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# MUSCLE ACTIVATION PATTERNS WHILE LIFTING STABLE AND UNSTABLE LOADS ON STABLE AND UNSTABLE SURFACES

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## ABSTRACT

Kohler, JM, Flanagan, SP, and Whiting, WC. Muscle activation patterns while lifting stable and unstable loads on stable and unstable surfaces. *J Strength Cond Res* 24(2): 313–321, 2010—In an attempt to mimic everyday activities that are performed in 3-dimensional environments, exercise programs have been designed to integrate training of the trunk muscles with training of the extremities. Many believe that the most effective way to recruit the core stabilizing muscles is to execute traditional exercise movements on unstable surfaces. However, physical activity is rarely performed with a stable load on an unstable surface; usually, the surface is stable, and the external resistance is not. The purpose of this study was to evaluate muscle activity of the prime movers and core stabilizers while lifting stable and unstable loads on stable and unstable surfaces during the seated overhead shoulder press exercise. Thirty resistance-trained subjects performed the shoulder press exercise for 3 sets of 3 repetitions under 2 load (barbell and dumbbell) and 2 surface (exercise bench and Swiss ball) conditions at a 10 repetition maximum relative intensity. Surface electromyography (EMG) measured muscle activity for 8 muscles (anterior deltoid, middle deltoid, trapezius, triceps brachii, rectus abdominis, external obliques, and upper and lower erector spinae). The average root mean square of the EMG signal was calculated for each condition. The results showed that as the instability of the exercise condition increased, the external load decreased. Triceps activation increased with external resistance, where the barbell/bench condition had the greatest EMG

activation and the dumbbell/Swiss ball condition had the least. The upper erector spinae had greater muscle activation when performing the barbell presses on the Swiss ball vs. the bench. The findings provide little support for training with a lighter load using unstable loads or unstable surfaces.

**KEY WORDS** core strength, instability training, electromyography, muscle activity, resistance training

## INTRODUCTION

In the past decade, there has been a shift toward functional training and away from the traditional weight training approach. Functional training is done through natural movements and multiple planes and may lead to better muscular balance and joint stability (21). One tenet of functional training is core training, which has grown considerably popular throughout the health and fitness industry in recent years (20). Realizing that muscles do not operate in isolation during sport and everyday activities, exercise regimens have been designed to integrate training of the trunk muscles with training of the extremities. Many believe that the most effective way to execute this integrated training is to perform traditional exercise movements on unstable surfaces, but scientific evidence has yet to conclusively substantiate this concept.

Instability training is considered beneficial as a rehabilitation tool (2). Previous studies have shown that an equivalent level of muscle activation can occur using less resistance, while stressing trunk and joint stabilizers during exercise (3). This is important for individuals recovering from injury, where resistance passes through an injured muscle or joint system. Training with reduced loads on an unstable surface could place less compressive forces on the body segments and therefore result in less stress during rehabilitation (3). Physical therapists have recognized this advantage of instability training and use this training style to help restore function (20), but its practicality in healthy populations is unsubstantiated.

One drawback with training on unstable surfaces is that several studies have found decreases in force production of the prime movers (3,5,17). Integrating a balance factor into a strength training program may not provide an adequate

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The research was partially supported by the Office of Graduate Studies and International Programs at the California State University, Northridge, CA.

The results of the present study do not constitute endorsement of the use of Swiss balls by the authors or the National Strength and Conditioning Association.

There is no conflict of interest regarding the information provided in this study.

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24(2)/313–321

*Journal of Strength and Conditioning Research*  
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overload necessary for muscle hypertrophy and strength gains (17). Consequently, the effectiveness of instability training is contingent on the specific training goal. If an athlete's aim is to increase strength outside the core, then it has been demonstrated that performing resistance exercise on unstable platforms would be detrimental to strength gains. The diminished force production suggests that the intensity required for strength training ( $>85\%$  1 repetition maximum [1RM]) necessitates the inclusion of resistance exercise using more traditional methods, as with stable surfaces (3).

There is a small body of evidence that demonstrates increased core musculature activity when using unstable surfaces in comparison to exercise done on a stable surface (2,5,15,16,22,24). However, these studies have used the same absolute load across conditions. Because lighter loads have to be used on unstable surfaces, these studies may not adequately reflect the demands of a task with the same relative load, which is how the exercises would be performed in the weight room or gym. Greater core activation may simply be necessary when raising a greater external resistance overhead.

