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NO DIFFERENCE IN 1RM STRENGTH AND MUSCLE ACTIVATION DURING THE BARBELL CHEST PRESS ON A STABLE AND UNSTABLE SURFACE

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ABSTRACT
Exercise or Swiss balls are increasingly being used with conventional resistance exercises. There is little evidence supporting the efficacy of this approach compared to traditional resistance training on a stable surface. Previous studies have shown that force output may be reduced with no change in muscle electromyography (EMG) activity while others have shown increased muscle EMG activity when performing resistance exercises on an unstable surface. This study compared 1RM strength, and upper body and trunk muscle EMG activity during the barbell chest press exercise on a stable (flat bench) and unstable surface (exercise ball). After familiarization, 13 subjects underwent testing for 1RM strength for the barbell chest press on both a stable bench and an exercise ball, each separated by at least 7 days. Surface EMG was recorded for 5 upper body muscles and one trunk muscle from which average root mean square of the muscle activity was calculated for the whole 1RM lift and the concentric and eccentric phases. Elbow angle during each lift was recorded to examine any range-of-motion differences between the two surfaces. The results show that there was no difference in 1RM strength or muscle EMG activity for the stable and unstable surfaces. In addition, there was no difference in elbow range-of-motion between the two surfaces. Taken together, these results indicate that there is no reduction in 1RM strength or any differences in muscle EMG activity for the barbell chest press exercise on an unstable exercise ball when compared to a stable flat surface. Moreover, these results do not support the notion that resistance exercises performed on an exercise ball are more efficacious than traditional stable exercises.

KEY WORDS strength training, chest press, bench press, 1RM strength, EMG, instability

INTRODUCTION
One of the more recent trends to emerge in the strength and conditioning, rehabilitation, and fitness fields is the replacement of stable surfaces with labile surfaces such as wobble boards, foam rollers, and exercise or Swiss balls. The premise for this approach is that an increase in instability will overload the neuromuscular system to a greater extent than traditional training methods (3). To date, there is little evidence supporting the efficacy of performing strength exercises on unstable surfaces compared to conventional stable surfaces (12).

Two studies have examined differences in muscle strength and muscle activation using the popular resistance exercise, the chest press. Anderson and Behm (1), in the first study to investigate an upper body force production and muscle activation on a exercise ball, reported a ~60% decrease in force output during a maximal voluntary isometric chest press, despite no difference in surface electromyography (EMG) activity, when compared with the same exercise on a stable surface. The authors speculated that the unstable surface might have increased the demand on stabilizer muscles, thus reducing the net force output whilst maintaining muscle EMG activity of the prime movers (1). More recently, Marshall and Murphy (11) compared the muscle EMG activity during a submaximal dynamic (eccentric and concentric) chest press exercise on an exercise ball and a stable bench using dumbbells with the same absolute load (equivalent to 60% of the 1RM determined on a stable bench). In this study, it was shown that the dumbbell chest press on the exercise ball elicited greater EMG activity in the anterior deltoid, transverse abdominus/internal oblique and rectus abdominus muscles than on the stable bench. If maximum force producing capability is indeed reduced on an unstable surface, as reported by Behm et al. (1,4), then the load determined on the stable surface in the study of Marshall and Murphy (11) will represent a greater relative load when used on the exercise ball, thus causing greater surface EMG activity.
To date, there are no studies comparing upper body and trunk muscle EMG activity during the chest press exercise on a stable and unstable surface whilst utilizing the same relative intensity. In addition, there are no studies examining differences in maximal dynamic muscle strength on a stable and unstable surface. Thus, the purpose of this study was to evaluate the differences in (i) chest press maximal dynamic force production (as indicated by 1RM strength) and (ii) in muscle activation during the chest press exercise at the same relative intensity between a stable (flat bench) and unstable surface (exercise ball).

The hypotheses of this study were, as in the study of Anderson and Behm (1), that (i) 1RM strength would be lower and (ii) that muscle surface EMG activity would be the same on the unstable exercise ball compared to the stable bench.

METHODS

Experimental Approach to the Problem
To examine differences in muscle strength and activation between a stable and unstable surface, a within-subject crossover design was used. The barbell (BB) chest press one repetition maximum (1RM) was evaluated on both the stable flat bench and the unstable exercise ball. Surface electromyographic (EMG) activity was recorded during the 1RM tests.

