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# Increased Deltoid and Abdominal Muscle Activity During Swiss Ball Bench Press

**Paul W.M. Marshall and Bernadette A. Murphy**

*Department of Sport and Exercise Science, University of Auckland, Tamaki Campus, Auckland, New Zealand.*

**Abstract.** Marshall, P.W.M., and B.A. Murphy. Increased deltoid and abdominal muscle activity during swiss ball bench press. *J. Strength Cond. Res. 20(4):745–750. 2006.*—The swiss is widely used in the recreational training environment as a supplement to conventional resistance training. One such application is to use the swiss ball as a bench support for bench press exercise. There is no evidence to indicate that the use of a swiss ball is beneficial for resistance training exercise. This study investigated muscle activity using surface electromyography of upper-body and abdominal muscles during the concentric and eccentric phases of the bench press on and off a swiss ball. Volunteers for this study were 14 resistance-trained subjects who performed isolated concentric and eccentric bench press repetitions using the 2 test surfaces with a 2-second cadence at a load equivalent to 60% maximum force output. The average root mean square of the muscle activity was calculated for each movement, and perceived exertion during the tasks was collected using a Borg Scale. The results of the study showed that deltoid and abdominal muscle activity was increased for repetitions performed using the swiss ball. Increased deltoid muscle activity supports previous findings for increased activity when greater instability is introduced to the bench press movement. Abdominal muscle activity increases were not hypothesized, but this finding provides scientific evidence for anecdotal reasoning behind swiss ball use as a potential core stability training device.

Key Words. electromyography, perceived exertion, unstable surface, resistance training

## Introduction

The swiss ball has emerged as a popular training tool in the recreational training environment (8). A primary focus of swiss ball training has been the lumbo-pelvic region (17, 24, 25). However, it is common to observe gym trainers using the swiss ball as a supplementary device for conventional resistance training.

One study has investigated the use of the swiss ball during the performance of 2 standard exercises for the leg muscles. These exercises were a leg extension and a plantarflexion task (4). This study did not demonstrate a substantial benefit from the use of the swiss ball for these exercises. A more common exercise that the swiss ball is used to supplement is the bench press. In this capacity the swiss ball is used as the supporting surface upon which the bench press exercise is performed. Previous research has demonstrated that there are greater levels of shoulder muscle activity (measured by electromyography) during the free-weight bench press in comparison to the machine bench press (18). It was suggested that the increased activity was due to the greater requirement for the shoulder muscles to stabilize the scapula and humerus during the movement, as well as to move the load.

Anecdotal reasoning behind why the swiss ball should be used for resistance training advocates the increased "core stability" focus. This is based upon the belief that training with the swiss ball will increase abdominal muscle activity. Recent evidence indicates that abdominal muscle activity was increased with the swiss ball when the exercise involved minimal contact between the person and the ball and during tasks in which a body segment was extended away from the base of support (17). The bench press exercise does not fulfill either of those requirements; however, there is no scientific evidence to refute the claims that resistance training with a swiss ball increases abdominal muscle activity.

An additional aspect of resistance training that must be considered is the type of muscle action used (13). It has been well established that there are different neuromuscular demands associated with the use of concentric or eccentric muscle actions (10). Therefore, it is appropriate that each individual muscle action is examined to determine whether the swiss ball may influence one type of muscle movement more than another.

For these reasons, the purposes of this study were (a) to evaluate muscle activity of the prime mover and abdominal muscles during performance of bench press exercises on and off of a swiss ball and (b) to determine whether the relationship between muscle activity and the surface is influenced by whether a concentric or eccentric muscle action is used.

The hypotheses of this study were (a) that activity of the deltoid muscle would be increased by use of the swiss ball, as this has introduced another level of instability above that demonstrated from the machine to the free-weight bench press and (b) that abdominal muscle activity will not be increased through use of the swiss ball because the load is directly above the base of support and the subject has substantial body contact with the surface.

## Methods

### Experimental Approach to the Problem

A within-subjects cross-over design was used to evaluate differences between the stable and unstable surface for muscle activity recorded during the bench press exercise. The independent variables were the muscle activities recorded from the prime muscles associated with performance of the task. The dependent variable to be manipulated in this study was the surface used for performance of the task.

