NOT ALL INSTABILITY TRAINING DEVICES ENHANCE MUSCLE ACTIVATION IN HIGHLY RESISTANCE-TRAINED INDIVIDUALS

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ABSTRACT

Wahl, MJ and Behm, DG. Not all instability training devices enhance muscle activation in highly resistance-trained individuals. *J Strength Cond Res* 22: 1360–1370, 2008—The objective of this study was to measure the electromyographic (EMG) activity of the soleus, bicep femoris, rectus femoris, lower abdominal, and lumbosacral erector spinae (LSES) muscles with a variety of (a) instability devices, (b) stable and unstable (Dyna Disc) exercises, and (c) a fatiguing exercise in 16 highly conditioned individuals. The device protocol had participants assume standing and squatting postures while balancing on a variety of unstable platforms (Dyna Disc, BOSU ball, wobble board, and a Swiss ball) and a stable floor. The exercise protocol had subjects performing, static front lunges, static side lunges, 1-leg hip extensions, 1-leg reaches, and calf raises on a floor or an unstable Dyna Disc. For the fatigue experiment, a wall sit position was undertaken under stable and unstable (BOSU ball) conditions. Results for the device experiment demonstrated increased activity for all muscles when standing on a Swiss ball and all muscles other than the rectus femoris when standing on a wobble board. Only lower abdominals and soleus EMG activity increased while squatting on a Swiss ball and wobble board. Devices such as the Dyna Disc and BOSU ball did not exhibit significant differences in muscle activation under any conditions, except the LSES in the standing Dyna Disc conditions. During the exercise protocol, there were no significant changes in muscle activity between stable and unstable (Dyna Disc) conditions. With the fatigue protocol, soleus EMG activity was 51% greater with a stable base. These results indicate that the use of moderately unstable training devices (i.e., Dyna Disc, BOSU ball) did not provide sufficient challenges to the neuromuscular system in highly resistance-trained individuals. Since highly trained individuals may already possess enhanced stability from the use of dynamic free weights, a greater degree of instability may be necessary.

KEY WORDS stability, balance, electromyography, strength, fatigue

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INTRODUCTION

The importance of optimal balance and stability for athletes is essential for performance and injury prevention (9). Instability devices are common in fitness facilities as a means of training. There is an abundance of training methodologies and exercises implementing various instability-training devices. The popular media and practitioners endorse and sell these products, promoting unstable training as a means of improving sport performance, force production, and core strength (26).

To maintain adequate levels of stability, trunk muscles compensate by altering the level and pattern of activation (4,23,24). A number of studies from the Memorial University Human Kinetics Laboratory have reported increased muscle electromyographic (EMG) activity when an exercise was performed with an unstable rather than a stable base (2,7). Anderson and Behm (2) demonstrated an increase in activation of the lower body and trunk musculature when performing squats under unstable conditions using Dyna Discs. Similarly, Behm et al. (7) demonstrated increased trunk activation when performing upper body unilateral and bilateral contractions on a Swiss ball. All the aforementioned studies as well as other similar studies (29,31) have used sedentary, elderly, or recreationally active individuals. There are no studies to our knowledge that have evaluated instability training with individuals who have trained extensively with relatively unstable free weights. Furthermore, no studies of which we are aware have compared the impact of a wide variety of instability devices (BOSU ball, Dyna Disc, Swiss ball, and wobble board) on EMG activity of the lower body and trunk musculature. In this study, a variety of devices, postures, exercises, and fatigue conditions were compared to investigate whether unstable conditions and the devices that create these conditions are beneficial to highly resistance-trained individuals. The benefit would be

TABLE 1. Experimental design.

Protocol	Unstable base	Stable base	Exercises	Analysis
Devices	Swiss ball	Floor	Standing	Separate 1-way repeated-measures ANOVA for stand and squat
	Dyna Disc		Squat	
	BOSU up			
	BOSU down			
	Wobble board			
Exercises	Dyna Disc	Floor	Static forward lunge	2-way repeated-measures ANOVA
			Static side lunge	Exercise × base
			1-leg hip extension	5 × 2
			1-leg reach	
			Calf raises	
Fatigue	BOSU up	Floor	Wall sit	2-way repeated-measures ANOVA
			1st contraction, contractions at 1/3 and 2/3 of fatigue duration and final contraction	Base × time
				2 × 4

ANOVA = analysis of variance.
The objective was to investigate muscle activation changes associated with instability training devices, exercises, and fatigue.
In all 3 experiments, the following muscles were monitored and analyzed: biceps femoris, rectus femoris, soleus, lower abdominals, and lumbosacral erector spinae.

represented by increases in EMG activity, which under nonfatiguing conditions would generally indicate increases in muscle recruitment and rate coding (5), indicating that the instability device provided greater challenges to the neuromuscular system than with a stable base.

Three distinct protocols were implemented. The objective of the first protocol was to determine differences in EMG activity while standing and squatting on a variety of unstable platforms and a stable floor. The objective of the second protocol was to examine the EMG activity associated with a variety of exercises that were performed under stable and unstable (Dyna Disc) conditions. Since significant differences in muscle EMG activity have been reported between instability devices, exercises, and base of support (2,7,8,29), it was hypothesized that the EMG activity would increase as the base of support became increasingly more unstable.

The objective of the third experiment was to investigate the extent of EMG activity associated with a fatigue test performed under stable and unstable (BOSU ball) conditions. Since previous instability research has demonstrated decreased force production with similar (2) or decreased activation (6), it was hypothesized that an unstable base would contribute to an earlier onset of fatigue and higher EMG activity.