Subjects
Thirteen healthy, recreationally-active subjects (10 male and 3 females, aged 24.1 ± 1.6 yrs; height, 176.7 ± 3.0 cm; weight, 76.0 ± 3.9 kg) volunteered for this study. None of these subjects were competitive lifters (i.e., powerlifters, weightlifters, bodybuilders). Prior to the study, subjects were informed of all testing procedures, possible associated risks and written consent was obtained. Subjects were screened and excluded from the study if they had less than 6 months recent resistance training experience or had a previous shoulder injury. All experimental procedures were approved by the Victoria University Human Research Ethics Committee. Subjects were instructed to refrain from any additional resistance training exercises that targeted the chest, shoulders, and/or upper arm muscle groups.

Procedures
Familiarization and Reliability. Approximately, 2 weeks prior to 1RM testing, subjects underwent a familiarization session where they were instructed on the correct technique for performing the chest press on both the bench and ball. The chest press exercise was performed on an anti-burst exercise ball (55 cm or 65 cm; Australian Barbell Co., Melbourne, Australia) or a standard flat bench press (Australian Barbell Co., Melbourne, Australia). On the exercise ball, each subject assumed a position where the upper shoulders, neck and head were supported on the ball, feet approximately shoulder width apart, and the thighs, hips and torso parallel with the floor (7,8) (Figure 1A). On the stable bench press, each subject’s hips, shoulders, neck and head were supported by the bench, with feet on the floor and approximately shoulder width apart (Figure 1B). Each subject’s preferred grip width was measured and recorded during familiarization on the stable bench press. This width was then used on all subsequent 1RM attempts on both the stable bench and unstable ball. The barbell used was 192 cm long with a diameter of 2.8 cm (Australian Barbell Co., Melbourne, Australia). During the familiarization sessions, each subject performed the exercise on both surfaces with increasing resistance up to approximately 90–95% of their perceived 1RM.

To assess the reliability in the 1RM test, subjects performed an initial 1RM test on both the bench and ball, each separated by 7 days. The order in which the tests were performed was alternated such that if the first subject performed the stable
bench 1RM and the exercise ball 1RM second, the next subject performed these tests in the reverse order. These 1RM values were then compared to a second 1RM test (see below).

**1RM Testing.** Approximately one week after the previous 1RM reliability tests, subjects underwent a second 1RM test on each surface, with muscle surface EMG activity recorded. Prior to each 1RM test, a 5 minute warm-up on an exercise bike at 60 rpm was performed followed by two warm-up sets: 1) 8 repetitions at approx. 50% of the 1RM, 2) 4 repetitions at approx. 70% of 1RM. Next, single attempts with increasingly heavier resistance of at least 1 kg were performed until the heaviest weight that could be lifted once with correct technique was determined. A 3-minute rest period was given between each lift. The 1RM was achieved within 3–6 attempts. For safety, two spotters were present at all times. Correct technique involved lowering the bar in a controlled manner until the bar lightly touched the chest then lifting the bar back to the start position with elbows fully extended. Careful attention was paid in making sure the bar was not bounced off the chest, especially on the exercise ball. The tempo of each 1RM attempt was not controlled such that as long as good technique was adhered to, subjects could take as long as required to complete the lift.

**EMG Recording.** Pairs of self-adhesive electrodes (10 mm Bio-Tac #7605 Tyco Health Care Group, Gosport, UK) were positioned according to the recommendations of Kasman et al. (9). For each subject, electrode placement was closely monitored with distances from bony landmarks, boundaries, and other prominences recorded to maintain consistency. Electrodes (2 cm contact diameter) were aligned parallel to the muscle fibers with a center-to-center distance of 3.5 cm. EMG signals were recorded from 6 locations: the sternal portion of pectoralis major (PM), the mid-belly of anterior deltoid (AD), the latissimus dorsi (LD; inferior of scapula), the external oblique (EO), the triceps brachii (TB) and biceps brachii (BB). The reference electrode was placed on the lateral epicondyle of the humerus. All electrodes were placed on the right hand side of the body.

Prior to electrode placement, the skin was prepared by shaving to remove any hair, abrading the skin with a coarse nylon pad to remove dead epithelial cells and cleaning the site with alcohol (10). Each electrode’s resistance was checked with its corresponding electrode and the reference electrode. If the electrode resistance was greater than 10 kΩ, the skin preparation procedure was repeated.

**EMG Signal Processing.** EMG signals were recorded using a telemetered EMG transmitter (Noraxon OY Telemoyo, Cologne, Germany) and receiver (RTFA-208 Noraxon, Cologne, Germany). The EMG signal response was restricted to 10–430 Hz by the inherent bandwidth limitations within the telemetry system (6 pole Butterworth band pass filters). The maximum allowable EMG signal amplitude was limited to +/− 10 mV. Custom menu driven data acquisition and analysis software was written for the application using National Instruments (Austin, TX) Labview version 8.0 (Victoria University Performance Technologies). Data from all channels were acquired at rate of 2000Hz, amplified (×1000) and subsequently stored on a PC hard disk. Raw EMG data was processed according to the method of Behm and colleagues (1,2,5). Briefly, the raw EMG data was smoothed for 10 samples and the average root mean square (RMS) value calculated.