### Subjects

The calculation of the sample size was carried out with $\alpha = 0.05$ (5% chance of type I error) and $1-\beta = 0.80$ (power 80%), and using the results provided from a previous study (18) that found differences between the performance of a machine and free-weight bench press for the electromyographic (EMG) activity of anterior deltoid (paired $t$-test; $\delta = 1.65$). This provided a sample size of $n = 14$ for this study.

Fourteen subjects with at least 6 months' worth of resistance training experience volunteered to participate in this study (9 men, 5 women; aged 23.69 ± 1.60 years; height, 1.74 ± .07 m; weight, 79.27 ± 13.92 kg). All subjects were familiar with the swiss ball bench press exercise but did not perform the task and had not performed the task on a regular basis as part of their training program. Subjects included in this study did not have any musculoskeletal pain, did not suffer from any neuromuscular disorders, and did not have any form of joint or bone disease. No subject was taking any form of performance-enhancing medication. Subjects were instructed to refrain from any resistance or anaerobic exercise and were required to maintain normal dietary habits in the 24 hours prior to testing. Subjects were required to present to testing in a 2-hour postprandial state. Informed written consent was obtained from each subject prior to his or her participation in this study. The University of Auckland Human Participants Ethics Committee approved all procedures used in this investigation.

### Procedure Overview

Subjects were required to perform isolated concentric or eccentric dumbbell bench press repetitions on a stable or swiss ball surface (Figure 1). The presentation of muscle action and surface was randomized for each subject. The use of isolated muscle action repetitions was designed to eliminate any contribution of the stretch-shortening cycle from consecutive bench press repetitions and also to eliminate any elasticity effects from the swiss ball that might contribute to the movement. Each repetition was a 2-second muscle action preceded by a 1-second preload phase. Subjects were familiarized with the cadence required prior to data collection. The cadence was controlled with audio output that paced the 2-second repetition using 0.5-second beats. The load was removed from the subject after each repetition. Three separate repetitions were performed for each movement on each surface.

The load chosen for the bench press exercises on the 2 test surfaces was calculated to be 60% of a 1 repetition maximum (1RM) performed on a stable surface for the concentric phase of the bench press movement. The 60% relative load was chosen because this is the lowest load recommended for use in strength training (13), and also for safety reasons related to performing the exercise on an unstable surface, where we are not sure of the relative demand of the exercise. The 1RM for each arm was obtained using a force transducer (sampled at 100 Hz, low-pass filtered at 10 Hz). The maximum force output of each arm was obtained from 2 repetitions. The maximum values for each arm were averaged, and the 60% load for the experiment was calculated ($F = m/a$, where $a = 9.81\ m{\cdot}s^{-2}$).

### Bench Press Procedures

For the bench press task, the subject was positioned on the respective surface so that his thoracic and lumbar spine was supported, but the cervical spine above C7 was unsupported. The same surface height was used for both conditions. A surface height was chosen from a range of swiss balls used (35–75 cm) so that the trunk of the subject was parallel to the ground and his knees were flexed to 90°. The legs were positioned with the feet hip-width apart. The shoulders were abducted to 90° and were maintained in this plane throughout each movement phase.