METHODS

Experimental Approach to the Problem

After an orientation session involving 2–3 repetitions of all stable and unstable exercises on a separate day, subjects performed activities involving both stable and unstable exercises over 2 separate sessions. Electromyographic activity was recorded during each session. Surface electrodes were placed on the rectus femoris, soleus, and biceps femoris, the lower abdominal, and the lumbosacral erector spinae (LSES) muscles in order to record the electromyogram over a 5-second duration. For the first (device) protocol, the subjects were randomly assigned to both standing and squatting postures using the following devices: (a) Swiss ball, (b) BOSU ball, (c) Dyna Disc, and (d) wobble board. Subjects were also randomly assigned to one of the fatigue protocols (stable versus unstable) during the initial session.

The second protocol was completed within 48 hours. This session required subjects to perform various lower body stable and unstable isometric holds of the following exercises: (a) front lunge, (b) side lunge, (c) hip extension, (d) reach, and (e) calf raise. Exercises performed under unstable conditions used a Dyna Disc under the foot of the load-bearing limb.

Finally, subjects performed the fatigue protocol, an isometric wall sit to failure under stable and unstable (BOSU ball) circumstances. Subjects were instructed to sit against a wall, unsupported, and maintain a knee angle of 90° with their feet either on the floor or a BOSU ball (concave surface down) until muscular failure occurred (Table 1).

Subjects

Sixteen subjects (Table 1) participated in the study (age, 26.6 ±7.0 years; weight, 81.8 ± 9.1 kg; height, 176.7 ± 8.0 cm). All subjects were considered highly experienced

TABLE 2. Subjects' anthropometric measures, 1RM bench press, 1RM leg press, and upper and lower body strength ratios.

	Mean ± *SD*
Age, y	26.6 ± 7.0
Height, cm	176.7 ± 8.0
Weight, kg	81.8 ± 9.1
Years of training	8.2 ± 7.4
1RM bench press, kg	121.3 ± 13.7
1RM leg press, kg	258.4 ± 27.9
Upper body ratio	1.49 ± 0.17*
Lower body ratio	3.18 ± 0.37†

1RMs and strength ratios were determined using American College of Sport Medicine guidelines for exercise testing and prescription (weight pushed/body weight). Data provided by the Institute for Aerobics Research, Dallas, TX, 1994.

1RM = 1 repetition maximum.

*Upper body strength ratios >1.48 = 90th percentile or well above average for 20- to 29-year-old males.

†Lower body strength ratios >2.27 = 90th percentile or well above average for 20- to 29-year-old males.

Adapted from American College of Sport Medicine Guidelines for Exercise Testing and Prescription, 5th ed. Study population for the data set was predominantly white and college educated.

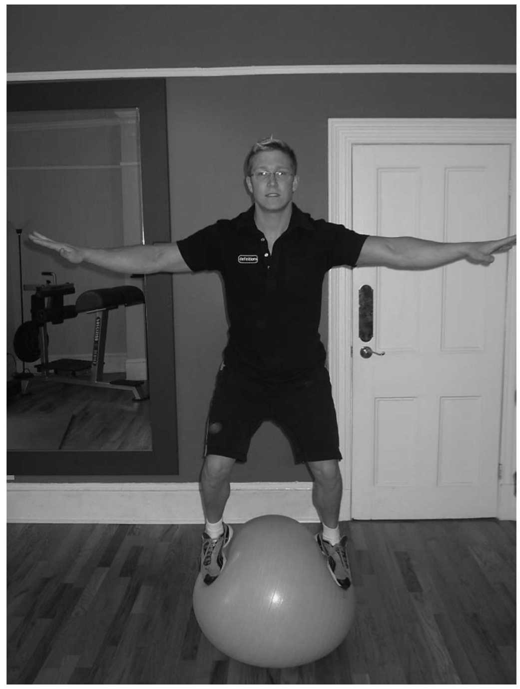

Figure 1. Standing posture on a Swiss ball.

resistance trainers due to their previous and current resistance training experience (8.2 ± 7.4 years) and their extensive involvement with resistance training activities involving free weights and instability devices. All participants would have had extensive experience with dynamic exercises such as squats and dead lifts among many others. Subjects' upper and lower body strength ratios were determined using the American College of Sports Medicine's (ACSM) guidelines for exercise testing and prescription (1). Mean upper and lower body strength ratios were 1.49 ± 0.17 and 3.18 ± 0.37, respectively. Both mean values exceed the 90th percentile of the male population for strength, indicating that subjects were considered well above average (1) or, for this study, highly conditioned (Table 2). Each subject was required to read and sign a consent form before participation. The Human Investigation Committee, Memorial University of Newfoundland, approved this study.

Procedures

Electromyography. Bipolar surface EMG electrodes were used to measure signals from the LSES, lower abdominal, biceps femoris, rectus femoris, and soleus muscles. General descriptive (i.e., LSES, lower abdominals) rather than specific (i.e., multifidus, longissimus, transverse abdominus, internal obliques) trunk muscle terminology is used here based on the conflicting findings of similar studies. A number of studies have used a similar L5–S1 electrode placement (2 cm lateral to the L5–S1 spinous process) to measure the EMG activity of the multifidus (11,15,16,22). In contrast, Stokes et al. (30) reported that accurate measurement of the multifidus requires intramuscular electrodes. Thus, the EMG activity detected by these electrodes in the present study is referred to as LSES muscle activity. Erector spinae muscles according to anatomic nomenclature include both superficial (spinalis, longissimus, iliocostalis) and deep (multifidus) vertebral muscles (17,19). Additional electrodes were placed superior to the inguinal ligament and 1 cm medial to the anterosuperior iliac spine (ASIS) for the lower abdominals. McGill et al. (20) reported that surface electrodes adequately represent the EMG amplitude of the deep abdominal muscles within a 15% root mean square difference. However, Ng et al. (22) indicated that electrodes placed medial to the ASIS would receive competing signals from the external obliques and transverse abdominus with the internal obliques. Based on these findings, the EMG signals obtained from this abdominal location are described in this study as the lower abdominals, which would be assumed to include EMG information from both the transverse abdominus and internal oblique.