Additionally, with notable exceptions (skiing, surfing, and skateboarding), few activities are performed requiring one to overcome a stable load while on an unstable surface. Conversely, there are many situations where one is on a stable surface (the ground) and has to overcome an unstable resistance (such as an opponent). It is easy to visualize the need for greater core activation when lifting an unstable load, yet little research has been performed comparing muscle activation patterns while lifting stable and unstable loads.

For these reasons, the purpose of this study was to evaluate muscle activity of the prime movers and core stabilizers during performance of the seated overhead shoulder press exercise while lifting stable (barbell) and unstable (dumbbells) loads on stable (bench) and unstable (Swiss ball) surfaces, using relative rather than absolute loads for each condition. We hypothesized that (a) the 10RM of the stable load/stable surface (SL/SS) condition would be the greatest, the stable load/unstable surface (SL/US) condition would be greater than unstable load/stable surface (UL/SS) condition, and the unstable load/unstable surface (UL/US) condition would be the smallest; (b) the integrated electromyographic (EMG) measures of the prime movers would follow the order of the 10RM; and (c) the integrated EMG measures of the core stabilizers would be in the reverse order of the 10RM (i.e., increase with increased instability).

## METHODS

### Experimental Approach to the Problem

A within-subjects crossover design was used to evaluate differences between stable and unstable loads (barbell vs. dumbbell) and stable and unstable surfaces (exercise bench vs. Swiss ball) for muscle activity recorded during the overhead shoulder press exercise. The independent variables included 4 different exercise conditions: SL/SS, UL/SS, SL/US, and

UL/US. The dependent variables were the 10RM of the exercise and the integrated EMG measures for the prime movers (anterior deltoid, middle deltoid, trapezius, and triceps brachii) and core stabilizers (rectus abdominis, external obliques, and upper and lower erector spinae) associated with performance of the task. The root mean square (RMS) of the EMG amplitude for each muscle, under each condition, was calculated for the duration of 3 repetitions to quantify muscle activation.

### Subjects

Thirty subjects with at least 12 months of resistance training experience volunteered to participate in this study (24 men and 6 women; aged  $30 \pm 8$  years; weight,  $75 \pm 14$  kg). Each subject could be classified as "recreationally trained" and had a 10RM for the overhead barbell press of  $39 \pm 14$  kg. All subjects were familiar with the 4 overhead shoulder press exercise conditions but had not performed all the tasks on a regular basis as part of their training program. Informed consent was obtained from each subject before his or her participation in this study, which was approved by this institution's Standing Advisory Committee on the Protection of Human Subjects.

### Testing Procedures

A familiarization session was used to determine a 10RM under each load/surface condition (Figure 1): barbell/bench, barbell/Swiss ball, dumbbell/bench, and dumbbell/Swiss ball. Subjects practiced each condition with a minimal load until they were comfortable performing the exercises and then progressively increased the weight. Subjects then completed a 10RM testing protocol, which was modified from Stone and O'Bryant (23). The subjects were allowed 1–2 warm-up sets (with approximately 50% and 75% of their estimated 10RM) before their first attempt at the 10RM. Subjects then attempted a maximal number of repetitions with their estimated 10RM. The load was increased or decreased in 4.54 kg increments, depending on if the subjects could perform more or fewer repetitions. The process was repeated until a 10RM was established. This process was repeated for each condition. For subject safety, testing was conducted in the most familiar condition (SL/SS) to establish a projected load that was used for testing the other conditions. For similar reasons, testing was done on a bench (SS) before ball condition (US). Thus, the conditions were performed by the subjects in the following order: (a) SL/SS, (b) SL/US, (c) UL/SS, and (d) UL/US. Rest periods were ad libitum but were a minimum of 60 seconds and limited to 3 minutes.

The 10RM lifted for each relative condition was used during a subsequent testing session, in which EMG recordings were obtained. All 4 conditions were randomized during a single session to avoid systematic errors. Subjects were instructed to perform the shoulder press exercise for 3 sets of 3 repetitions for each condition. A surface height for the Swiss ball was chosen to match the height of the exercise bench



**Figure 1.** Overhead shoulder press conditions. A) Stable load/stable surface, (B) stable load/unstable surface, (C) unstable load/stable surface, and (D) unstable load/unstable surface.