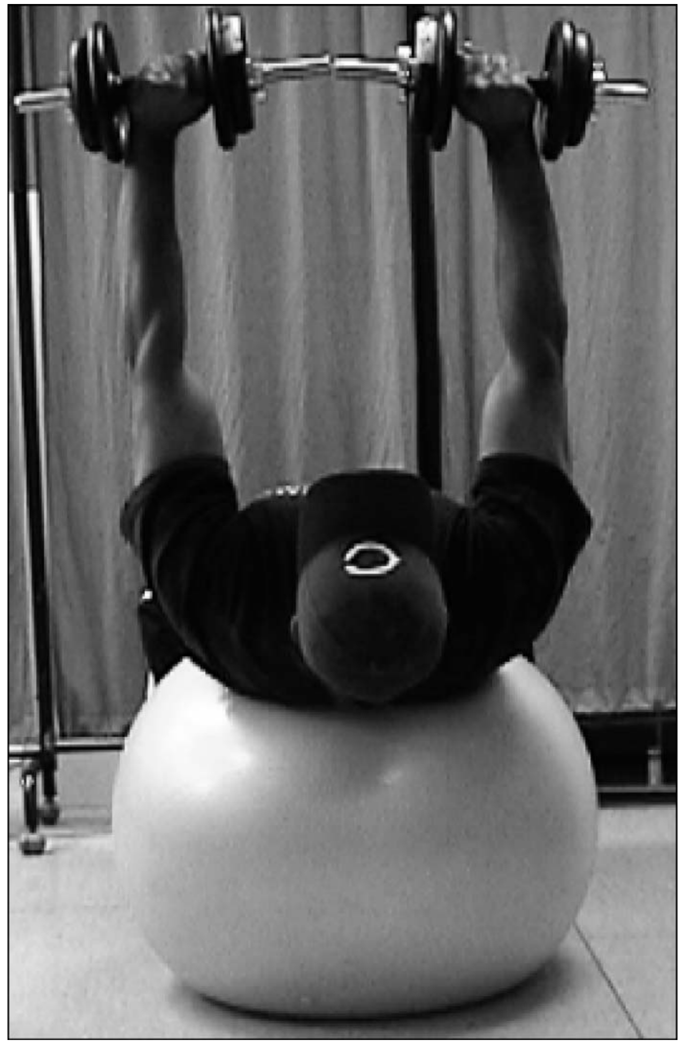

**Figure 1.** Swiss ball dumbbell bench press at full extension (end of concentric action, beginning point of eccentric action).

The concentric phase started after the preload phase with the dumbbells held at the level of the sternum. On the audio command, the subject performed the concentric phase of the lift, terminating at full elbow extension with both dumbbells together.

The eccentric phase started with the preload phase held at full elbow extension. On the audio command, the subject lowered the weight into the starting position used for the concentric phase.

### EMG Recordings

Pairs of bipolar Red Dot (3M, St. Paul, MN) silver/silver-chloride (Ag/AgCl) surface electrodes were placed on the belly of the following muscles on the right side of the body (contact diameter, 2 cm; center-to-center distance, 3 cm) aligned parallel to the muscle fibers; anterior deltoid (AD), biceps brachii (BB), triceps brachii (TB), pectoralis major (PM), rectus abdominus (RA), and transversus abdominus/internal obliques (TA/IO). The site placement for

**TABLE 1.** Average root mean square (RMS) electromyographic (EMG) (mV) results measured for the concentric and eccentric actions on both test surfaces. Also presented are the results of the repeated measures analysis of variance (ANOVA) for comparison between action and surface (*p* values are presented for comparison between muscle action, comparison between the surface used, and the interaction to determine whether the action used influences the difference between surfaces).

| | Swiss ball | | Stable | | |
|---|---|---|---|---|---|
| Muscle* | Concentric | Eccentric | Concentric | Eccentric | ANOVA results |
| RA | 69.30 ± 35.53 | 61.37 ± 23.37 | 47.61 ± 11.84 | 35.60 ± 13.51 | Action: 0.11<br>Surface: 0.0003<br>Interaction: 0.74 |
| TA/IO | 114.71 ± 76.59 | 109.56 ± 89.34 | 73.02 ± 98.26 | 54.08 ± 63.97 | Action: 0.59<br>Surface: 0.03<br>Interaction: 0.76 |
| PM | 453.55 ± 150.61 | 316.53 ± 161.87 | 421.25 ± 128.31 | 274.14 ± 134.38 | Action: 0.001<br>Surface: 0.34<br>Interaction: 0.89 |
| TB | 218.67 ± 68.13 | 131.66 ± 58.37 | 240.28 ± 78.91 | 139.91 ± 69.61 | Action: 0.00001<br>Surface: 0.42<br>Interaction: 0.72 |
| AD | 449.39 ± 227.86 | 304.81 ± 187.28 | 337.24 ± 216.78 | 187.74 ± 145.73 | Action: 0.007<br>Surface: 0.034<br>Interaction: 0.96 |
| BB | 178.29 ± 73.87 | 172.30 ± 58.96 | 154.09 ± 73.19 | 132.09 ± 47.82 | Action: 0.42<br>Surface: 0.07<br>Interaction: 0.64 |

* RA = rectus abdominus; TA/IO = transversus abdominus/internal obliques; PM = pectoralis major; TB = triceps brachii; AD = anterior deltoid; BB = biceps brachii.

the TA/IO was medial and inferior to the anterior superior iliac spine in a site previously indicated to be accurate for measurement from these muscles, which cannot be separated at this level (16, 19).