All electrodes were placed on the right side of the body. Skin surfaces for electrode placement were shaved, abraded, and cleansed with alcohol to improve the conductivity of the EMG signal. Electrodes (Kendall Medi-trace 100 series; Kendall, Chikopee, MA) were placed on the soleus, 2 cm distal to the gastrocnemius head as well as the mid-belly of the

Figure 2. Standing posture on a Dyna Disc.

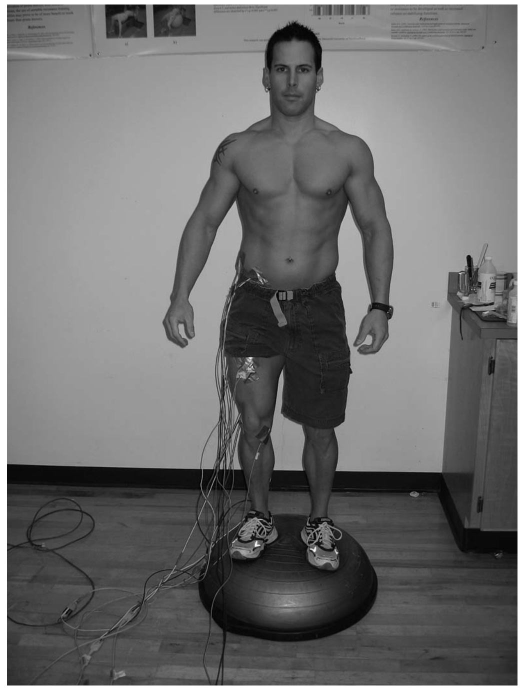

Figure 3. Standing posture on a BOSU ball concave side up.

rectus femoris and biceps femoris. Electrode placement was identified for the second testing session by using indelible markers on the electrode sites for the first session. The EMG signals were amplified (MEC 100 amplifier; Biopac Systems, Inc., Santa Barbara, CA), monitored and directed through an analog-digital converter (Biopac MP100) to be stored on the computer (Sona, St. John's, Newfoundland, Canada). The EMG signals were collected over 15 seconds at 2000 Hz and amplified (×500). Electromyographic activity was sampled at 2000 Hz with a Blackman 61-dB band-pass filter between 10 and 500 Hz, amplified (Biopac Systems MEC bipolar differential 100 amplifier; input impedance = 2 mega (M), common mode rejection ratio >110 dB minimum (50/60 Hz), noise >5 UV), and analog-to-digitally converted (12 bit), and stored on personal computer for further analysis.

The integrated EMG activity was calculated over a 5-second interval of the 15-second data collection period; started by the investigator once the subject was in position. Calculations began 5 seconds after the start of data collection and ceased 5 seconds before the finish of the specific exercise. The initial and final 5 seconds of collected EMG activity were discarded to minimize postural adjustments at the start or possible fatigue at the end. There was no need to normalize the signal to a maximal voluntary contraction since the experiment was a repeated-measures design comparing within individuals with all conditions performed within 2 days and electrode placement precisely outlined by a marker. The stable condition was considered the reference condition to which all unstable EMG activity was compared.

After the instability device and exercise testing, a fatigue test was performed. Electromyographic changes were monitored by comparing the initial contraction, the contraction at the initial third of fatigue duration, contraction at the second third of fatigue duration, and final contraction. Integrated EMG was collected for 15 seconds of each time period monitored during the fatigue test. The first 5 seconds of each monitored epoch were recorded and analyzed.

Instability Devices. All subjects attended an orientation session at least 24 hours before testing to familiarize themselves with the exercises.

During the initial testing, exercises were performed with a random allocation technique on a Swiss ball (55 cm) (Figure 1), Dyna Disc (30 cm) (Figure 2), BOSU ball (55 cm) concave side up (Figure 3), BOSU ball (55 cm) concave side down (Figure 4), and a 40-cm wobble board (Figure 5). The 40-cm wobble board made contact with the floor on a 10-cm diameter concave wood cone. The subjects were positioned either in a standing posture or in a squatting posture with 60° of flexion at the knee (measured before and during testing using a goniometer). Both postures placed the feet 30 cm apart. Exercise postures were held for a 15-second period started by the investigator once the subject was in correct position. All exercises were performed during a single

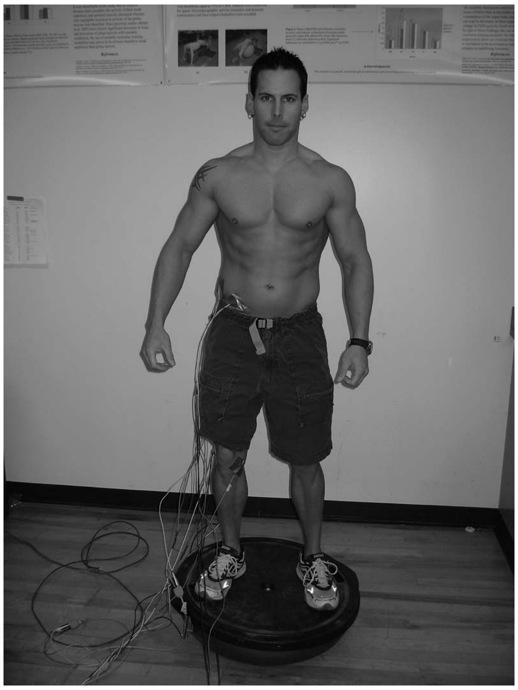

Figure 4. Standing posture on a BOSU ball concave side down.

