Shoulder muscle EMG activity during push up variations on and off a Swiss ball
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Abstract

Background: Surface instability is a common addition to traditional rehabilitation and strength exercises with the aim of increasing muscle activity, increasing exercise difficulty and improving joint proprioception. The aim of the current study was to determine if performing upper body closed kinetic chain exercises on a labile surface (Swiss ball) influences myoelectric amplitude when compared with a stable surface.

Methods: Thirteen males were recruited from a convenience sample of college students. Surface electromyograms were recorded from the triceps, pectoralis major, latissimus dorsi, rectus abdominis and external oblique while performing push up exercises with the feet or hands placed on a bench and separately on a Swiss ball. A push up plus exercise was also evaluated with hands on the support surface.

Results and discussion: Not all muscles responded with an increase in muscle activity. The pectoralis major muscle was not influenced by surface stability. The triceps and rectus abdominis muscles showed increases in muscle activity only when the hands were on the unstable surface. The external oblique muscle was only influenced by surface stability during the performance of the push up plus exercise. No muscle showed a change in activation level when the legs were supported by the Swiss ball instead of the bench.

Conclusion: Muscle activity can be influenced by the addition of surface instability however an increase in muscle activity does not influence all muscles in all conditions. The relationship between the participant’s center of mass, the location of the unstable surface and the body part contacting the Swiss ball may be important factors in determining the muscle activation changes following changes in surface stability.

Introduction

Exercise balls, wobble boards and other labile surfaces commonly replace stable surfaces during the performance of resistance training exercises for both injury management and performance improvement. A common assumption is that an unstable surface places an increased
demand on the neuromuscular system to stabilize articular joints which may have been created more unstable due to the labile surface. The purported benefits of training with this instability are improvements in joint proprioception and greater muscle activation requirements. Research investigating ankle disc training has shown improvements in proprioception and muscle reflex latency time [1,2] following the training regime and reduction in injury prevalence [3]. Similar improvements in joint proprioception have been documented in unstable shoulders following rehabilitation therapy using unstable surfaces [4].

It is often assumed that performing a resistance exercise on unstable surfaces results in greater muscle activity in an attempt to achieve joint stability. This assumption has mixed and somewhat sparse support. The majority of research has investigated the influence of labile surfaces on trunk muscle activity during trunk training exercises. Some research shows a consistent increase in selected (not all) trunk muscles during curl ups on an exercise ball [5], upper body exercises while seated on an exercise ball [6] and during unstable weighted squat movements while standing on semi inflated wobble discs [7]. Others have shown inconsistent changes across subjects with no statistical increase in muscle activity when replacing a Swiss ball for an exercise bench during resistance exercises for the upper body [8,9] and changes dependent upon centre of gravity location relative to the unstable surface during bridging/core stability exercises [9,10].

Anderson & Belm [11] documented the muscle activity of the primary movers and the force output during a chest press while lying on a Swiss ball (labile surface) and on a bench. The authors found a decrease in absolute force production on the labile surface when compared with the force produced on the stable surface; however, there was no difference in the amount of muscle activity between the two conditions. Suggesting that more muscle activation was required to achieve the same amount of force production on an unstable surface compared with a stable surface. This suggests that for the same amount of force production on an unstable surface compared with a stable surface requires a greater amount of muscle activation. An exercise similar to the chest press is the push up exercise. A review of the literature failed to provide any work documenting the influence of an unstable surface on the myoelectric activity of the shoulder and trunk muscles during push up exercises. This exercise assumes that the required force production during the push up will be consistent (due to gravity and bodyweight) regardless of the stability of the support surface. Therefore investigating this exercise allows us to determine if an unstable support surface necessitates greater muscle activation when the same force requirements are demanded across the same exercise performed on an unstable (Swiss ball) and stable surface (bench). It is the purpose of the current study to determine the effect of an unstable surface under the hands or under the feet during the push up and push up plus exercise on shoulder and trunk muscle activation levels.

Methods
Patient characteristics
Thirteen healthy males (average age in years (standard deviation) 26.3 (1.5), average height (standard deviation) 176.7 cm (4.99) and average weight (standard deviation) 75.6 kg (7.34) with greater than 6 months of weight training experience without back pain or upper limb injuries were recruited from a convenience sample of college students. Participants were required to sign an information and informed consent form prior to the study approved by the institution’s Research Ethics Board.

Study protocol
To optimize EMG signal collection participants from a college population were recruited because of their athletic abilities and low subcutaneous fat. The myoelectric activity of the pectoralis major, latissimus dorsi, triceps, rectus abdominis and external oblique muscles were recorded during a series of different variations of the classic push up exercise.