(55 cm), and the exercise bench did not have a back support. All subjects performed the exercise on the same exercise bench and Swiss ball (Figure 1). The concentric phase started with the barbell or dumbbells held at shoulder level. The elbows were maintained in the frontal plane throughout each movement phase. Subjects positioned themselves directly on the top center of the Swiss ball. The legs were positioned with knees flexed at 90° and the feet hip-width apart. Subjects were instructed to perform the concentric and eccentric portions of the shoulder press movement at a specific cadence in seconds (1-1-1) to normalize time.

On an audio command, the subjects lifted the load to shoulder level and performed the concentric phase of the lift, terminating at full elbow extension. The eccentric phase started at full elbow extension. The subjects lowered the weight to the starting position used for the concentric phase at approximately a 1-second cadence. A 1-second pause was held before the subject began the next repetition's concentric phase. Subjects were informed if the movement was being performed too fast or too slow.

Electromyographic recording was initiated at the end of a 3-second countdown before the subject lifting the weight to

the starting position and continued over the full 9 seconds required to complete the exercise. Subjects were asked to repeat trials when there was a miscommunication or an electrical malfunction. Rest intervals were ad libitum, but the minimum rest interval between trials was 60 seconds.

### Electromyographic Recordings

Surface EMG was used to measure muscle activity for 8 muscles. The muscles included the prime movers (anterior deltoid, middle deltoid, trapezius, and triceps brachii) and the core stabilizers (rectus abdominis, external obliques, and upper and lower erector spinae). Muscle activity was recorded unilaterally on the dominant side for each subject.

Each EMG site was cleansed with alcohol and shaved if necessary before single differential bipolar electrodes (Delsys, Boston, MA, USA) were applied to the skin surface. The sensor contacts were made from 99.9% pure silver bars measuring 10 mm in length, 1 mm in diameter, and spaced 10 mm apart. The EMG sensors were positioned on the center of the muscle belly, away from the tendons and edge of the muscle, and positioned parallel to the orientation of the muscle fibers being measured, according to descriptions by Cram et al. (11) for the upper extremity and Anderson and Behm (2) for the trunk musculature. One reference electrode was adhered to the sacrum.

A dual-mode portable EMG and physiological signal data acquisition system (Delsys Myomonitor IV Portable EMG System; Delsys) was used for data collection. Data collection and analysis were conducted using EMG Works 3.5 (Delsys). The wireless data acquisition protocol included a sample frequency (1000 Hz) and band pass filter (20–500 Hz). The RMS was calculated for the combined eccentric and concentric phases of the movement using a 125 ms window. The RMS values of the 3 sets for each condition were averaged and formed the basis of the muscle activity analysis.

### Statistical Analyses

The calculation of 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 previous studies (3,6,16,21) that found differences between muscle activity under stable and unstable surface conditions. This provided a sample size of  $n = 30$  for this study.

Statistical analyses for all RMS EMG measures used a 1-way analysis of variance (ANOVA) with repeated measures (SPSS 16.0; SPSS, Inc., Chicago, IL, USA) to determine overall differences in average EMG of the muscles

**TABLE 1.** Average ( $\pm$  SD) external resistance (kg) of the 10 repetition maximum measured for each of the 4 shoulder press conditions and the percentage of the SL/SS (stable load/stable surface) condition.\*†

Condition	SL/SS	SL/US	UL/SS	UL/US
Load (kg)	39 (14)	35 (13)	33 (14)	30 (11)
Percent	100	89 (6)	86 (13)	79 (12)

\*SL/US and UL/SS no significant difference.

†SL/US = stable load/unstable surface; UL/SS = unstable load/stable surface; UL/US = unstable load/unstable surface.

among the 4 conditions. The level of significance was set at 0.05. Fisher's least significant difference test was used for post hoc analysis, to determine the differences between tasks.

To determine reliability between trials of the EMG recordings for each muscle, intraclass correlation coefficients were calculated using a 2-way mixed model. Ten subjects from the sample participated in 2 testing sessions using an identical protocol. Intraclass correlation coefficients for the integrated EMG data ranged from 0.673 to 0.967 with a mean of 0.874.