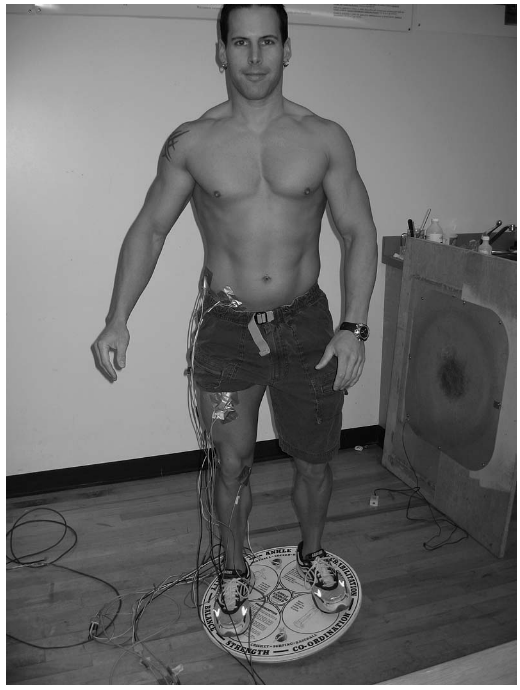

Figure 5. Standing posture on a wobble board.

experimental session with a 2-minute rest between each exercise. The exercises were performed twice. Exercises included both stands and squats on both a stable floor and the instability devices.

Instability Exercises

The second session identified the extent of activation with a variety of stable and unstable lower body exercises. Dyna Discs were used to create an unstable base for the tested leg in an attempt to identify activation using electromyography. The subjects were positioned on the Dyna Disc to ensure the orientation of trunk musculature and angle of hips and knees were similar to their stable counterparts. The following exercises were chosen as a representative sample of common instability exercises.

Static Forward Lunge (Figure 6). Assuming a long lunge position, the participants positioned their back knee 1 cm above the floor while keeping the front knee (90°, measured before and during testing using a goniometer) over the ankle. Subjects were instructed to keep the head and chest up and to position the hands behind their head to maintain back posture while lowering their hips. The knee of the back leg was slightly flexed. For unstable testing, the Dyna Disc was placed under the midfoot of the front leg (right foot).

Static Side Lunge (Figure 7). Subjects were instructed to stand with feet roughly 1.2 m apart and told to sit to their right side keeping the weight on the right heel as they sat to a 75° (measured before and during testing using a goniometer) knee angle. Subjects were instructed to keep the head and chest up and position the hands behind their head to maintain back posture. For unstable testing, the Dyna Disc was placed under the midfoot of the bent leg (right foot).

One-Leg Hip Extension (Figure 8). Subjects were instructed to lie supine with their left leg extended toward the ceiling at 90° (measured before and during testing using a goniometer) from the floor. The right foot was placed flat on the floor or Dyna Disc. The subjects were then instructed to lift their hips while evenly distributing the force over their foot holding this position for 15 seconds. For unstable testing, the Dyna Disc was placed under the midfoot of the active leg (right foot).

One-Leg Reach (Figure 9). Subjects were instructed to stand with their right foot on the floor or Dyna Disc, then reach with their left hand and touch a point 20 cm from the front of their right foot. Subjects were instructed to bend at both knees to maintain balance and to achieve both hip and knee flexion.

Calf Raises. Subjects were instructed to balance on their right foot either on the floor or the Dyna Disc without holding onto any supports. They were then told to plantar flex until fully extended.

Fatigue

The third protocol identified the rate of fatigue while performing a wall sit under stable and unstable conditions.

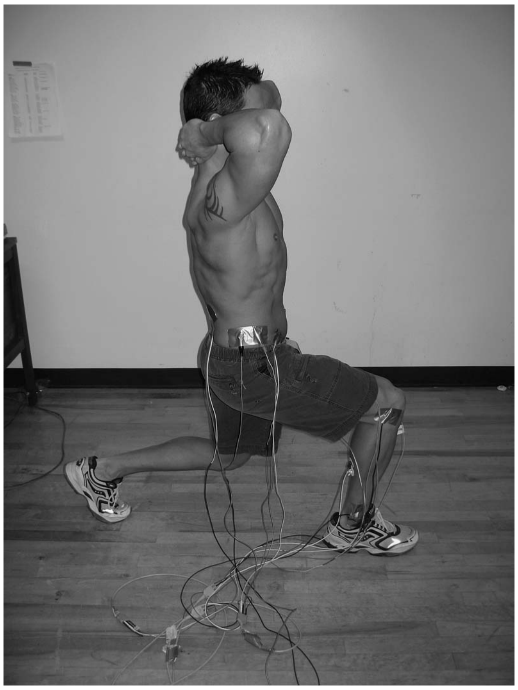

Figure 6. Forward lunge.