Data collection hardware characteristics
Disposable bipolar Ag-AgCl disc surface electrodes with a diameter of one cm were adhered over the muscle groups parallel to their fiber orientation in the muscle belly. Before the application of the electrodes the skin was shaved with a disposable razor and abraded with a cotton swab and alcohol. The electrodes were attached to 5 leads which were connected to an EMG data collection system (Bortec, Calgary AB). The myoelectric activity of the muscles was collected with customized software (Deltys EMGWorks, Boston, MA, USA). Raw EMG was amplified between 1000 and 20,000 times depending on the subject. The amplifier had a CMRR of 10,000:1 (Bortec EMG, Calgary AB, Canada.). Raw EMG was band pass filtered (10 and 1000 Hz) and A/D converted at 2048 Hz using a National Instruments data acquisition system.

Maximum Voluntary Contractions (MVC)
In order to compare muscle activity across subjects and give biologically meaningful data maximal normalization contractions were performed for each muscle. This required the subject to maximally contract each muscle against the manual resistance provided by the experimenter. A maximal isometric contraction occurred twice for each muscle to ensure that an acceptable signal was recorded for each subject. The maximum muscle activity was calculated and recorded from a suitable maximum contraction and all subsequent muscle activity was
expressed as a percentage of this maximum voluntary contraction (MVC).

**Electrode placement and MVC testing procedure**
The triceps electrode was placed on the long head (middle of the muscle belly) between origin and insertion. The MVC saw the shoulder and elbow flexed to 90 degrees while the EMG was recorded during resisted elbow and shoulder extension. The pectoralis major electrode was placed four fingerbreadths below the clavicle, medial to the anterior axillary border. With the elbow flexed 90 degrees and the shoulder abducted 75 degrees the subject performed a maximal palm press while the muscle activity was recorded. The latissimus dorsi electrodes were 3 finger fingerbreadths distal to and along the posterior axillary fold, parallel to the lateral border of the scapula. With the elbow extended and the arm abducted 30 degrees in the coronal plane and internally rotated, attempted maximum shoulder extension, abduction and internal rotation was resisted with the muscle activity recorded. The rectus abdominis electrode was placed 3 cm lateral to the umbilicus in a vertical orientation. With the participant supine and trunk flexion was resisted and the MVC was recorded. The external oblique electrode was placed 15 cm lateral to the umbilicus on a 45 degree inferior angle. With the subject lying supine with thighs flexed 90 degrees, resisted side bending was recorded.

**Exercise protocol**
Following the maximal voluntary contractions the participants were required to perform the following exercises in random order (arbitrarily determined by the experimenters). Participants performed the exercises identically across exercises. Three repetitions occurred for each exercise at the same rate. Participants began in the upright position when the EMG collection began. This position was held for 4 seconds. The eccentric (lowering) portion lasted 2 seconds. The patient then held the lowered position for 4 seconds. The concentric (raising) portion of the movement lasted for 2 seconds with a 4 second holding position once again in the upright position. Three repetitions were recorded during a 40 second collection period. An electrical trigger (foot switch) was used to mark the beginning of the first descent and the finish of the last repetition.

**Movement tasks**
All movements were completed in a random order in a standardized position with the hands shoulder width apart with the subject’s middle finger under the acromio-clavicular joint. The bench height and exercise ball height were standardized and identical to each other. A minimum of 3 minutes of rest occurred between exercises to prevent the influence of fatigue on myoelectric amplitude changes. This rest period is similar and exceeds other studies investigating similar phenomena [5,7,9].

1. Push up with feet on an exercise bench.
2. Push up with feet on exercise ball.
3. Push up with hands on exercise bench.
4. Push up with hands on exercise ball.
5. Push up plus with hands on exercise bench. Starting in the push up position the participant rolls the shoulders forward (scapular protraction) and then lowers their body while allowing the shoulder blades to approximate (scapular retraction).
6. Push up plus with hands on exercise ball. Same movement as #5.

**EMG analysis**
Both MVC data and myoelectric data from the exercises tasks were processed in the identical manner. Using EMG analysis software (EMGWorks, Delays, Boston, MA) the myoelectrical was first demeaned (bias removed therefore the signal alternates around 0), then a root mean square technique (window of 150 ms and an overlap of 75 ms) was used to smooth the data thus providing a linear envelop of EMG activity. Using the electrical markings left by the foot switch trigger at the start and end of the movement the mean activity for the 3 repetitions was calculated. This mean activity was then expressed as a percentage of the peak activity found during the maximum voluntary contraction (MVC) for the corresponding muscle.

**Statistical analysis**
A series of paired t-tests were used to assess for the influence of the Swiss ball on muscle amplitude. Differences across the different exercises was not examined-only between the stable and unstable conditions.

**Results**
Table 1 shows the average muscle activity and standard deviations for the 6 different exercises studied. The latissimus dorsi values were removed from the study as the first six participants analyzed showed primarily noise and little muscle activity during the performance of the push up. The triceps muscle was significantly influenced by the addition of the Swiss ball during the performance of the push up with the hands on the ball surface and during the push up plus with the hands on the ball surface. Both exercises showed a statistically significant increase in muscle activity when performed on the Swiss ball. Conversely, the triceps activity was not influenced when the Swiss ball...
Table 1: Average trunk and shoulder muscle activity during the push up and push up plus exercises when performed on a Swiss ball and an exercise bench.