**Measurement of Range of Motion During 1RM Tests.** To determine whether there were any differences in the range of motion (ROM) during the stable bench press and exercise ball press that could explain any differences in 1RM strength or muscle activation, a single axis goniometer (Biometrics, Ladysmith, Va.) was used to record the elbow angle throughout each 1RM strength test. The goniometer was attached to the inside of the subject’s elbow joint using double-sided tape with additional tape used to further secure the end pieces to the skin. The goniometer was zeroed with the elbow in full extension (i.e., 0° represents beginning of the eccentric phase). The goniometer data was recorded and displayed on a PC screen together with the EMG recording, thus allowing the elbow angle to be matched to the EMG signal. This combined data allowed the determination of the start and end of each repetition, the change from the eccentric phase to the concentric phase, and the durations (secs) of the Ecc and Con phases (see lowest panel in Figure 2).

**Statistical Analyses.** GraphPad Prism was used for all statistical analyses except for the intraclass correlation (ICC), which was performed using SPSS. All results are presented as mean ± SEM, with n indicating the number of subjects in each group. For comparison between two groups, two-tailed paired Student’s t-tests were used. Repeated measures one-way analysis of variance (ANOVA) with Bonferroni’s posttest was used for multiple group comparisons. Significance was set at P ≤ 0.05. Results are presented as Mean ± SEM.

**Results.** Figure 2 shows the raw EMG traces for each muscle examined and changes in elbow angle relative to time during a 1RM test performed on a stable bench.

**1RM Strength.** The mean variability in 1RM strength tests for both surfaces, conducted on separate days approximately one week apart, was 0.96 ± 0.17 kg or 1.3 % for the stable chest press and 0.21 ± 0.33 kg or 0.1 % for the unstable ball chest press. An ICC of 0.997 was found for the two stable chest press and the two unstable chest press 1RM tests.

There was no significant difference (P = 0.68) in 1RM strength between the stable (73.4 ± 6.5 kg) and unstable ball press (73.0 ± 6.8 kg). The individual 1RM for each subject on both surfaces are shown in Figure 3.
this study did not support our first hypothesis that, as previously demonstrated by Behm & colleagues (1), force production on the unstable surface would be lower on the stable surface. Our results did, however, support our second hypothesis that muscle activation, as indicated by surface EMG activity, would be the same for the stable and unstable surface if the same relative intensity were used. In this study there were no differences in grip width, elbow ROM or the duration of the total lift or the eccentric and concentric phases, between 1RM lifts on the stable or unstable surfaces. We can not rule out, however, that the bar path could have been different between the two surfaces. Also, the day-to-day variation in 1RM values for each surface was very small (<1.5%; ICC 0.997) indicating that the 1RM tests were reliable and thus no learning effect took place.

It is important to note that there were no falls or injuries sustained during any 1RM test conducted for this study. Thus, provided that athletes or clients have reasonable chest press experience (>6 months), are given the appropriate familiarisation and spots are utilized, maximal strength testing on an exercise ball is a feasible and relatively safe procedure.

Anderson and Behm (1) were the first to report that, despite no difference in muscle EMG activity, the development of force was impaired when performing a maximal isometric chest press on an exercise ball compared to a stable surface. The authors reasoned that net force might be reduced because both the prime mover and stabilizer muscles had an increased stabilization function. In the current study, we found no difference in 1RM chest press between the exercise ball and flat stable bench. The reason for the disparity between these two studies is unclear. An obvious difference between the two studies is that we utilized dynamic contractions with a loaded barbell while the study of Anderson and Behm (1) used isometric contractions with two independent handles attached, via straps, to force transducers on the floor. Although bilateral contractions were performed in both studies, the independence of each hand in the study of Anderson and Behm (1) may have increased the effort required to maintain equilibrium and the requirement of muscles to stabilize during the maximal isometric contractions, thus reducing net force output. The use of a longer (Olympic style) barbell in the current may also have provoked greater perturbations in balance. An additional difference could be the posture adopted during the performance on the maximal contractions. The paper of Anderson and Behm (1) describes subjects on the stable surface as having their shoulders, head, and neck supported on the bench whereas when the subjects were on the exercise ball, their head and neck were not supported. In the current study, each subject’s head and neck were supported on both the bench and ball (see Methods) as is often prescribed the exercise ball literature (7,8). In the study of Anderson & Behm (1), significant effort, in the form of an isometric ventroflexion of the neck, would be required to keep the head and neck in a neutral position whilst performing the maximal

**Figure 3.** The individual 1RM values for each subject on both the stable and unstable surface.

**Range of Motion**

There was no significant difference ($P = 0.08$) in the depth to which the BB was lowered (i.e. the angle of the elbow at the end of the eccentric phase) during the 1RM tests on either the bench or ball ($101.3 \pm 3.6^\circ$ vs $105.7 \pm 2.0^\circ$, respectively).