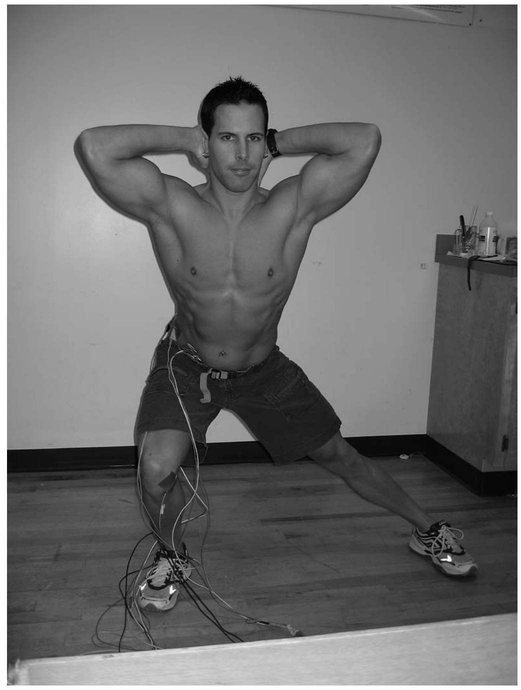

Figure 7. Side lunge.

A BOSU ball was used to create an unstable base. Subjects assumed a sitting position against a wall with a knee angle of 90° (measured before testing using a goniometer) and a hip angle of 90° and feet spaced 30 cm apart. For unstable tests, subjects placed their feet 30 cm apart on the flat side of the BOSU ball (convex side on floor). The testing was completed when subjects could no longer hold the specified exercise posture. Subjects were instructed to relax when visual inspection indicated a significant deviation of ≥5° from the initial 90° knee angle.

Subjects were analyzed by comparing the rate of fatigue under each condition (stable and unstable) using time as well as an EMG comparison during the protocol.

Statistical Analyses

In the initial investigation (standing and squatting on a variety of instability devices), statistics were performed separately on each muscle group. Data were analyzed with separate 1-way analyses of variance (ANOVAs) with repeated measures for standing and squatting. The 6 platforms to be compared were the Swiss ball, Dyna Disc, BOSU ball up, BOSU ball down, wobble board, and stable floor.

In the second investigation (a variety of exercises performed on a Dyna Disc and the floor), data were analyzed with a 2-way ANOVA with repeated measures on both levels. The 2 levels (2×5) were state of stability (stable or unstable) and exercise (front lunge, side lunge, hip extension, reach, calf raise).

The fatigue investigation used a 2-way ANOVA repeated measures (2×4) to determine whether significant differences occurred with the EMG activity between the stability condition and fatigue duration (first contraction, contraction at first third of fatigue duration, contraction at two-thirds of fatigue duration, and final contraction). A 1-way ANOVA repeated measures was used to distinguish significant

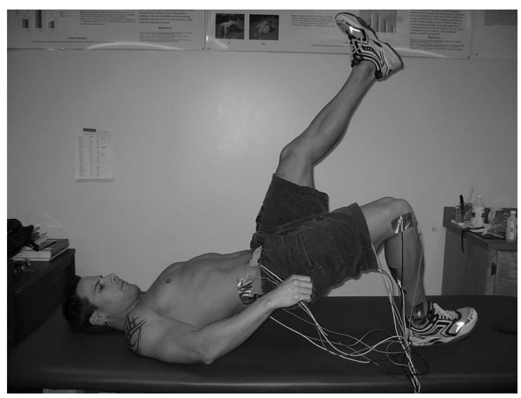

Figure 8. One-leg hip extension.

Figure 9. One-leg reach.

Table 3. Intraclass correlation coefficient reliability.

	SS	SW	SD	SBD	SBU	SSB
Soleus	0.96	0.9	0.92	0.89	0.98	0.99
Biceps femoris	0.91	0.9	0.98	0.9	0.92	0.96
Rectus femoris	0.73	0.86	0.98	0.8	0.82	0.82
LSES	0.94	0.97	0.99	0.97	0.96	0.99
LAS	0.95	0.9	0.99	0.72	0.96	0.99
	SqS	SqW	SqD	SqBD	SqBU	SqSB
Soleus	0.95	0.9	0.99	0.73	0.96	0.99
Biceps femoris	0.87	0.9	0.9	0.89	0.97	0.72
Rectus femoris	0.96	0.96	0.98	0.93	0.96	0.93
LSES	0.94	0.89	0.97	0.72	0.94	0.73
LAS	0.99	0.97	0.97	0.99	0.99	0.98

Reliability was assessed with a Cronbach model intraclass correlation coefficient (ICC) with all subjects. Repeated tests were conducted within a single testing session.

SS = stable standing; SW = standing wobble board; SD = standing Dyna Disc; SBD = standing BOSU ball down; SBU = standing BOSU ball up; SSB = standing Swiss ball; LSES = lumbosacral erector spinae; SqS = stable squat; SqW = squat on wobble board; SqD = squat on Dyna Disc; SqBD = squat on BOSU ball down; SqBU = squat on BOSU ball up; SqSB = squat on Swiss ball.

differences in fatigue duration between stable and unstable conditions.

For all protocols, where significant differences were detected ($p \leq 0.05$), a Bonferroni (Dunn) procedure was used to identify the individual differences among the exercises. Effect sizes (ESs) are shown in parentheses within the results (25). Reliability was assessed with a Cronbach model intraclass correlation coefficient (21) for all subjects (Table 3). Repeated tests were conducted within a single testing session.