<table>
<thead>
<tr>
<th></th>
<th>Triceps</th>
<th>Pectoralis Major</th>
<th>Rectus Abdominis</th>
<th>External Oblique</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bench</td>
<td>Ball</td>
<td>Bench</td>
<td>Ball</td>
</tr>
<tr>
<td>PUHands</td>
<td>22.2 ± 8.8</td>
<td>*43.1 ± 17.3</td>
<td>21.4 ± 11.8</td>
<td>26.65 ± 14.5</td>
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<tr>
<td></td>
<td>p = 0.002</td>
<td>p = 0.041</td>
<td>p = 0.221</td>
<td>p = 0.004</td>
</tr>
<tr>
<td>PUFoots</td>
<td>32.7 ± 17.5</td>
<td>29.9 ± 10.1</td>
<td>30.4 ± 9.7</td>
<td>29.9 ± 7.6</td>
</tr>
<tr>
<td></td>
<td>p = 0.355</td>
<td>p = 0.717</td>
<td>p = 0.997</td>
<td>p = 0.742</td>
</tr>
<tr>
<td>PUPHands</td>
<td>18.7 ± 10.3</td>
<td>*29.6 ± 14.7</td>
<td>14 ± 7.2</td>
<td>21.4 ± 18.5</td>
</tr>
<tr>
<td></td>
<td>p = 0.024</td>
<td>p = 0.099</td>
<td>p = 0.011</td>
<td>p = 0.011</td>
</tr>
</tbody>
</table>

Muscle activity is expressed as a percentage of a maximum voluntary contraction (MVC). * indicates a statistically significant difference (p < .05) between the exercises using a Swiss ball or bench as the support surface (PUHands = push up with hands on bench/ball, PUFoots = push up with feet on ball/bench and PUPHands = push up plus exercise with hands on ball/bench).

The addition of the Swiss ball did not influence the muscle activity of the pectoralis major during all exercises. Similar to the triceps, the Swiss ball addition resulted in a significant increase in the myoelectric activity of the rectus abdominis during push ups with the hands on the Swiss ball and the push up plus. There was no change in muscle activity when the feet were on the unstable surface. The external oblique was not influenced by the addition of the Swiss ball for either standard push up exercise. The external oblique was significantly increased during the push up plus exercise with the hands on the Swiss ball but not when the feet were on the ball.

Figure 1
EMG linear envelopes during a push ups with the hands on an exercise bench and a Swiss ball. ENG activity is non-normalized and is therefore in arbitrary EMG units. A bias was added to the activity of the pectoralis major, rectus abdominis and external oblique for ease of viewing to prevent overlap of the muscle's linear envelopes. Three pushups occurred over the course of 30 seconds.
**Figure 2**
Raw EMG during three push ups with the hands on an exercise bench or a Swiss ball for the triceps and pectoralis major muscle. PMBench = Pectoralis Major EMG on bench; PMBall = Pectoralis Major EMG on ball. Bas added to triceps activity for ease of viewing. Trial was 30 seconds in length.

Discussion
Replacing an exercise bench for a Swiss ball can increase muscle activity however the effect is both task and muscle dependent. The triceps and rectus abdominis were the two muscles most affected by the addition of an unstable surface. The pectoralis major muscle – the primary mover – was not influenced by the addition of the Swiss ball during any push up variation.

It is not possible to conclude that surface instability automatically results in increases in muscle activity. Merely adding an unstable surface is insufficient to influence all muscles. Of note is that placing the feet on the unstable surface resulted in no changes in muscle activity in all of the muscles studied. Our findings suggest that the unstable surface needs to be under the hands in order to result in an assumed destabilization effect and a subsequent increase in muscle activity during push up variations. It also appears that the further the distance the centre of mass is above the base of support (when unstable) can also influence the trunk muscle activity. While we did not measure the position of the centre of mass in this study we believe it is safe to assume that the centre of mass of the subject is higher relative to the Swiss ball when the hands are on the Swiss ball than when the feet are on the Swiss ball. A different result may occur if the feet are placed on the Swiss ball and the hands are on a bench of equal height to the Swiss ball. This vertical distance from the Swiss ball...
may be an important factor in determining which exercises will see changes in myoelectric activity with the addition of a Swiss ball. Of interest was the finding that the external oblique was not influenced by the Swiss ball during the standard push up; however, when the participants performed the push up plus which finds the arms extended and the participant’s chest farther away from the Swiss ball the external oblique showed greater activity during the unstable condition. We assume in our study that the centre of mass is higher during the push up plus with the arms extended than during the push up exercise that saw the elbows flex and extend with no scapular protraction at the top of the push up. The finding that the distance between chest and hands on a Swiss ball influences trunk muscle activity has previously been reported by Marshall and Murphy [9] during bridging/front support exercises.