Before electrode placement the skin was prepared to reduced impedance to below 5 kΩ by shaving excess hair, abrading the area with fine sandpaper, and cleansing the skin with an isopropyl alcohol swab. The reference electrode was placed on the olecranon. Assuming bilateral symmetry during the task, electrodes were placed on the right side of the body only.

EMG signals were collected using a Grass Instruments Data Acquisition Board (Grass-Telefactor, West Warwick, RI; common mode rejection of 90 dB at 60 Hz; input impedance, 100 MΩ, −6 dB band-pass roll-off at 10 and 1,000 Hz) at 2,000 Hz with 16 bit A/D conversion into a Pentium IV computer. Data collection and analysis were conducted using LabVIEW (National Instruments Corporation, Austin, TX). The average root mean square (RMS) for each 2-second contraction was calculated (9). The average RMS of the 3 repetitions for each movement formed the basis of the muscle activity analysis.

### Perceived Exertion

The subject's general whole-body perceived exertion for each concentric and eccentric phase on each surface was evaluated using Borg's 15-point perceived exertion scale (6). The subject was instructed that a rating of 20 would correspond to the exertion during the 1RM procedure, and a rating of 7 would correspond to the unweighted bench press used to familiarize the subject with the surface and task. Subjects and experimenter were blinded with regard to the result entered for each series of movements so that no direct comparison of the number entered could be made. Previous studies have used ratings of perceived exertion for eccentric and concentric movements on a manner similar to this study (14, 27).

### Statistical Analyses

The Statistical Package for the Social Sciences (SPSS, version 11.5; SPSS, Inc., Chicago, IL) was used for the data analysis. To determine the variability between trials for the EMG measurements for each muscle, the intraclass correlation coefficient was calculated (1.1, [23]). Repeated-measures analysis of variance (ANOVA, movement × muscle) was used to determine the differences in average EMG. A priori repeated contrasts with Bonferroni's adjustment for multiple comparisons were used to determine where the differences between positions and tasks were. The effect size, "d," was calculated to determine the standardized mean difference between surface conditions for each muscle (12). Classifications of effects sizes are small, d = 0.20; medium, d = 0.50; large, d = 0.80. The significance of this study was determined at $p \leq 0.05$.

## RESULTS

The average absolute load (per dumbbell) lifted for the 60% relative-intensity bench press movement was 20.62 ± 7.22 kg. Although there was a gender difference for the absolute load lifted (males lifted significantly greater absolute load, $p < 0.001$), there was no gender effect found for the EMG measurements.

There was a significant difference between the surfaces for the activity of RA, TA/IO, and AD (Table 1). The activity of each muscle was significantly greater on the swiss ball. There was significantly greater EMG activity measured during the concentric action for PM, TB, and AD (Table 1). The calculated effect sizes for these differences show medium to high scores for all between-surface differences identified by the ANOVA analysis (Table 2).

Subjects had greater perceived exertion during the concentric action compared to the eccentric action for the respective surfaces (stable concentric, 12.93 ± 0.99; ec-

**Table 2.** Calculated effect sizes (d values) for the standardized differences between the stable and unstable surface for each muscle contraction. Note that * denotes effect sizes where the results from the repeated-measures analysis of variance (ANOVA) demonstrated a significant difference between the surfaces for the contraction.†

| Muscle | Concentric | Eccentric |
|---|---|---|
| RA | 1.83* | 1.92* |
| TA/IO | 0.43* | 0.87* |
| PM | 0.25 | 0.31 |
| TB | 0.28 | 0.12 |
| AD | 0.52* | 0.80* |
| BB | 0.33 | 0.84 |

† RA = rectus abdominus; TA/IO = transversus abdominus/internal obliques; PM = pectoralis major; TB = triceps brachii; AD = anterior deltoid; BB = biceps brachii.

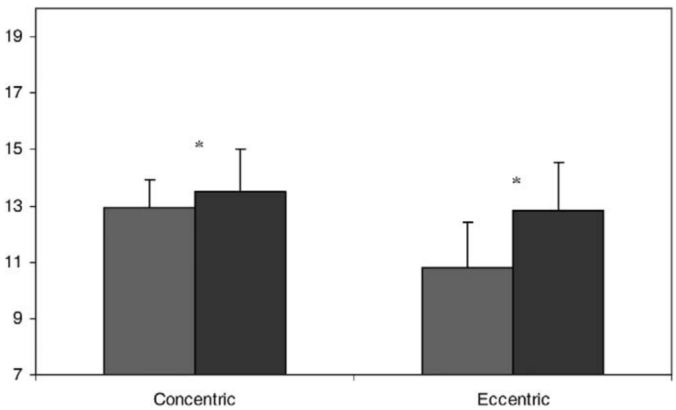


**Figure 2.** Results comparing perceived exertion (RPE) scores for the concentric and eccentric actions on both surfaces. * Significant difference between the surfaces for perceived exertion during the muscle action ($p < 0.01$).

