Activity of Shoulder Stabilizers and Prime Movers During an Unstable Overhead Press

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Abstract

Williams, MR Jr, Hendricks, DS, Dannen, MJ, Arnold, AM, and Lawrence, MA. Activity of shoulder stabilizers and prime movers during an unstable overhead press. *J Strength Cond Res* 34(1): 73–78, 2020—Overhead reaching is a common movement that relies heavily on muscles for dynamic stability. Stabilizer muscle activation increased during squatting and bench pressing with an unstable load, but the overhead press (OHP) has yet to be examined. The purpose of this study is to compare muscle activity of the shoulder stabilizers and prime movers and excursions of the center of pressure (CoP) during the OHP in 2 unstable and one stable conditions. Twelve men (aged 25.3 ± 2.7 years, mass: 91.5 ± 8.4 kg, height: 1.81 ± 0.06 m) pressed 50% of their 1 repetition maximum for 10 repetitions over 3 conditions: a straight stable barbell (SS), a straight unstable (SU) barbell with kettlebells suspend by elastic bands, and an unstable Earthquake (EU) bar with kettlebells suspended by elastic bands. Activity of the shoulder stabilizers and prime movers were measured via surface and indwelling electromyography. Center of pressure excursion of the right foot was also measured. A multivariate analysis was used to determine significant differences between conditions. Pressing with the EQ increased activation of the biceps brachii, erector spinae, latissimus dorsi, pectoralis major, rectus abdominus, rhomboids, and serratus anterior over the SS condition, whereas only the SU condition increased activation in the erector spinae and latissimus dorsi muscles. The EQ condition produced greater CoP excursion (35.3 ± 7.9% foot length) compared with the SU (28.0 ± 7.2% foot length) and SS (22.2 ± 6.3% foot length) conditions. Therefore, the EU condition may be an effective exercise to activate scapular stabilizers.

Key Words bandbell, stability, earthquake bar

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Introduction

In the United States, there are 4.5 million health care visits because of shoulder pain and an average of 250,000 rotator cuff repairs yearly (13). Because of the high prevalence of shoulder injuries, training focused on developing scapular stability has become a mainstay in both the fitness and rehabilitation industries. Furthermore, the shoulder is at higher risk of injury during overhead sports, which expose the shoulder to high loads and forces (e.g., baseball, softball, volleyball, and tennis) (4). In particular, the rotator cuff is often subjected to very high eccentric forces during overhead sports; therefore, it is important for the overhead athlete to have adequate strength in these muscles to prevent injury (4). Instability during a movement can increase antagonist muscle activity, increasing joint stiffness and stability, which helps protect joints from excessive forces (1–3). In both the fitness and rehabilitation industries, unstable training has become widely used in an effort to improve joint stability (5). Proponents of unstable training believe that incorporating some aspect of instability into an exercise will increase the demands placed on stabilizing musculature and improve neuromuscular control (14). However, there are multiple methods to incorporate instability into exercise.

One way to incorporate instability into exercise is to perform the exercise on an unstable surface. Behm and Anderson (2) found that performing resistance exercises sitting or lying on an unstable surface results in decreased force output and a decrease in the amount of weight lifted. Furthermore, activation of the triceps brachii, middle deltoid, rectus abdominus, and the external oblique decreased when pressing a barbell overhead on a stability ball compared with pressing the barbell on a stable bench (3). Despite the lack of promising results, unstable surface training has shown with regards to muscle activation that unstable surface training continues to be very prevalent; products such as the BOSU ball, stability ball, and the DynaDisc can be found in many gyms and physical therapy clinics. An alternative to unstable surface training is unstable load training (ULT), in which the load being lifted is made unstable with a combination of flexible barbells, weights, and elastic bands. Although many articles can be found on fitness websites claiming increases in muscle fiber recruitment, motor unit recruitment, and