The lack of change in the pectoralis major muscle during the push ups on the different stability surfaces is interesting considering the dramatic change in the triceps muscle. This may be due to the differences between the joints and associated movements that the two muscles cross. There is greater redundancy in the motor control of muscles crossing the anterior shoulder. The joint is stabilized by a multitude of muscles (biceps brachii, anterior deltoid, rotator cuff) and shoulder adduction torque is also created by a number of muscles in addition to the pectoralis major. There is also a smaller range of motion compared with the elbow joint. The pectoralis major is a single joint muscle whereas the triceps brachii is a two joint muscle which has stability and movement demands both at the elbow and the shoulder possibly resulting in such a dramatic change in muscle activity when the Swiss ball replaced the bench during the push up. The pectoralis major may only be
concerned with its primary movement and have a smaller role in responding to changes in stability which may be controlled by other muscles which influence the shoulder joint. In contrast, the triceps brachii is the main extensor of the elbow with little help from the anconeus. Due to its mechanical advantage relative to the length of the forearm it may also have difficulty in responding to changes in stability compared with pectoralis major. It should also be noted that there is often a range of responses as seen in previous research [6]. Not every individual responded in the same manner to a change in surface stability. It is possible that there are individual factors that modulate the response to surface stability which also suggests that training may be influence the response to instability. We don’t know if the increase in muscle activity or lack of change is involuntary or can be subject to change with training and feedback.

A limitation to explaining our results is the lack of kinematic and kinetic information describing the push up variations in our study. Having information on the centre of mass and its relationship to the bases of support (feet and hands) in the different exercises may help explain the different results found when the feet were placed on the Swiss ball compared with the hands on the Swiss ball. An attempt was made in this study to control for joint posture and the influence of gravity on the body’s centre of mass. The exercise conditions were assumed to be identical except for the addition of the Swiss ball. An attempt was made to control for the speed of movement as well. These controls were imparted visually and with simple measurements. It is possible that subtle variations did exist between the conditions but we feel that these differences would not affect the results as they would be overplayed by the natural variability that is seen in EMG recording during any well controlled exercise.

Of practical interest are the low values for muscle activity during the exercises. For the population studied it implies that these exercises are insufficient to produce improvements in strength. Adaptations in terms of endurance or motor control are possible. A less athletic population may achieve strength benefits from these exercises.

Conclusion
The muscular response during push up exercises on unstable surfaces is task and muscle dependent. When the hands are supported by the Swiss ball (but not the feet) increases in muscle activity can be seen with a greater number of muscles affected.

Competing interests
The author(s) declare that they have no competing interests.

Authors’ contributions
GL: Conception, design, data collection, data analysis, manuscript preparation
RM, IM, MC, MF: design, data collection, manuscript preparation

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Replacing a Swiss ball for an exercise bench causes variable changes in trunk muscle activity during upper limb strength exercises

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Abstract

Background: The addition of Swiss balls to conventional exercise programs has recently been adopted. Swiss balls are an unstable surface which may result in an increased need for force output from trunk muscles to provide adequate spinal stability or balance. The aim of the study was to determine whether the addition of a Swiss ball to upper body strength exercises results in consistent increases in trunk muscle activation levels.

Methods: The myoelectric activity of four trunk muscles was quantified during the performance of upper body resistance exercises while seated on both a stable (exercise bench) and unstable (swiss ball) surface. Participants performed the supine chest press, shoulder press, lateral raise, bicep curl and overhead triceps extension. A repeated measures ANOVA with post-hoc Tukey test was used to determine the influence of seated surface type on muscle activity for each muscle.

Results & Discussion: There was no statistically significant (p < 0.05) difference in muscle activity between surface conditions. However, there was large degree of variability across subjects suggesting that some individuals respond differently to surface stability. These findings suggest that the incorporation of swiss balls instead of an exercise bench into upper body strength training regimes may not be justified based only on the belief that an increase spinal stabilizing musculature activity is inherent. Biomechanically justified ground based exercises have been researched and should form the basis for spinal stability training as preventative and therapeutic exercise training regimes.

Conclusion: Selected trunk muscle activity during certain upper limb strength training exercises is not consistently influenced by the replacement of an exercise bench with a swiss ball.

Background

The use of physioballs/Swiss balls in strength and conditioning programs has become ubiquitous. Swiss balls have been incorporated into strength training regimes and
touted as a means to more effectively train the musculoskeletal system. Performing strength exercises on Swiss balls has been advocated on the belief that a stable surface will provide a greater challenge to the trunk musculature, increase the dynamic balance of the user and possibly train users to stabilize their spines to prevent and treat injury.

Despite a few studies, the research supporting these ideas is sparse. Vera-Garcia et al. [1] documented increases in rectus abdominis and external oblique activity during curl ups when performed on a Swiss ball compared with a stable surface. Mom [2] documented trunk muscle activation levels during a variety of trunk muscle exercises showing that substantial levels of trunk muscle activity occurs. However, because the exercise tasks were not also performed on a stable surface it is unknown how much the Swiss ball’s instability contributed to a demand for muscle activation. Andersen [3] investigated the influence of a Swiss ball on upper limb muscle activation and force production during a chest press. The study found that while muscle activation in the primary movers was not different between surfaces, the amount of force generated was significantly less on a Swiss ball. These results were mirrored in a previous study [4] investigating force and muscle activation of the lower extremity on unstable surfaces.