centric, 10.79 ± 1.63; swiss ball concentric, 13.50 ± 1.51; eccentric, 12.86 ± 1.70: action comparison, $p < 0.001$). Subjects' perceived exertion scores were significantly greater for each action on the swiss ball compared to the stable surface (Figure 2; $p < 0.01$).

## Discussion

The results of this study provided support for the first hypothesis that deltoid muscle activity would be increased by using the swiss ball. However, there existed evidence that was contrary to the second hypothesis of this study, namely that there would be no influence on abdominal muscle activity associated with using the swiss ball. Indeed, we did find that the swiss ball bench press did increase the activity of the abdominal muscles in comparison to the stable surface.

Previous research found that at 60% 1RM there was a significant increase in anterior deltoid muscle activity for free-weight bench press compared to machine bench press (18). It has been suggested that during free-weight bench press compared to machine bench press that bar movement must be stabilized in 2 directions (15). The research that demonstrated increased deltoid activity during the free weight indicated that these muscles were responsible for providing the increased shoulder stabilization required to maintain the more complicated movement (18). It is possible that the results of the current study demonstrating increased deltoid activity on the swiss ball may be due to the demand to stabilize the shoulder in all 3 anatomical movement planes. This indicates a hierarchical progression of the bench press exercise variations for recorded EMG activity. The progression moves from the machine bench press, which has the lowest muscle activity, to the free weight, with the swiss ball variation eliciting the greatest amount of muscle activity. Future research using 3-dimensional kinematic analysis is required to demonstrate whether increased 3-dimensional movement is the reason for increased deltoid activity.

Increased abdominal muscle activity was not a hypothesized result for this study. Previous research has found that abdominal muscle activity was increased using the swiss ball for callisthenic activities, such as the curl-up and single leg hold exercise (17, 25). The increased abdominal activity on the swiss ball during both the concentric and eccentric movement phases provides evidence for the anecdotal use of the swiss ball as a "core stability" training tool. The instability theorized to be caused by the swiss ball needs to be investigated to explain why the abdominal muscle activity increased. It may be possible that 3-dimensional variations in the system center of pressure (which can be measured with a force platform) beneath the swiss ball could explain why abdominal activity increased. The anatomical evidence demonstrates that the abdominals play an important role in spinal stability, although they are not more important than any other trunk muscle with regard to the provision of stability (7). Barker and colleagues (3) demonstrated that tensile forces and areas affected by the medial and posterior layers of the lumbar fasciae are associated with traction applied via the transversus abdominus muscle. It was also noted that a contralateral effect was observed for traction applied to transversus abdominus between T12 and S3 (3). Vleeming et al. (26) have also reported that traction to abdominal muscles resulted in contralateral fascial movement below the level of L4. These results indicate that the contraction of the deep abdominal muscles and tension transmitted via the lumbar fascia provide a likely mechanism to influence the segmental neutral zone, the conceptualized measure for spinal stability (20–22). There is currently a small body of evidence that demonstrates increased activity of the abdominal and lumbar musculature when using a swiss ball in comparison to exercise on a stable surface (1, 5, 17, 25). It may be possible that the instability introduced by the swiss ball increases the demand on the abdominal muscles to stabilize the spine via their fascial attachments to reduce displacement of the lumbar segments and maintain the neutral zone.