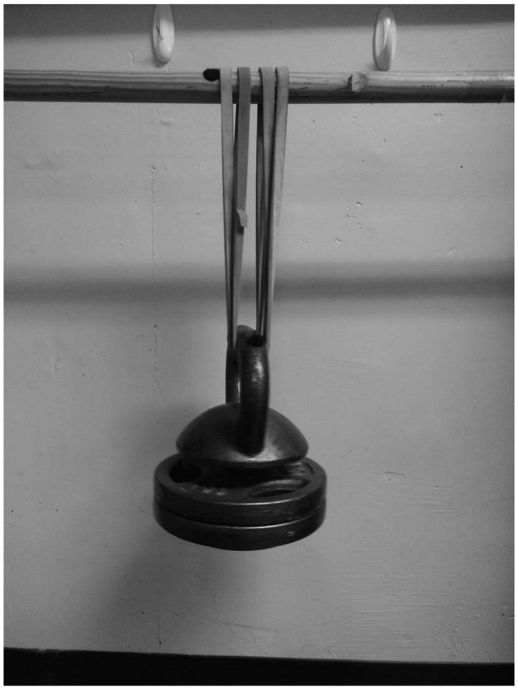

Figure 1. Bands "quadruple looped" around a kettlebell.

muscle spindle recruitment (6,18,19,20) during unstable resistance training, there is limited scientific evidence to substantiate those claims. However, there is some supporting evidence of the efficacy of ULT. Squatting with an unstable load increased activation of the rectus abdominus, external oblique, and soleus (11) as compared to a stable load. Ostrowski et al. found increased activation of the biceps brachii during a bench press when using an unstable load, although the unstable load was lighter than the comparative stable load (16). Given the lack of a bench, an unstable load may have even greater effect on the stabilizing muscles of the shoulders and trunk during a standing overhead press. Furthermore, ULT may challenge a person's overall standing stability. Issues with balance commonly arise because of the normal process of aging, neurological conditions, or musculoskeletal conditions such as low back pain (17) and can increase an individual's risk of falls. Balance training that challenges standing stability can improve a person's ability to generate force under unstable conditions in the everyday environment, which can decrease fall risk and the risk of fall-related injury (1).

Existing research has focused primarily on the effects of unstable surface training, but recent evidence (1–3) suggests that ULT may lead to greater increases in stabilizer and antagonist muscle activation, which can lead to greater joint stability. To the best of our knowledge, this investigation is the first to assess muscle activation when pressing an unstable load overhead and will provide insights regarding potential rehabilitation and fitness benefits. The purpose of this study is to determine whether overhead pressing with unstable loads is more challenging than pressing with a stable load. Furthermore, we used 2 unstable load conditions to determine whether there would be any differences between the 2 setups. Therefore, we measured the activity of the prime movers, shoulder stabilizers, and standing stability during a standing overhead press with 2 unstable and 1 stable loads. We hypothesized that pressing with unstable loads would (a) increase all prime movers and stabilizing muscle activation and (b) increase the anterior/posterior movement of the center of pressure (CoP) as compared to overhead pressing with a stable load. We also hypothesized that an unstable load using a flexible barbell will increase the activity of prime movers and shoulder stabilizers and increase anterior/posterior movement of the CoP as compared to an unstable load that uses a standard barbell.

Methods

Experimental Approach to the Problem

For the design of this experiment, we used a within-subject comparison with 3 different conditions. Twelve male volunteers with resistance training experience pressed 50% of their 1 repetition maximum (1RM) overhead press during 3 conditions (standard barbell and plate weights [SS], standard barbell with kettlebells suspended from the bar using 1/2 in. bands [US], and the Earthquake Bar with kettlebells suspended with 1/2 inch bands [EQ]). Pilot testing found that 50% of each participant's 1RM was the highest percentage that allowed for participants to consistently complete 10 repetitions under each condition.

Subjects

Twelve recreationally active men who were currently resistance training (age 25.3 ± 2.7 years, mass 91.5 ± 8.4 kg, height 1.81 ± 0.06 m, 7.3 ± 2.4 years lifting experience, and standing overhead press 1RM 77.1 ± 11.5 kg; mean ± *SD*) volunteered for this study. Subjects were excluded if they had a shoulder injury within 6 months, pain with overhead pressing, or history of multiple shoulder dislocations. Seven participants reported having limited experience (none had incorporated it into their regular exercise routine) with ULT. This study was approved by the institutional review board of the University of New England, and all participants provided written informed consent (IRB #041217-007).