Swiss balls are currently used to replace stable benches during the performance of upper body strength training exercises. While previous work has documented the myoelectric activity of the trunk muscles during exercises specifically designed to train the trunk muscles, no study has documented the effect of an unstable surface on trunk muscle activity during resistance exercises for the upper limbs. Due to common use of Swiss balls this lack of research is significant for both performance and safety concerns (i.e. Swiss balls may increase the risk of falling without providing an exercise benefit). Adequate spinal stability is important in the prevention and treatment of low back injuries [5]. Stability is achieved through the co-activation of trunk muscles; therefore, endurance training has been postulated to be beneficial in training trunk muscles to provide stability. It is possible that performing upper body strength exercises on a swiss ball can increase trunk muscle activity to a sufficient extent to adequately stress the spinal stabilizing musculature to achieve beneficial endurance training effects. This may render conventional trunk resistance exercises superfluous and increase the efficiency of rehabilitation and prophylactic exercise programs. Contrarily, an elevated muscle activation level may be contraindicated in subjects with low back injury or unstable spines. Co-activation of the trunk muscles has a compressive loading cost that may outweigh the benefits of trunk muscle training. Safe exercises on stable ground have been advocated and thoroughly investigated with a detailed biomechanical model [6] which provide an excellent balance between muscle stress and low compressive shear penalty, the same cannot be argued for the majority of exercises incorporating the use of Swiss balls.

In light of the popularity of Swiss balls and the lack of research investigating their influence on trunk muscle activity during upper limb strength exercises, it was the aim of this study to determine if the use of a Swiss ball instead of an exercise bench results in consistent increases across subjects in trunk muscle activation levels during upper body strength training exercises.

Methods
Participant Characteristics
Seven healthy males (average age (standard deviation) 28 (3.8)) average height in cm (standard deviation) 179.7 (7.13) and average mass in kg 84.6 (8.09) and five females (age = 23.6 (6.3)) height 168.3 cm (5.04) and mass 61 (5.2)) with weight lifting and abdominal exercise experience were recruited from a convenience sample consisting of college students. Subjects currently experiencing low back pain or a history of low back pain within 3 months were excluded from the study. Participants read and signed an information and consent form approved by the institutions Internal Review Board.

Experimental Design
A single factor repeated measures design was used to analyze the effect of trunk muscle activity during common weight training exercises on a Swiss ball compared to the trunk muscle activity found during the performance of the exercises on an exercise bench. All subjects performed 6 different exercises on two different support surfaces for a total of 12 separate movement tasks during a single testing session. The order of the tasks was kept constant with every subject.

Instrumentation
EMG data was collected using disposable bipolar Ag-AgCl disc surface electrodes with a diameter of one cm, adhered bilaterally over the muscle groups with a centre-to-centre spacing of 2 cm. Raw EMG was amplified between 1000 and 20,000 times depending on the subject. The amplifier had a CMRR of 10,000:1 (Bortec EMG, Calgary AB, Canada). Raw EMG was band pass filtered (10 and 1000 Hz) and A/D converted at 2000 Hz using a National Instruments data acquisition system.

Electrode Placement
Skin preparation included shaving (when necessary) and cleansing and abrading the skin with alcohol solution prior to applying the electrodes to reduce skin impedance. Four sites on participants right sides were chosen for electrode placement: (1) rectus abdominus (RA) 3 cm lateral
to the umbilicus. [2] External Oblique (EO) 1.5 cm lateral to the umbilicus oriented in the direction of the muscle fibres (3) Internal oblique (IO) 10 cm lateral to midline (inferior 2 cm) to the ASIS angled superomedial to inferolateral parallel to the underlying muscle fibres and (4) Erector Spinae 2 cm lateral to L4–L5 interspinous space in a superomedial to an inferolateral orientation over the muscle fibers. A reference electrode was placed over the eleventh rib. The investigators may have made slight modifications and adjustments for any anatomical variations between subjects.

Normalization task procedure
Subjects were required to perform maximum voluntary contractions for the trunk musculature. Subjects were required to perform a 3-second maximal supine isometric trunk curl up and bilateral twist against an immovable resistance to maximally recruit the rectus abdominis, external oblique and internal oblique. Subjects performed this movement supine with the spine in neutral. Second, the subjects performed an isometric prone trunk extension against a fixed resistance to maximally recruit the lumbar rectus spine. All subjects performed the normalization tasks in the same order. Participants practiced the exercises before the collection of data. The muscle activity during all subsequent exercise tasks was expressed as a percent of the peak activity found during the normalization procedure. The peak activity was found visually after the signal had been processed in an identical manner to the exercise tasks.

Exercises Performed
Subjects performed six exercise tasks. The six exercises were modified to be performed while seated on the table surface of an exercise ball resulting in a total of 12 separate movement tasks:

1.a Supine abdominal curls on a flat bench with feet flat on floor and folded across chest.