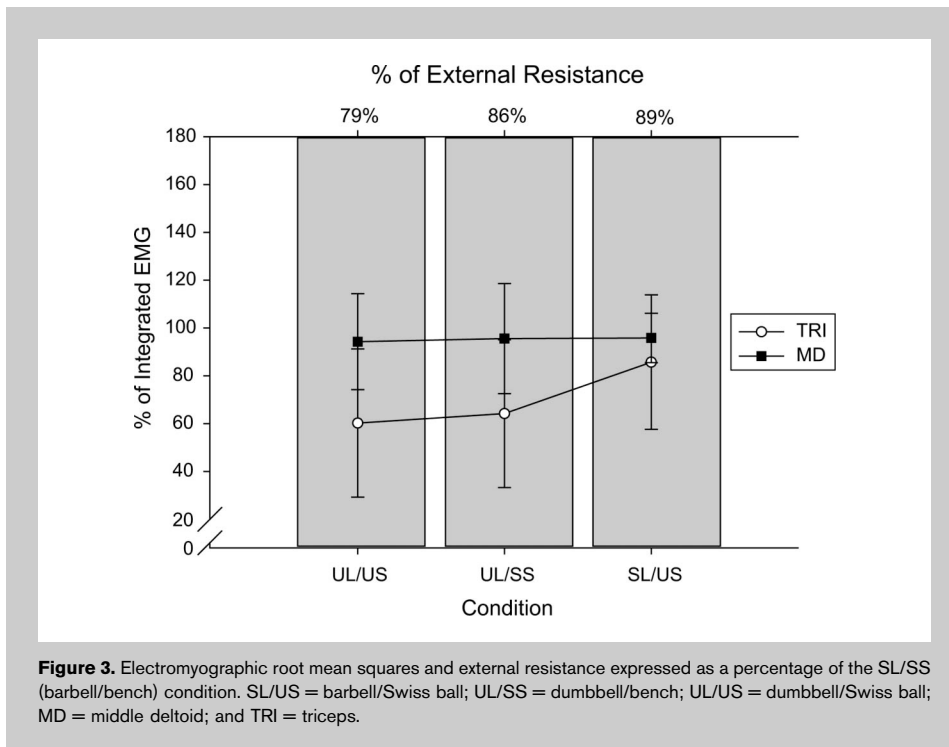
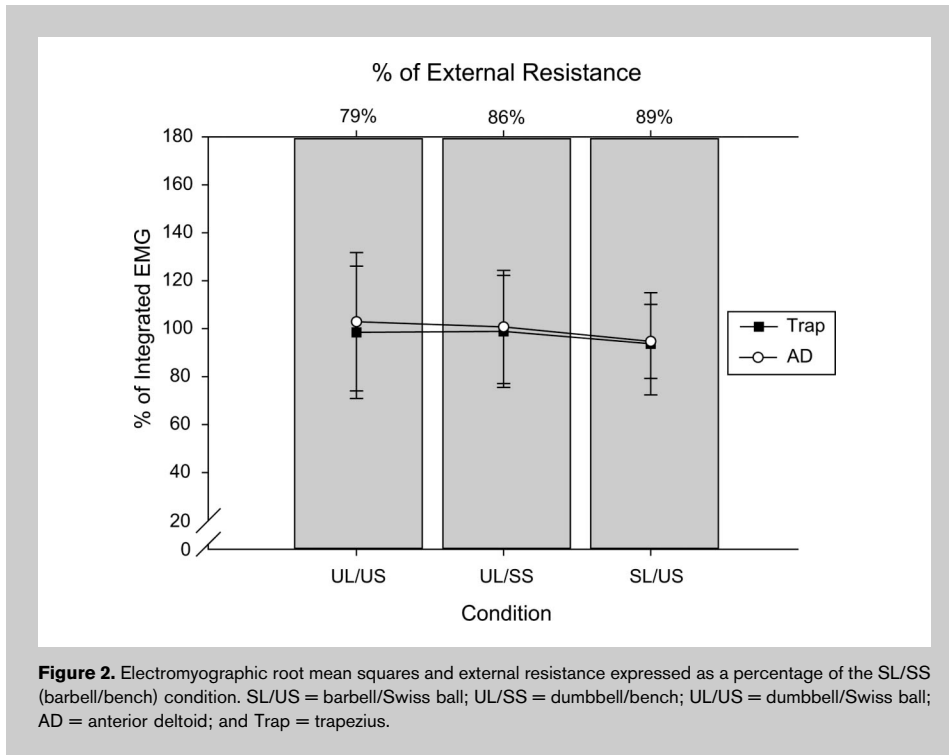
### RESULTS