Procedures

Data were collected over 2 sessions. To minimize fatigue, participants were asked to abstain from exercise for at least 48 hours before testing. During the first session, participants completed a 1RM overhead press with a standard barbell and plate weights (14). At least 1 week after the first session, participants performed 10 repetitions of an overhead press under 3 different conditions (25 lb barbell with plate weights [SS], 25 lb barbell with kettlebells suspended from elastic

Table 1. Normalized integrated muscle activity.*

	Anterior deltoid	Middle deltoid	Posterior deltoid	Triceps brachii	Pectoralis major	External oblique	Erector spinae	Rectus abdominus
Straight bar stable load	915 ± 497	267 ± 205	85 ± 99	259 ± 206	86 ± 29	46 ± 42	32 ± 22	33 ± 31
Straight bar unstable load	929 ± 498	285 ± 240	92 ± 105	275 ± 203	92 ± 35	51 ± 42	40 ± 27†	36 ± 24
Earthquake bar	1,043 ± 533	294 ± 272	99 ± 92	297 ± 167	118 ± 44†‡	62 ± 45	55 ± 39†	62 ± 37†‡
Interclass correlation	0.983	0.976	0.984	0.985	0.909	0.980	0.929	0.928

	Latissimus dorsi	Biceps brachii	Rhomboid	Serratus anterior	Upper trapezius	Subscapularis	Supraspinatus	Infraspinatus
Straight bar stable load	54 ± 36	291 ± 185	66 ± 69	312 ± 282	171 ± 131	364 ± 489	21 ± 12	110 ± 120
Straight bar unstable load	60 ± 36†	303 ± 162	76 ± 80	351 ± 305	176 ± 117	446 ± 636	22 ± 16	180 ± 275
Earthquake bar	75 ± 41†‡	512 ± 262†‡	89 ± 73†	411 ± 310†‡	211 ± 129	489 ± 748	33 ± 19	119 ± 152
Interclass correlation	0.983	0.859	0.990	0.989	0.971	0.919	0.781	0.853

*% resting*s, mean ± *SD*.
†Significantly ($p < 0.05$) greater than straight bar stable condition.
‡Significantly ($p < 0.05$) greater than straight bar unstable condition.

bands [SU], and Earthquake Bar [Bandbell, Columbus, OH, USA] with kettlebells suspended from elastic bands [EQ]). Elastic bands were 1/2 in. mini-bands (EliteFTS, London, United Kingdom) and "quadruple looped" around the kettlebells (Figure 1). Adjustable kettlebells were used to load the barbell with the correct load (rounded to the nearest 5 pounds). Condition order was randomized for each subject. Randomization was performed so that each condition occurred the same number of times in each position (first, second, or third) across all subjects. For each condition, a 5-repetition warm-up set was performed with 25% of 1RM. After a 3-minute rest, participants performed 1 set of 10 repetitions at 50% of 1RM. On completing each set of 10, participants were asked to rate their perceived exertion (RPE) based on the Borg Scale (0–10). Between each condition, participants rested for 5 minutes. A metronome was used to maintain the tempo of 1-second concentric and 2-second eccentric for all presses.

Table 2. Rating of perceived exertion (RPE).*

	RPE
Straight bar stable load	3.4 ± 1.2
Straight bar unstable load	4.5 ± 1.3†
Earthquake bar	6.0 ± 1.2†‡
Interclass correlation	0.701

*Mean ± *SD*.
†Significantly ($p < 0.05$) greater than straight bar stable condition.
‡Significantly ($p < 0.05$) greater than straight bar unstable condition.