Results

Instability Devices

Standing. The 1-way repeated-measures ANOVA for the device protocol indicated that the wobble board produced 51%, 44%, 43%, and 38%, respectively, greater soleus EMG activity than standing on a stable floor, Dyna Disc, BOSU down, and BOSU up ($p < 0.004$, ES = 0.65, 0.57, 0.56, 0.49, respectively). Concurrently, there was 34%, 26%, 24%, and 17%, respectively, greater soleus EMG activity with the Swiss ball than when standing on a stable floor, Dyna Disc, BOSU down, and BOSU up ($p < 0.004$, ES = 0.41, 0.30, 0.28, 0.20, respectively) (Table 4).

There was 34%, 26%, 33%, and 33%, respectively, greater lower abdominals EMG activity with the wobble board than when standing on a stable floor, Dyna Disc, BOSU down and BOSU up ($p = 0.03$, ES = 0.48, 0.36, 0.46, 0.49, respectively). Similarly, there was 31%, 22%, 30%, and 32%, respectively, greater lower abdominals EMG activity with the Swiss ball than in the stable, Dyna Disc, BOSU down, and BOSU up standing conditions ($p = 0.03$, ES = 0.46, 0.33, 0.45, 0.48, respectively) (Table 4).

When standing, there was the had 88%, 61%, 64% and 64%, respectively, greater rectus femoris EMG activity during the Swiss ball condition than in the stable, Dyna Disc, BOSU down, and BOSU up standing conditions ($p < 0.0001$, ES = 1.08, 0.77, 0.41, 0.80, respectively) (Table 4).

During wobble board standing, there was 70%, 65%, 56% and 53%, respectively, greater biceps femoris EMG activity than in the stable, Dyna Disc, BOSU down, and BOSU up standing conditions ($p < 0.0001$, ES = 1.21, 1.13, 0.98, 0.95, respectively). Correspondingly, there was 57%, 49%, 36% and 33%, respectively, greater biceps femoris activity during Swiss ball standing than in the stable, Dyna Disc, BOSU down, and BOSU up standing conditions ($p < 0.0001$, ES = 1.21, 1.06, 0.81, 0.75, respectively) (Table 4).

During standing postures, there was 52% greater LSES EMG activity during the Dyna Disc condition than the stable condition ($p < 0.0001$, ES = 0.73). There was also 68%, 44%, and 42%, respectively, less LSES EMG activity in the stable, BOSU up, and BOSU down conditions compared to the wobble board condition ($p < 0.0001$, ES = 1.36, 0.89, 0.84, respectively). In tandem, there was, respectively, 70%, 47%, and 46% greater LSES EMG activity during the Swiss ball conditions compared to the stable, BOSU up, and BOSU down ($p < 0.0001$, ES = 1.97, 1,32, 1.26, respectively) (Table 4). There were no significant differences in LSES EMG activity between the Dyna Disc and the wobble board and Swiss ball.

Squats. During squatting, there was 69%, 43%, 57%, 49%, respectively, more EMG activity in the soleus muscle with the wobble board than in the stable, Dyna Disc, BOSU up, and BOSU down conditions ($p < 0.0001$, ES = 0.91, 0.58, 0.76, 0.64, respectively). In addition, during the Swiss ball

TABLE 4. Mean values for iEMG (mVs) for the standing posture.

Muscle	Stable	Dyna disc	BOSU up	BOSU down	Wobble board	Swiss ball
LSES	0.10 ± 0.06*	0.21 ± 0.15*	0.18 ± 0.11	0.18 ± 0.09	0.32 ± 0.15†	0.33 ± 0.11†
Lower abdominals	0.12 ± 0.07	0.13 ± 0.09	0.12 ± 0.08	0.12 ± 0.07	0.18 ± 0.12†	0.17 ± 0.11†
Rectus femoris	0.02 ± 0.03	0.08 ± 0.06	0.06 ± 0.05	0.07 ± 0.05	0.12 ± 0.10	0.19 ± 0.15†
Biceps femoris	0.04 ± 0.03	0.05 ± 0.04	0.06 ± 0.04	0.07 ± 0.04	0.14 ± 0.09†	0.10 ± 0.05†
Soleus	0.28 ± 0.45	0.32 ± 0.45	0.33 ± 0.45	0.36 ± 0.45	0.58 ± 0.50†	0.43 ± 0.35†

The lumbosacral erector spinae (LSES) activity with the Dyna Disc was not significantly different from that of the wobble board or Swiss ball.
*Significant differences between the 2 values designated by asterisks.
†Significant difference from other unmarked (no asterisks) values in the row.

condition, the soleus demonstrated 54%, 18%, 40%, and 25%, respectively, more EMG activity than in the stable, Dyna Disc, BOSU up, and BOSU down conditions ($p < 0.0001$, ES = 0.77, 0.24, 0.53, 0.35, respectively). The lower abdominal muscles showed 39%, 57%, 48%, and 63%, respectively ($p = 0.0002$, ES = 0.49, 0.64, 0.71, 0.54, respectively) more activity with the wobble board than in the stable, Dyna Disc, BOSU down, and BOSU up conditions. Likewise, there was 38%, 56%, 47% and 62%, respectively, more EMG activity in the lower abdominals with the Swiss ball than in the stable, Dyna Disc, BOSU down, and BOSU up conditions ($p = 0.0002$, ES = 0.58, 0.79, 0.86, 0.67, respectively) (Table 5). There were no significant differences in EMG activity among the conditions in the LSES, rectus femoris, and biceps femoris.

Instability Exercises

There were no significant differences detected between any of the exercises performed on a stable floor and the unstable Dyna Disc.