For the external resistance (Table 1), 1-way ANOVA revealed that the main effect for condition was significant, with SL/SS being 11.2% greater than SL/US ( $p < 0.001$ ), 14.5% greater than UL/SS ( $p < 0.001$ ), and 22.2% greater than UL/US ( $p < 0.001$ ). Stable load/unstable surface and UL/SS were 12.4% and 9% greater than UL/US ( $p < 0.001$  and 0.001,

**TABLE 2.** Average ( $\pm$  SD) root mean square (RMS) electromyographic (EMG) (mVs) results measured for the 4 shoulder press conditions.

Muscle	UL/US	UL/SS	SL/US	SL/SS
AD	507 (213)	500 (2125)	472 (162)	495 (199)
MD	405 (213)	410 (164)	420 (177)	442 (202)
TRAP	433 (265)	441 (280)	429 (266)	450 (262)
TRI	41 (13)	45 (18)	71 (44)	87 (50)
RA	21 (35)	20 (20)	148 (18)	23 (30)
EO	26 (27)	28 (28)	21 (16)	26 (16)
LES	25 (28)	19 (15)	365 (26)	31 (21)
UES	35 (25)	29 (21)	54 (34)	48 (28)

UL/US = unstable load/unstable surface; UL/SS = unstable load/stable surface; SL/US = stable load/unstable surface; SL/SS = stable load/stable surface; AD = anterior deltoid; MD = middle deltoid; TRAP = trapezius; TRI = triceps; RA = rectus abdominis; EO = external obliques; LES = lower erector spinae; UES = upper erector spinae.



respectively) but not significantly different from each other ( $p = 0.134$ ).

Group means for each muscle under each condition are presented in Table 2. For the anterior deltoid and trapezius

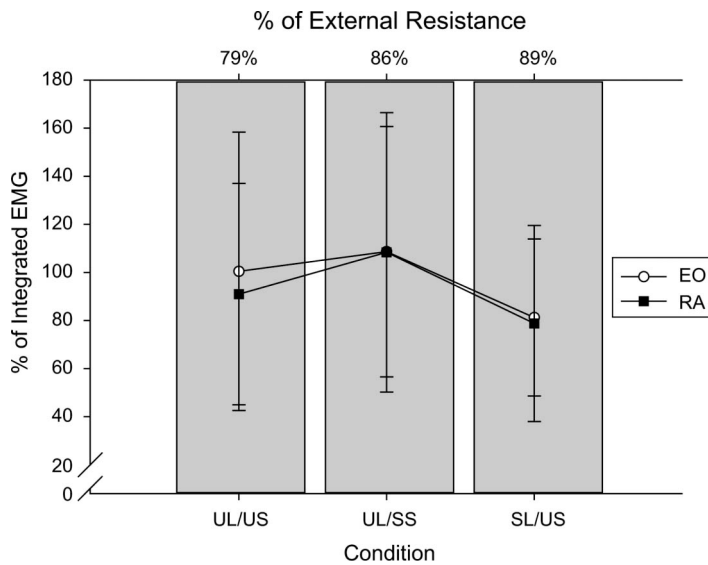
( $p = 0.001$ ). Post hoc analysis revealed that SL/SS was 18.7% greater than SL/US ( $p = 0.002$ ), and UL/SS was 27.4% greater than SL/US ( $p = 0.015$ ). Unstable load/stable surface and UL/US conditions were not significantly different from

(Figure 2), 1-way ANOVA revealed that the main effect for condition was not significant ( $p = 0.478$  and  $0.212$ , respectively).