Anderson and Behm (2) reported no significant difference in EMG activity of the pectorals, triceps, latissimus dorsi, and rectus abdominus when performing maximal isometric chest presses under stable and unstable conditions. Maximum isometric force was decreased by 60% with the unstable base (2). Similar findings for decreased leg extensor and plantar flexor force output using an unstable surface have also been shown (4). The current study investigated a dynamic movement on the unstable surface using a 60% relative load of the maximum force output performed for the bench press in a stable environment. Based on previous research showing decreased force output on the unstable surface, it is reasonable to

**TABLE 3.** Results of the intraclass correlation coefficient (ICC, *r* value) calculations for the reliability between trials of the muscle activity values measured (average root mean square [RMS; mV]). The first value presented is the *r* value between trials 1 and 2; the second value represents between trials 2 and 3.*

| | Swiss ball | | Stable | |
|---|---|---|---|---|
| Muscle | Concentric | Eccentric | Concentric | Eccentric |
| RA | 0.96, 0.95 | 0.93, 0.92 | 0.70, 0.77 | 0.85, 0.96 |
| TA/IO | 0.78, 0.86 | 0.89, 0.84 | 0.95, 0.98 | 0.87, 0.87 |
| PM | 0.84, 0.71 | 0.94, 0.96 | 0.77, 0.87 | 0.92, 0.96 |
| TB | 0.71, 0.75 | 0.76, 0.67 | 0.76, 0.87 | 0.97, 0.91 |
| AD | 0.89, 0.75 | 0.77, 0.94 | 0.94, 0.91 | 0.92, 0.98 |
| BB | 0.85, 0.66 | 0.65, 0.61 | 0.52, 0.81 | 0.59, 0.79 |

* RA = rectus abdominus; TA/IO = transversus abdominus/internal obliques; PM = pectoralis major; TB = triceps brachii; AD = anterior deltoid; BB = biceps brachii.

believe that the 60% relative load for the stable surface would not be the same relative intensity on the swiss ball as a result of the decrease in maximal force output that is possible within this condition. Therefore, the increased muscle activity demonstrated in this experiment is probably due to the combination of the greater relative load for performance of the task on the unstable surface combined with the potential instability introduced by the swiss ball.

The increase in abdominal muscle activity may have been caused by conscious activation of these muscles, since the subjects were likely aware of the anecdotal reasoning behind using the swiss ball. The majority of between-trial reliability values for the abdominal muscles were in excess of 0.90 (Table 3). If subjects were consciously activating their abdominal muscles, it is reasonable to believe that the reliability values would have been significantly reduced by this variability. As mentioned previously, the collection of center-of-pressure information using a force platform would help provide information regarding the level of instability of the unstable surface. Future research should utilize force platform measurements to help explain the changes in muscle activity that have been observed using the swiss ball.

EMG data was not normalized to a maximal voluntary contraction (MVC), as is normally performed. This was because the muscle activity was measured during dynamic movement, and most MVC procedures are performed during an isometric contraction. The use of an isometric MVC was not relevant for this study. Also, it was not a purpose of this study to provide relative muscle activity values, because a relative load was used to standardize the experimental workload between conditions.

Only experienced lifters were used in this study. It may be possible that inexperienced lifters would exhibit different muscle responses and perceived exertion results as a result of unfamiliarity with both the task and the surface.

While the relative intensity of the load used in this study has been found to provide a strength training effect, higher relative training intensity has been shown to lead to greater changes in muscle cross-sectional area (11). Future research needs to investigate swiss ball exercises with higher and lower relative intensities to determine whether the muscle activity differences found are a function of load. It may be possible that with lower relative intensities there is no difference between the surfaces, whereas with higher intensities (>70%), greater differences between the surfaces and potentially increased activity of the prime mover muscles may be found.

## PRACTICAL APPLICATIONS

The wide use of swiss ball training in the recreational environment means that it is important that objective data on muscle activity patterns are recorded. The results of this study demonstrate the acute effects of performance of bench press using the swiss ball and cannot be used to infer a potential training effect. This study demonstrates that the acute effect of utilizing the swiss ball in the performance of bench press exercise is an increase in the muscle activity of stability muscles associated with the task, the deltoid and abdominal muscles. The swiss ball did not lead to increased activity for the prime movers of the exercise, the pectoralis and triceps. A training study employing the swiss ball bench press exercise needs to be performed to determine the chronic effects of this mode of exercise, especially in populations in which instability of the shoulder girdle is an issue. This will help provide evidence for the effective use of the swiss ball. This study does contribute to the body of evidence demonstrating increased abdominal muscle activity during exercise performed on the swiss ball. This provides support for anecdotal application of the swiss ball as a mode of training to enhance abdominal muscle activity, although reference should always be made to the mechanical effects of the increased loading of the spine via lumbar fascial attachments.

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Address correspondence to Paul W.M. Marshall, p.marshall@auckland.ac.nz.