Fatigue-related Electromyographic Activity

Main effects were discovered for instability conditions and time during the fatigue testing with the soleus. With data collapsed over time, the stable soleus had 51.2% greater EMG activity than the unstable soleus ($p = 0.03$, ES = 1.01). There were no other significant muscle activity differences between stable and unstable conditions. Overall, with data collapsed over instability conditions, the last contraction had 36.1% greater soleus EMG activity than the first contraction ($p = 0.0008$, ES = 0.33). The interactions illustrated that under stable conditions, the last contraction had 46.4% and 34.5% more soleus EMG activity than the first and second contractions, respectively ($p = 0.001$, ES = 0.39 and 0.84, respectively).

Similarly, with data collapsed over instability conditions, the lower abdominals exhibited a 44% increase in EMG activity during the final contraction compared to the second contraction ($p = 0.003$, ES = 0.50). The biceps femoris also exhibited a 35% increase in activity during the final contraction compared to the first contraction ($p = 0.001$, ES = 0.55).

As for the fatigue time, there was a trend ($p = 0.09$, ES = 1.1) for longer wall sit times under stable conditions (Figure 10).

Reliability

Intraclass correlation coefficients illustrated the very good to excellent reliability (0.72–0.99) of the procedures (Table 3).

TABLE 5. Mean values for iEMG (mV) for the squatting posture.

Muscle	Stable	Dyna Disc	BOSU up	BOSU down	Wobble board	Swiss ball
LSES	0.76 ± 0.90	0.52 ± 0.34	0.46 ± 0.25	0.68 ± 0.82	0.80 ± 0.82	0.42 ± 0.22
Lower abdominals	0.11 ± 0.08	0.08 ± 0.09	0.07 ± 0.06	0.09 ± 0.07	0.18 ± 0.15*	0.18 ± 0.14*
Rectus femoris	0.48 ± 0.31	0.55 ± 0.50	0.51 ± 0.50	0.49 ± 0.44	0.42 ± 0.30	0.50 ± 0.32
Biceps femoris	0.05 ± 0.02	0.06 ± 0.07	0.07 ± 0.05	0.08 ± 0.05	0.10 ± 0.08	0.07 ± 0.03
Soleus	0.13 ± 0.08	0.23 ± 0.14	0.17 ± 0.11	0.21 ± 0.13	0.41 ± 0.30*	0.28 ± 0.19*

iEMG = integrated electromyography; LSES = lumbosacral erector spinae.
*Significant difference from other unmarked values in the row.

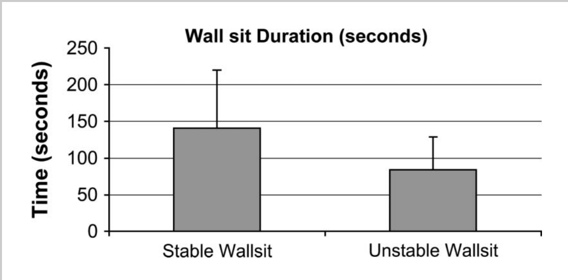

Figure 10. Mean time in seconds of the stable and unstable wall sit exercise. Vertical bars represent *SD*.

Discussion

The most unique finding of this study was the lack of increase in muscle activation (EMG) of experienced resistance-trained individuals with activities performed on the unstable bases provided by Dyna Disc and BOSU balls. This finding applied in the first protocol (devices) to the soleus, rectus femoris, biceps femoris, and lower abdominals when standing on a Dyna Disc or a BOSU ball. It applied to the all muscles tested when squatting on a Dyna Disc and BOSU ball. It also applied to all muscles tested in the second protocol (exercises) for the exercises performed on a Dyna Disc. Finally, the lack of muscle activation differences for the rectus femoris, biceps femoris, LSES, and lower abdominals was also applicable to the wall sit fatigue test performed on a BOSU ball. This is the first study to use experienced resistance-trained individuals to demonstrate a lack of significant difference in muscle activation when comparing moderately unstable balance devices to a stable base. Similar to previously published research, the apparently greater instability of the Swiss ball and wobble board did result in greater muscle activation than found with a stable surface and, specific to this study, generally greater muscle activation than Dyna Discs and BOSU balls.

Current research both complements and challenges the findings of this study. Several studies have investigated the neuromuscular responses to training under stable and unstable bases using different exercises, tools, and populations (2,3,12,18,29). Cosio-Lima et al. (10) showed a significant increase in trunk muscle EMG activity and balance scores with an unstable versus stable trunk training program in previously untrained women. Vera-Garcia et al. (31) demonstrated that a curl-up performed under unstable conditions significantly increased rectus abdominus and external oblique activation over curl-ups performed on a stable base. Behm et al. (7) found similar results, indicating that unilateral upper body exercises as well as lower abdominals– and LSES-targeted callisthenic exercises performed under unstable conditions exhibited greater EMG activity than their stable counterparts. Anderson and Behm (2) reported greater soleus and LSES EMG activity when squats were performed on a Dyna Disc than on a stable floor. Interestingly, the present study did not show any significant difference in activation between stable and moderately unstable (Dyna Discs and BOSU balls) exercises. However, the aforementioned studies did not use experienced resistance-trained individuals whose balance may have been augmented by years of training (mean, 8.2 ± 7.4 years) with free weights.