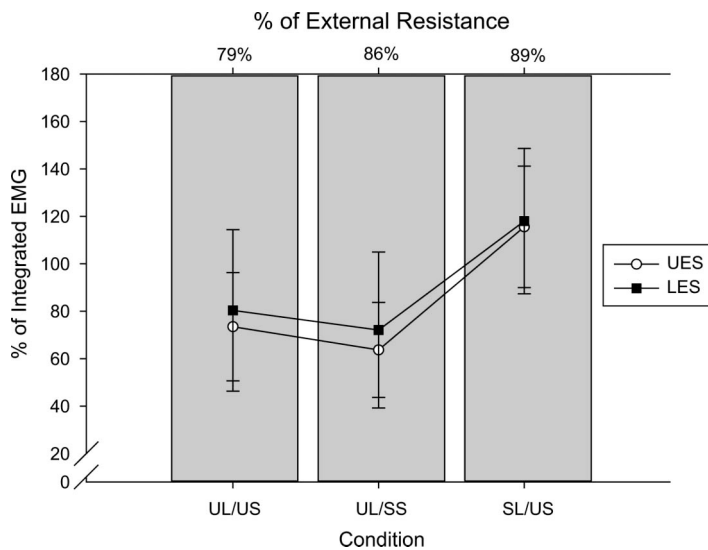
For the middle deltoid (Figure 3), the main effect for condition was significant ( $p = 0.046$ ). Post hoc analysis revealed that SL/SS was 4.2% greater than SL/US ( $p = 0.026$ ) and 5.7% greater than UL/US ( $p = 0.029$ ). Stable load/stable surface and UL/SS were not significantly different ( $p = 0.087$ ).

For the triceps (Figure 3), the main effect for condition was significant ( $p < 0.001$ ). Post hoc analysis revealed that SL/SS was 14.3% greater than SL/US ( $p = 0.001$ ), 35.8% greater than UL/SS ( $p < 0.001$ ), and 39.8% greater than UL/US ( $p < 0.001$ ). Stable load/unstable surface was 21.5% greater than UL/SS ( $p = 0.001$ ) and 25.5% greater than UL/US ( $p < 0.001$ ). Unstable load/stable surface was 4.0% greater than UL/US ( $p = 0.047$ ).

For the rectus abdominis (Figure 4), the main effect for condition was significant ( $p = 0.007$ ). Post hoc analysis revealed that SL/SS was 21.2% greater than SL/US ( $p = 0.002$ ), and UL/SS was 29.6% greater than SL/US ( $p = 0.020$ ). Unstable load/stable surface and UL/US conditions were not significantly different from SL/SS ( $p = 0.192$  and  $0.785$ , respectively). Stable load/unstable surface and UL/SS conditions were not significantly different from UL/US ( $p = 0.202$  and  $0.774$ , respectively). For the external obliques (Figure 4), the main effect for condition was significant



**Figure 4.** Electromyographic root mean squares and external resistance expressed as a percentage of the SL/SS (barbell/bench) condition. SL/US = barbell/Swiss ball; UL/SS = dumbbell/bench; UL/US = dumbbell/Swiss ball; RA = rectus abdominis; and EO = external obliques.



**Figure 5.** Electromyographic root mean squares and external resistance expressed as a percentage of the SL/SS (barbell/bench) condition. SL/US = barbell/Swiss ball; UL/SS = dumbbell/bench; UL/US = dumbbell/Swiss ball; LES = lower erector spinae; and UES = upper erector spinae.

SL/SS ( $p = 0.487$  and  $0.970$ , respectively). Stable load/unstable surface and UL/SS conditions were not significantly different from UL/US ( $p = 0.074$  and  $0.078$ , respectively).

For the lower erector spinae (Figure 5), the main effect for condition was significant ( $p < 0.001$ ). Post hoc analysis

revealed that SL/SS was 27.9% greater than UL/SS ( $p < 0.001$ ), and SL/US was 45.9% greater than UL/SS ( $p < 0.001$ ) and 37.6% greater than UL/US ( $p = 0.033$ ). Stable load/unstable surface and UL/US conditions were not significantly different from SL/SS ( $p = 0.134$  and  $0.261$ , respectively). Unstable load/stable surface and UL/US were not significantly different ( $p = 0.178$ ).

For the upper erector spinae (Figure 5), the main effect for condition was significant ( $p < 0.001$ ). Post hoc analysis revealed that SL/SS was 36.3% greater than UL/SS ( $p < 0.001$ ) and 26.5% greater than UL/US ( $p < 0.009$ ), 51.9% greater than UL/SS ( $p < 0.001$ ), and 42.1% greater than UL/US ( $p < 0.001$ ). Unstable load/unstable surface was 9.8% greater than UL/SS ( $p = 0.031$ ).

