes open to eyes closed. Such changes are demonstrated in the present work with the reduced bicaps femoris activity, suggesting a reduced hip corrective strategy for balance, and improved efficiency with reduced muscle activity required post training.

Conclusion

The ability to report significant findings across all measures in present study was limited by a small sample size and short training period; however, while all muscle EMG results did not reach significance from pre- to post-training, favourable changes in stabilizing muscles were observed and balance in a standing position improved post training. Improved balance with reduced muscle EMG activity may suggest that the improved coordination of muscles involved in balance reduced body sway post training; the core and postural muscles were able to control body position with less activity post training suggesting improved muscle coordination and efficiency. Such findings over a short four week program are promising, suggesting that short duration programs may be of benefit physiologically and may have greater appeal to participants and less costs than longer duration programs. These results support the use of progressive balance training to improve bi- and uni-pedal standing balance in middle aged women, particularly in the more challenging eyes closed condition.

Acknowledgement

Fabio Deluigi received a scholarship from the University of Bologna, Faculty of Exercise and Sport Science to perform research in Canada to fulfil the requirements of his undergraduate thesis. The Associate Vice President of Research from the University of the Fraser Valley provided funding for purchase of electrodes.

References