1.b Modified: supine abdominal curl on a Swiss ball with feet flat on floor and Swiss ball positioned under the low back.

2.a Supine dumbbell chest press on a flat bench, with feet flat on floor. Subjects started with weight at chest level and hands shoulder width apart. Subjects pressed weight up until elbows were extended.

2.b Modified: supine chest press on a Swiss ball with feet flat on floor and Swiss ball positioned under the shoulders and thoracic spine.

3.a Seated shoulder press on flat bench with no back support and feet on the floor. Subjects started with weights at shoulder level and pressed up to full elbow extension.

3.b Modified: seated shoulder press on Swiss ball.

4.a Seated lateral shoulder raise on flat bench. The weighted straight arm was abducted to 90 degrees from 0 degrees of abduction.

4.b Modified: seated lateral shoulder raise on a Swiss ball.

5.a Seated two arm biceps curl on flat bench. Subjects started in the anatomical position and flexed the arms bilaterally.

5.b Seated two arm biceps curl on Swiss ball.

6.a Seated double arm overhead triceps extension on a flat bench. Subjects began with their shoulders and elbows fully flexed and the weight behind their head. The elbow was then extended to raise and lower the weight.

6.b Modified: seated double arm overhead triceps extension on a Swiss ball.

Exercises 2–6 were performed with dumbbells. Each subject selected a weight such that they are able to complete 4 repetitions of each task without reaching fatigue. The exercise task saw the subject perform slow controlled concentric contractions followed by eccentric lowering of the weight. This was considered one repetition. Without pause 3 repetitions were repeated during a trial. The same weight was used for both the original and modified versions of each exercise task. The weight varied from 10 – 40 lbs. All six exercises were performed in order from 1 to 6 (a) on a hard flat bench then repeated in the same order on a Swiss ball (1–6b). Two sets occurred for each exercise task. It should be noted that the curl up exercise is performed on the ground and on the Swiss ball does not control for posture, muscle length or other factors which can influence the myoelectric signal. This exercise was mainly included to give the reader a biologically significant reference for the amount of muscle activity occurring during the exercises. An inference of whether a Swiss ball influences muscle activity during a curl up can not be made due the significant differences in posture. For the other exercises studied a neutral lumbar curve could be maintained through out either condition.

Description of Exercise Movement
After being instrumented, subjects performed the normalization tasks and then the 12 movement tasks. The subjects were instructed to perform the concentric phase for 2
seconds and the eccentric phase for 4 seconds (under the count and supervision of two examiners). Data was collected for 25 seconds during each exercise.

**EMG Processing**
The raw myoelectric signal of all trials for both the MVCs and the exercise tasks was processed identically. A linear envelop was calculated by first full wave rectifying (the absolute value of each data point) and then smoothing using a 100 ms moving average with a 50 ms overlap. The average activity over the course of the movement was then calculated for each trial and expressed as a percentage of the activity found during the MVC for each specific muscle and participant.

**Statistical Analysis**
A repeated measures ANOVA was then used to determine if a difference in type of supporting surface influenced trunk muscle activity for each muscle. A post hoc Tukey test was used to examine if statistically significant (p < .05) differences exist in trunk muscle activity for the different exercises performed.

**Qualitative Analysis**
The difference in muscle activity (expressed as a %MVC) was also calculated for each subject (12), muscle (4) and exercise (6) between the two surface conditions for a total of 240 differences in muscle activity. A change greater than 5% MVC was considered significant. The number of occurrences of a significant increase or decrease in muscle activity was recorded.

**Results**
There was no significant difference found between performing each of the six exercises on the Swiss ball and the flat bench for any of the four muscle groups investigated. Tables one to six detail the average muscle activity for each muscle group during the six different exercises studied. Twenty-six muscles showed significant increases in muscle activity and 22 muscles showed a significant decrease in muscle activity across all conditions.

While there was not a statistically significant increase in any muscle studied, the internal oblique muscle tended to have the greatest number of increases in muscle activity when on the Swiss ball compared with the bench. The grouped average internal oblique muscle activity difference between the two conditions tended to be greater than 5% MVC during the cut up, bench press and shoulder press. The bench press exercise showed a trend for muscles to increase their myoelectric signal on the Swiss ball (14 occurrences), while there were only two instances when a muscle's activity decreased more than 5% MVC.

Absolute increases of greater than 11% MVC were seen in the internal oblique in three subjects when performing the bench press on a Swiss ball compared with performing the bench press on the more stable bench. One subject's average activity was approximately 3% MVC on the bench and increased to more than 17% MVC when on the Swiss ball. In the biceps curl exercise had 6 occurrences of trunk muscles increasing their activity on the Swiss ball while the triceps extension had only one incidence of an increase in muscle activity yet seven occurrences where the average muscle activity decreased more than 5% MVC. The lateral raise exercise showed no trends with only 3 instances of activity increases and 3 instances where muscle activity decreased for all muscles studied. While the shoulder press showed a trend of increased internal oblique activity on the Swiss ball (average absolute difference of 6.52% MVC) there was only 2 instances where any trunk muscle increased its activity on the Swiss ball more than 5% MVC and 5 instances of a muscle showing a decrease in activity of more than 5% MVC.