**DISCUSSION**

The results of this study supported part of the first hypothesis: the 10RM of the SL/SS (barbell/bench) condition was the greatest, and the 10RM of the UL/US (dumbbell/Swiss ball) condition was the least. However, the 10RM between the SL/US (barbell/Swiss ball) and the UL/SS (dumbbell/bench) conditions were similar. The second hypothesis predicted that the integrated EMG measures of the prime movers would follow the order of the 10RM (SL/SS > SL/US > UL/SS > UL/US); however, the integrated muscle activity did not provide consistent evidence to support it. The

middle deltoid and triceps tended to follow this trend, but the anterior deltoid and trapezius muscles did not. Finally, it was hypothesized that the integrated EMG measures of the core stabilizers would be in the reverse order of the 10RM. The present results do not support this position for overhead

presses performed with barbells and dumbbells on exercise benches (without back support) and Swiss balls.

As the stability of the conditions decreased, the amount of external resistance decreased as well. This finding supports previous investigations, which showed a decrease in either RMs or force output while performing activities on an unstable surface (5,17). The effect of an unstable loads on force output has been less investigated and is less clear. Cotterman et al. (10) found that subjects had a larger 1RM on the barbell bench press compared with the Smith machine bench press by 16%. The authors hypothesized that the mechanical pattern dictated by the bar in a Smith machine may have put the upper extremity at a mechanical disadvantage at certain points in the range of motion, which would result in a more stable device producing less force. Welsch et al. (25) found that the load of a 10RM dumbbell bench press is 63% that of a barbell bench press. Our results suggest a more modest decrease between dumbbell and barbell loads: during the overhead press, the dumbbell loads were approximately 85% of the barbell loads. Additionally, our results indicate that increasing the instability of either the load (UL) or surface (US) without back support resulted in similar decreases in the 10RM.

When all other conditions are the same, an increase in force is typically associated with an increase in EMG activity of the working muscles, although this relation is not always a linear one (1). While this was the basis for our second hypothesis, the trend was followed by only the triceps muscle group across all 4 conditions, although the middle deltoid followed for 3 of the 4 conditions. Behm et al. (5) found that instability decreases neural drive to the prime movers and increases antagonistic muscle activity in the form of cocontraction. However, their results were for the vasti and hamstrings during a knee extension exercise, which may not have had great demands for stability at the knee joint.

The finding that the EMG activity of the trapezius and anterior deltoid was relatively consistent across conditions may be explained by the fact that they also function as scapular (13) and glenohumeral (GH) (14) stabilizers, respectively. During both unstable loads and unstable surfaces, increased muscle activity may be necessary to stabilize both the scapula and GH joints. The increase in activity required for stabilization may have offset the decrease in activity that would be expected with a decreased load, resulting in the same level of activation across conditions.

The triceps is a prime mover of elbow extension, and the long head additionally acts as a shoulder extensor. Its function in posterior GH stability is unclear (12). The finding that the triceps activation followed the same trends as the magnitude of the external resistances would seem to indicate that it plays a minimal role in stabilizing either the GH or elbow joints during these tasks. Given that the position of the arm during the overhead press (i.e., abducted and externally rotated) produces shear in the anterior direction and the elbow has a high degree of bony congruency, this explanation seems plausible.

The findings for the middle deltoid are not as easy to explain. The middle deltoid muscle activation followed the general trend of the magnitude of the external resistance (SL/SS > SL/US > UL/US) with the exception that the SL/SS and UL/SS conditions were not significantly different. The middle deltoid is a prime mover for shoulder abduction and can play a role in GH stabilization (14). The unstable surface may not have been an effective stimulus to increase the GH stability requirements in the inferior direction but the unstable load may have been. This would have the effect, similar to the anterior deltoid and trapezius, of the increased activation necessary for stabilization being offset by the decreased activation consistent with a lower external resistance. The unstable load combined with the unstable surface may have created a decline in external load that was greater than the need for stabilization. This hypothesis would require further testing.

In contrast to the muscles of the upper extremity, the core muscles had no actions as prime movers during this activity, and so their activation served to stiffen the spine and thus enhance its stability (9), particularly because none of the conditions provided back support. Core activation was not consistent across conditions, but the rectus abdominis had similar activation patterns to the external oblique, and the upper erector spinae had similar activation patterns to the lower erector spinae.