**Duration of the 1RM Lift**

There was no significant difference in the total duration ($5.35 \pm 0.47$ vs $5.01 \pm 0.37$ sec; $P = 0.58$), nor the eccentric ($1.64 \pm 0.21$ vs $1.86 \pm 0.20$ sec; $P = 0.55$) or concentric ($3.71 \pm 0.33$ vs $3.15 \pm 0.29$ sec; $P = 0.11$) phases of the 1RM test on either stable or unstable surface, respectively.

**EMG Activity**

There was no significant difference in the RMS EMG activity within the same muscle during the eccentric or concentric phase of the 1RM test between the stable bench and unstable ball (see Table 1). When the concentric RMS EMG values were made relative to the eccentric values it was found that there was greater EMG activity on the concentric phase for all muscles, regardless of surface, with the exception of LD on the ball and BB on both the bench and ball (see Table 2). There were no significant differences in agonist antagonist ratios (i.e. PM/LD, AD/LD, or TB/BB) for the total 1RM or for the individual eccentric and concentric phases (data not shown).

**Discussion**

This is the first study to investigate maximal dynamic contractions performed on the exercise ball. The results of
Table 1. Average root mean square (RMS) electromyographic (EMG) activity (mV) during the concentric and eccentric phases of the 1 repetition maximum (1RM) chest press on the stable bench and unstable ball (Mean ± SEM).

<table>
<thead>
<tr>
<th>Muscle*</th>
<th>Stable bench Eccentric</th>
<th></th>
<th>Stable bench Concentric</th>
<th></th>
<th>Unstable ball Eccentric</th>
<th></th>
<th>Unstable ball Concentric</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM</td>
<td>0.15 ± 0.02</td>
<td></td>
<td>0.22 ± 0.03</td>
<td></td>
<td>0.14 ± 0.02</td>
<td></td>
<td>0.22 ± 0.03</td>
</tr>
<tr>
<td>AD</td>
<td>0.28 ± 0.03</td>
<td></td>
<td>0.39 ± 0.04</td>
<td></td>
<td>0.28 ± 0.02</td>
<td></td>
<td>0.41 ± 0.04</td>
</tr>
<tr>
<td>LD</td>
<td>0.02 ± 0.00</td>
<td></td>
<td>0.05 ± 0.02</td>
<td></td>
<td>0.03 ± 0.01</td>
<td></td>
<td>0.06 ± 0.01</td>
</tr>
<tr>
<td>EO</td>
<td>0.03 ± 0.00</td>
<td></td>
<td>0.08 ± 0.02</td>
<td></td>
<td>0.02 ± 0.00</td>
<td></td>
<td>0.06 ± 0.01</td>
</tr>
<tr>
<td>TB</td>
<td>0.13 ± 0.02</td>
<td></td>
<td>0.20 ± 0.03</td>
<td></td>
<td>0.13 ± 0.02</td>
<td></td>
<td>0.18 ± 0.03</td>
</tr>
<tr>
<td>BB</td>
<td>0.21 ± 0.03</td>
<td></td>
<td>0.15 ± 0.03</td>
<td></td>
<td>0.20 ± 0.03</td>
<td></td>
<td>0.14 ± 0.02</td>
</tr>
</tbody>
</table>

*PM = pectoralis major; AD = anterior deltoid; LD = latissimus dorsi; EO = external oblique; TB = triceps brachii; BB = biceps brachii.

Isometric contraction, potentially invoking the tonic neck reflex (6). Berger and Smith (6) have shown that active ventroflexion reduces power output during the bench press exercise. Thus, in the study of Anderson and Behm (1), it is possible that the tonic neck reflex, in addition to the instability created by the independent handles and the exercise ball, combined to reduce maximal isometric force. In the study of Marshall and Murphy (11), the head and neck (above spinal level C7) of subjects were not supported on both the stable bench and exercise ball thus eliminating this variable. Further research into the effect of different postures adopted during resistance exercises on the exercise ball is required.