**Discussion**
Replacing an exercise bench with a Swiss ball is not a guarantee for increased trunk muscle activation during upper body strength exercises. There does not appear to be a consistent, generalized response to the addition of a Swiss ball. Statistically, there is no difference between conditions; however, the study population showed large variability. This suggests that individuals respond differently to unstable surfaces. Health and fitness professionals who advocate the addition of Swiss balls into exercise programs for the upper limbs can not support this change via the argument that the spinal musculature system is stressed to a greater extent (i.e. increased muscle activity) for all individuals. Importantly, this study does not dismiss the use of Swiss balls for exercises designed to train the trunk muscles. Increases in trunk muscle activity have been documented for these exercises [1] but a general increase in trunk muscle activity was not seen for the upper-limb strength exercises studied in the current study. The study's findings also suggest that performing upper-limb strength exercises on a Swiss ball does not cause excessive compressive loading due to increased trunk muscle co-activation and therefore may be safe for the low back injured. Changes in compressive or shear loading may be different due to postural factors but this was not measured in the presented study. What needs to be questioned is what benefit exists in performing upper-limb strength exercises on a Swiss ball. An injury risk may still be present because Swiss balls are unstable and may increase the risk of falling and subsequent injury. If the justification is to 'train the core' (i.e. recruit agonist-antagonist trunk muscles) then this can't be supported by the results of this study. If other justifications are made (increases in balancing ability, recruitment of secondary
hip and leg muscles) then this exercise modification may be reasonable. To minimize injury risk, like any exercise program, exercise difficulty progression should be used in incorporating Swiss balls into an exercise program. Participants who wish to use a Swiss ball in their exercise program should learn the basic upper body strength moves on a stable surface first.

Advocating the use of the Swiss ball in exercise or rehabilitation programs may be justified via other benefits. A recent study has documented short-term gains in one-legged stance following an exercise program of abdominal curl ups and trunk extensions on a Swiss ball [7]. Swiss balls are often more portable and affordable than a traditional weight bench and may therefore increase exercise compliance and adoption. Anecdotally, Swiss ball classes are popular and enjoyable.

Exercise prescription should be goal dependent. If a therapist merely wants variety in an exercise program and

Table 1: Abdominal curl up exercise muscle activation levels (% MVC, standard deviation in brackets), average difference between surfaces and number of participants whose change in activity was greater than 5% MVC during