According to Schmidt and Lee (27), even 2 very similar tasks, such as throwing a football and throwing a javelin, will correlate nearly zero with each other. Conversely, our study found very similar EMG values between exercises performed under moderately unstable (Dyna Disc and BOSU ball) and stable conditions. It could be speculated that resistance training with free weights provides an environment of low to moderate instability where learned motor programs may be transferred to other moderately unstable platforms. In accordance with the concept of training specificity, training with moderately unstable free weights transfers to other similar moderately unstable exercises. This may indicate why no significant differences were found between 2 apparently different environments. De Luca and Mambrito (12) showed that EMG activity decreased with the uncertainty of movement and increased with task awareness. Highly resistance-trained individuals who have performed years of resistance training with moderately unstable free weights have become accustomed to specific exercises and therefore have a strong familiarity with the movements resulting in augmented EMG activity. This experience could reduce the unpredictability of an exercise performed on a moderately unstable tool (Dyna Discs and BOSU balls) due to the ingrained motor program of the exercise. Regardless of the cause, the current study shows that not all instability devices are effective for increasing muscle activation in highly resistance-trained individuals. If greater balance skills are sought, then devices with greater instability (i.e., smaller point of contact with body or base, greater distances of body from base of support, greater malleability of the device) should be used.

Not all studies have reported increased muscle activation with instability devices when the subjects were not highly trained. Behm et al. (7) found that there was no significant difference in activation of the trunk musculature during bilateral upper body exercises (chest press, shoulder press) performed on both unstable and stable bases. Anderson and Behm (3) also showed no significant increase in activation of the trunk musculature during bench presses performed on the Swiss ball. Both studies used bilateral contractions of the upper limbs, which may not generate similar disruptive moments seen in unilateral exercises because both limbs are involved in the movement, allowing the resistance to be maintained directly above the torso and center of gravity. As well, the increased load associated with these specific resistance training exercises may serve to distort the instability device and actually provide a more stable platform by flattening at the bottom (3).

Results demonstrating similar activation as exhibited by the current subjects may best be explained by Gage et al. (13). With the body acting as an inverted pendulum (13), the center of gravity vacillates constantly. Activation of postural muscles including trunk musculature acts to maintain equilibrium or balance. Since highly resistance-trained individuals add further resistance above the center of gravity with many exercises (squats, shoulder press, cleans), there is even a greater stress placed on maintaining the equilibrium of the body's inverted pendulum during these exercises. Hamlyn and Behm (14), investigated trunk activation under stable and unstable conditions, demonstrating that squats and dead lifts using 80% of the 1 repetition maximum performed on a stable floor elicited a greater activation of the trunk musculature than unstable trunk callisthenic exercises. This study supports Siff (28) who indicated that the best exercises to stimulate trunk muscles are those that load the trunk with external resistance such as a squat or dead lift. Thus, some of the instability devices now available such as BOSU balls and Dyna Discs may not present sufficient stability challenges to the highly resistance-trained individual. The highly resistance-trained individual may need to increase his or her disruptive torque through a combination of load and moderate instability (i.e., squats, dead lifts, and cleans).

An established shortcoming of instability training is the lesser ability to load under unstable conditions (3,6,12,18). Highly resistance-trained individuals performing exercises under moderately unstable conditions may not exhibit changes in EMG activity with the exercise. As motor programs are ingrained, the load and its positioning in relation to the center of gravity may become the formative variables. An investigation into loading using a variety of instability devices may yield further results as to the training effect of these tools. While instability is inherent with free weights, the current importance placed on instability training devices may be overemphasized with individuals who consistently create moderately unstable environments with free-weight exercises. Greater degrees of instability such as found with Swiss balls and wobble boards may be necessary in this type of population to increase limb and trunk muscle activation.

Similar to the first 2 protocols, a moderate degree of instability (BOSU ball) did not produce significant changes in activation in any tested muscles except the soleus during the fatigue protocol or produce a significant change in the rate of fatigue in highly resistance-trained individuals. However, stable wall sit conditions elicited greater soleus activation. It is speculated that under unstable conditions with the feet placed on the moderately unstable BOSU ball, the plantar flexors would not be able to exert similar forces as under stable conditions (6). This might force the individuals under unstable conditions to use a greater variety of lower limb muscles (i.e., gastrocnemius, peronei) to lock their lower body into place. The tendency for a greater rate of fatigue with unstable conditions may be related to the additional work of the synergists to cope with the moderate instability.

In conclusion, it has been shown that the use of moderately unstable training devices such as Dyna Discs and BOSU balls are not as effective as Swiss balls and wobble boards in increasing activation in the lower body and trunk musculature with highly resistance-trained individuals. A determining variable in this research is that all subjects were highly resistance-trained individuals who had extensive experience in the use of heavy free-weight resistance and load-bearing exercises. The current study tested exercise postures using body weight even though resistance training typically employs the use of greater overload. An investigation into the EMG activity associated with these postures and devices under loaded conditions may provide more definitive answers as to the effectiveness of these tools. Moreover, an investigation into the effectiveness of training with instability tools, such as the wobble board, Swiss ball, Dyna Disc, and BOSU ball in a less highly trained population that may benefit from instability devices, would provide useful insight. This may extend to populations who seek to rehabilitate muscle without harboring external load, which may amplify injury or dysfunction.

Practical Applications

The present research does not nullify the benefits of instability training devices to augment trunk muscle activation and stress balance. However, just as highly resistance-trained individuals might not obtain strength training adaptations from low loads, they may also not receive additional muscle activation or balance training effects from moderately unstable devices. Training experience with free weights can provide an environment of moderate instability that stresses and forces training adaptations to an individual's equilibrium. Individuals who have extensive experience with free weights need greater instability challenges. The instability of a device is dependent on or can be manipulated by altering the extent of the base of support (a smaller base results in less stability), the vertical or horizontal distance from the base of support (i.e., large-diameter balls may be less stable to stand on), and the architecture of the device, among other factors.

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