The external obliques play an important role stabilizing the spine during upright lifting tasks (4). McGill (18) notes that the abdominal muscles work together to increase spinal stability and that the rectus abdominis transmits the lateral force from the obliques to form a continuous hoop of tension around the abdomen. This would explain the similar activation patterns between the external obliques and rectus abdominis during these activities.

Further inspection of EMG RMS data reveals that exercises performed on stable surfaces tended to require greater abdominal muscle activation, suggesting that a heavier load lifted overhead will require greater activation of these muscles. The statistical significance of this trend was not always consistent. It is often assumed that increased muscle activation will increase spinal stiffness and thus increase stability of the spine. Brown and McGill demonstrated (8), via a mathematical model, that this is not always the case: increasing the activation of the rectus abdominis beyond an optimal point may have a destabilizing effect on the spine in the frontal plane. This may explain our findings, but further research is required.

The iliocostalis and longissimus of the erector spinae are often considered to be 2 distinct muscles. However, they act as one muscle with 2 functional groups: a lumbar portion and a thoracic portion (7), which we referred to as the LES and UES, respectively. McGill et al. (19) suggest that the thoracic portion of these muscles produce an extensor moment about the spine with minimal compressive forces, whereas the lumbar portions produce an extensor moment and a posterior

shear force that would counteract an anterior shear force on the body. This indicates that the UES should increase with load, whereas the LES should increase with instability. Our findings do not support this contention. The activation patterns of the UES and LES were similar between conditions. The stable load tended to require greater activation than their unstable load counterparts, and the activation of the UES appeared to be more affected by the surface conditions than the LES: the greatest activation of the UES occurred with the SL/US condition. Performing the exercise with a barbell may have placed the load more anterior to the spine than the dumbbells, which could have required a greater extensor moment and thus more activation. This may also explain why the activation patterns of the erector spinae mirrored the abdominals. These are other areas for further investigation.

Our results should be interpreted in light of the limitations of the study and drive future research in this area. First, we did not randomize the order of the 10RM tests. We felt it safer to test the stable surfaces before the unstable surfaces to establish a baseline load to use for the other conditions. Had the order of 10RM testing been randomized, the subjects may have been subjected to a precarious situation (if the estimated 10RM was too heavy) or an excessively fatiguing protocol (if the estimated 10RM was too light). We felt that the benefits of a previously established baseline load outweighed the drawbacks of testing in a sequential order. Second, the variations between the stable and unstable conditions were not large. We chose to compare dumbbells and barbells rather than a more stable load (such as a Smith machine) or less stable load (such as liquid-filled objects or hanging additional resistance from a chain) because of the large disparity between strength expressed using barbells vs. dumbbells (25), because the RM on a Smith machine may actually be less than using a barbell (10), and because these are arguably 2 of the most common forms of resistance exercise found in gyms and weight rooms. Other forms of resistance should be considered in subsequent investigations. Third, a more stable surface, such as a bench with a back support, may have led to different results. The back support may provide additional stability to the core, which could in turn lead to lifting larger loads than those used during the SL/SS condition and influence the results. Fourth, investigations should incorporate motion analysis in addition to EMG to determine if the differences in muscle activation are because of instability or changes in posture necessitated by using different implements and different surfaces with and without back support. Fifth, although all of our subjects were familiar with performing exercises on a Swiss ball, they did not use it as their primary surface for training. Differing results may be found with a population that trains primarily on Swiss balls. Finally, the study is limited to integrated muscle activation patterns while performing the overhead shoulder press. Different exercises may produce different results, and the

effectiveness of the instability training needs to be determined using a randomized intervention trial.

## PRACTICAL APPLICATIONS

When comparing muscle activation patterns using different surface and load conditions, relative, rather than absolute, loads should be used across conditions because increasing instability decreases the amount of load that can be lifted. Increasing instability via either the load or the surface affects the amount of load that can be lifted similarly. Based on the muscle activation patterns, our results do not support the use of training with dumbbells or Swiss balls over training with the heavier loads associated with a barbell on an exercise bench for developing core musculature during the overhead lift. The use of a backrest may provide additional benefits with this exercise and should be examined in future investigations.

## ACKNOWLEDGMENTS

The authors would like to thank the Office of Graduate Studies and International Programs at California State University, Northridge, CA, for their funding and thesis support program. We would like to acknowledge the efforts of Nicholas Kundu, from Delsys, Inc., for his technical support throughout the experiment.

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