<table>
<thead>
<tr>
<th>Surface</th>
<th>Muscles studied during abdominal curl up exercise</th>
<th>Rectus Abdominis</th>
<th>External Oblique</th>
<th>Internal Oblique</th>
<th>Erector Spinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball</td>
<td></td>
<td>29.0 (31.1)</td>
<td>21.2 (20.6)</td>
<td>32.9 (27.6)</td>
<td>1.2 (1.5)</td>
</tr>
<tr>
<td>Bench</td>
<td></td>
<td>25.7 (16.6)</td>
<td>21.1 (13.4)</td>
<td>27.1 (16.4)</td>
<td>6.2 (16.8)</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td>3.36 (20.6)</td>
<td>2.17 (11.65)</td>
<td>5.82 (18.2)</td>
<td>3 (7.61)</td>
</tr>
<tr>
<td>Increase</td>
<td></td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Decrease</td>
<td></td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2: Bench Press Exercise muscle activation levels (% MVC, standard deviation in brackets), average difference between surfaces and number of participants whose change in activity was greater than 5% MVC.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Muscles studied during bench press exercise</th>
<th>Rectus Abdominis</th>
<th>External Oblique</th>
<th>Internal Oblique</th>
<th>Erector Spinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball</td>
<td></td>
<td>7.4 (6.3)</td>
<td>5.7 (6.8)</td>
<td>13.5 (9.2)</td>
<td>6.06 (5.9)</td>
</tr>
<tr>
<td>Bench</td>
<td></td>
<td>4.7 (6.2)</td>
<td>3.1 (2.8)</td>
<td>8.2 (6.8)</td>
<td>3.1 (1.6)</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td>2.68 (6.49)</td>
<td>2.52 (4.7)</td>
<td>5.2 (6.26)</td>
<td>2.93 (5.9)</td>
</tr>
<tr>
<td>Increase</td>
<td></td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Decrease</td>
<td></td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 3: Biceps Curl Exercise muscle activation levels (% MVC, standard deviation in brackets), average difference between surfaces and number of participants whose change in activity was greater than 5% MVC.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Muscles studied during biceps curl exercise</th>
<th>Rectus Abdominis</th>
<th>External Oblique</th>
<th>Internal Oblique</th>
<th>Erector Spinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball</td>
<td></td>
<td>5.0 (5.6)</td>
<td>3.0 (4.4)</td>
<td>9.0 (6.4)</td>
<td>8.7 (7.4)</td>
</tr>
<tr>
<td>Bench</td>
<td></td>
<td>4.2 (5.7)</td>
<td>2.2 (1.9)</td>
<td>6.9 (6.0)</td>
<td>6.5 (6.3)</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td>.63 (2.65)</td>
<td>74 (2.84)</td>
<td>2.14 (5.79)</td>
<td>2.23 (4.67)</td>
</tr>
<tr>
<td>Increase</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Decrease</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 4: Lateral raise exercise muscle activation levels (% MVC, standard deviation in brackets) average difference between surfaces and number of participants whose change in activity was greater than 5% MVC.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Muscles studied</th>
<th>Rectus Abdominis</th>
<th>External Oblique</th>
<th>Internal Oblique</th>
<th>Erector Spinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball</td>
<td>5.2 (6.3)</td>
<td>3.0 (3.3)</td>
<td>7.8 (7.6)</td>
<td>3.6 (3.0)</td>
<td></td>
</tr>
<tr>
<td>Beach</td>
<td>5.3 (8.5)</td>
<td>2.0 (1.9)</td>
<td>6.5 (6.1)</td>
<td>4.6 (4.2)</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-0.7 (2.1)</td>
<td>0.9 (2)</td>
<td>1.2 (1.97)</td>
<td>-1.4 (2.6)</td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Shoulder press exercise muscle activation levels (% MVC, standard deviation in brackets) average difference between surfaces and number of participants whose change in activity was greater than 5% MVC.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Muscles studied</th>
<th>Rectus Abdominis</th>
<th>External Oblique</th>
<th>Internal Oblique</th>
<th>Erector Spinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball</td>
<td>6.0 (6.29)</td>
<td>4.1 (3.4)</td>
<td>21.7 (31.5)</td>
<td>3.7 (3.3)</td>
<td></td>
</tr>
<tr>
<td>Beach</td>
<td>6.9 (5.6)</td>
<td>3.5 (3.6)</td>
<td>15.2 (15.2)</td>
<td>12.4 (20.3)</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-0.9 (4.29)</td>
<td>0.6 (2.59)</td>
<td>6.52 (30.23)</td>
<td>-1.07 (4.62)</td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Triceps extension exercise muscle activation levels (% MVC, standard deviation in brackets) average difference between surfaces and number of participants whose change in activity was greater than 5% MVC.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Muscles studied</th>
<th>Rectus Abdominis</th>
<th>External Oblique</th>
<th>Internal Oblique</th>
<th>Erector Spinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball</td>
<td>4.3 (3.6)</td>
<td>3.7 (4.3)</td>
<td>13.5 (12.5)</td>
<td>3.4 (3.3)</td>
<td></td>
</tr>
<tr>
<td>Beach</td>
<td>9.8 (16.6)</td>
<td>4.3 (4.9)</td>
<td>16.3 (16.5)</td>
<td>2.1 (2.6)</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-5.51 (14.04)</td>
<td>0.7 (1.91)</td>
<td>2.76 (5.8)</td>
<td>3.1 (3.42)</td>
<td></td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Increased exercise compliance and enjoyment then the adoption of a Swiss ball appears reasonable but not justified biomechanically. If the aim of a therapist is to rehabilitate or prevent low back injury then sound biomechanically justified or clinically proven rehabilitation protocols should be advocated. Kovac et al [6] provides biomechanical support for ground based simple exercises (curl up, side bridge, four point kneeling with leg extension) to adequately train the spinal stabilizers while minimizing the compressive/shear penalty and ensuring adequate spinal stability.

This study is limited to the exercises investigated and weights used. For many of the exercises the weight was not near the maximum load the participant could use. The weight levels were chosen based on the rationale that the same low weight is used during "FitBall" classes geared toward a novice exerciser. Challenging each subject with a greater load may influence trunk muscle activity. Future...
work should address this limitation. Additionally, only surface electromyographic activity was recorded. The muscles studied are considered global stability muscles and may not adequately represent the muscle activation levels in smaller intersegmental spinal muscles. These muscles have a greater proprioceptive function and if the Swiss ball stresses these muscles to a greater extent this may form the basis for an improved balance effect following training. As well, no measures of range of motion occurred. It is possible that different ranges of motion were seen which would alter the myoelectric signal amplitude without a change in force production due to the length tension properties of muscle. Conversely, more advantageous postures would allow greater force production and hence spinal stability without changes in muscle activity. This study is also limited to conclusions regarding the stability of the surface examined. Other labile surfaces (wobble boards) may result in differences in trunk muscle activity recruitment. These results can not be generalized to all unstable surfaces and all training exercises.

Conclusion
A consistent generalized trend was not seen across subjects (subjects did not uniformly increase trunk muscle activity) when replacing an exercise bench with a Swiss ball during upper limb strength exercises. Individual responses were variable. This suggests that participants respond differently to surface stability modifications.

Competing interests
The author(s) declare that they have no competing interests.

Authors’ contributions
GL: Conception, design, data collection, data analysis, manuscript preparation
TG, JL, PP, ST: design, data collection, manuscript preparation

References