In order to make an appropriate comparison of muscle activation during a given movement under different conditions, it is important to use the same relative loading or intensity. Our study has shown that there was no difference in muscle EMG activity between the chest press performed on the stable bench and unstable ball with the same relative intensity (100% 1RM). This is in contrast to the recent study of Marshall and Murphy (11) that reported greater EMG activity in the anterior deltoid, rectus abdominus and transverse abdominus/internal oblique during the exercise ball dumbbell chest press compared to a stable bench, indicating a greater requirement for shoulder and trunk stabilization on the unstable surface. However, the authors note that the resistance used on the exercise ball was equivalent to 60% of the 1RM determined on the stable bench. Thus, if the instability of the exercise ball does contribute to a reduction in force production, then this resistance (60% of stable bench 1RM) would represent a higher relative intensity on the exercise ball. As acknowledged by the authors, this could, at least in part, explain the greater muscle activation on the exercise ball. A potential limitation of the current study is that only one abdominal muscle was examined for EMG activity. Thus, it is possible that during the 1RM chest press on the exercise ball that other abdominal muscles (rectus abdominust internal oblique/transverse abdominus) were activated to a greater extent than on the stable surface.

Table 2. Relative concentric root mean square (RMS) electromyographic (EMG) activity during the 1 repetition maximum (1RM) chest press on the stable bench and unstable ball. Concentric RMS EMG expressed as percentage of eccentric RMS EMG (Mean ± SEM).

<table>
<thead>
<tr>
<th>Muscle*</th>
<th>Stable bench Eccentric</th>
<th></th>
<th>Stable bench Concentric</th>
<th></th>
<th>Unstable ball Eccentric</th>
<th></th>
<th>Unstable ball Concentric</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM</td>
<td>100 ± 0.00</td>
<td></td>
<td>157.6 ± 16.9*</td>
<td></td>
<td>100 ± 0.00</td>
<td></td>
<td>158.1 ± 9.7*</td>
</tr>
<tr>
<td>AD</td>
<td>100 ± 0.00</td>
<td></td>
<td>154.9 ± 19.3*</td>
<td></td>
<td>100 ± 0.00</td>
<td></td>
<td>152.9 ± 11.5*</td>
</tr>
<tr>
<td>LD</td>
<td>100 ± 0.00</td>
<td></td>
<td>194.2 ± 43.4*</td>
<td></td>
<td>100 ± 0.00</td>
<td></td>
<td>183.3 ± 16.9</td>
</tr>
<tr>
<td>EO</td>
<td>100 ± 0.00</td>
<td></td>
<td>261.7 ± 53.8*</td>
<td></td>
<td>100 ± 0.00</td>
<td></td>
<td>314.7 ± 48.7#</td>
</tr>
<tr>
<td>TB</td>
<td>100 ± 0.00</td>
<td></td>
<td>157.1 ± 8.4*</td>
<td></td>
<td>100 ± 0.00</td>
<td></td>
<td>148.3 ± 7.7*</td>
</tr>
<tr>
<td>BB</td>
<td>100 ± 0.00</td>
<td></td>
<td>83.7 ± 18.2</td>
<td></td>
<td>100 ± 0.00</td>
<td></td>
<td>86.2 ± 13.7</td>
</tr>
</tbody>
</table>

*PM = pectoralis major; AD = anterior deltoid; LD = latissimus dorsi; EO = external oblique; TB = triceps brachii; BB = biceps brachii;
* = significantly different from Eccentric.
In agreement with the studies of Anderson and Behm (1) and Marshall and Murphy (11) we found evidence of a contraction-type effect on both surfaces. With the exception of BB, all other muscles examined had greater EMG activity during the concentric compared to the eccentric phase. Although not statistically significant, BB EMG activity tended to be higher during the eccentric phase (Figure 2). Thus, BB (most likely the long head) may play a role in stabilizing the glenohumeral joint during the eccentric phase of the chest press movement with maximal loading.

**Practical Applications**

The current study demonstrates the relative safety of performing a 1RM chest press movement on an exercise ball. Our results show that there are no differences in force output or muscle activation during a barbell 1RM chest press on an exercise ball or stable bench. These findings raise the question as to whether there is any additional benefit to performing the chest press exercise on an unstable surface compared to the traditional stable bench. It should be noted that if coaches/trainers choose to incorporate the exercise ball chest press into a training program, at least they can do so without the fear that it will result in a reduction in the training stimulus. More research is required to examine the effect of equivalent relative intensities when using dumbbells (unilaterally or bilaterally) and to study the effect of adopting different postures (i.e. head and neck supported or not supported) while performing strength exercises on the ball.

**Acknowledgments**

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**References**