During the second session, indwelling and bipolar (2 cm interelectrode distance) surface electromyography (EMG) sensors (Noraxon USA Inc., Scottsdale, AZ, USA) were used to record muscle activity. Indwelling wires were inserted into the supraspinatus, infraspinatus, and subscapularis. All insertions were performed by the same individual. The fine wire insertion of the subscapularis followed the technique of Németh and Broström (15) and placement was confirmed with the Gerber push test (10). Wire placement of the supraspinatus was confirmed by the "full can" test (9). Manual muscle tests for the 3 rotator cuff muscles were then performed to ensure proper placement of the indwelling electrodes. Surface EMG sensors were placed over the latissimus dorsi, upper trapezius, serratus anterior, erector spinae, rhomboids, rectus abdominus, external obliques, pectoralis major, anterior/middle/posterior deltoid, triceps brachii, and biceps brachii. All surface EMG sensors were placed according to SENIAM recommendations (7,9). A linear envelope was created for each EMG signal by filtering with a band-pass (20–200 Hz), rectifying the signal, and performing a low-pass filter with a 6-Hz cutoff. Reflective markers were placed at the center and ends of the barbell, as well as on the toes and heels of each of the subject's right foot. The motion of the markers was tracked using 8 Oqus Series-3 cameras (Qualisys AB, Gothenburg, Sweden) set at 150 Hz. Subjects stood with their right foot on a force plate (AMTI, Watertown, NY, USA), and the CoP of the right foot was then normalized to foot length. Muscle activity for each participant was normalized to a static standing trial and then integrated using the trapezoid rule. All data analysis was completed with Visual 3D (C-Motion, Germantown, MD, USA).

Statistical Analyses

A power analysis was conducted with the biceps EMG data from the first 10 subjects collected using an online calculator (https://www.dssresearch.com/KnowledgeCenter/toolkitcalculators/samplesizecalculators.aspx). It was determined that 5 participants were needed to power this study. Biceps data were used as the biceps have been previously shown to be different between stable and unstable conditions while pressing (16). Magnitude of muscle activation, CoP excursion, and ratings of perceived exertion were compared between conditions using a repeated measures analysis of variance (SPSS version 21; IDM, Chicago, IL, USA) with a post-hoc Bonferonni correction with significance set at $p \leq 0.05$.

Results

The EQ condition produced significant increases in muscle activation compared with the SS condition in the biceps brachii ($p = 0.01$, $d = 0.97$), erector spinae ($p = 0.03$, $d = 0.73$), latissimus dorsi ($p < 0.01$, $d = 0.54$), pectoralis major ($p = 0.01$, $d = 0.86$), rectus abdominus ($p > 0.01$, $d = 0.85$), rhomboids ($p = 0.01$, $d = 0.32$), and serratus anterior ($p = 0.02$, $d = 0.33$) (Table 1). The EQ condition also increased muscle activation as compared to the SS condition in the pectoralis major ($p = 0.02$, $d = 0.65$), rectus abdominus ($p < 0.01$, $d = 0.83$), latissimus dorsi ($p = 0.01$, $d = 0.39$), biceps brachii ($p = 0.01$, $d = 0.96$), and serratus anterior ($p = 0.04$, $d = 0.20$).

While the SU condition produced greater activation than the SS condition in the erector spinae ($p = 0.02$, $d = 0.32$) and latissimus dorsi muscles ($p = 0.03$, $d = 0.17$) (Table 1). The EQ condition produced significantly greater CoP excursion (35.3 ± 7.9% foot length) compared with the SU (28.0 ± 7.2% foot length, $p = 0.012$, $d = 0.97$) and SS (22.2 ± 6.3% foot length, $p = 0.002$, $d = 1.83$) conditions ($r = 0.708$). However, the difference between the SU and SS conditions was not significant ($p = 0.053$). Participants also reported significantly higher RPE values in the US ($p = 0.05$, $d = 0.88$) and EQ ($p < 0.01$, $d = 2.17$) conditions as compared to the SS condition. Furthermore, RPE values were greater in the EQ condition than those in the US condition ($p < 0.01$, $d = 1.20$) (Table 2).

Discussion

The major findings of our study were that the EQ condition increased activity of the scapular stabilizers, CoP excursion, and reported RPE values as compared to both the SS and SU conditions. Our hypothesis that activation of the shoulder prime movers and stabilizers would increase when lifting an unstable load was partially supported. Although activation of the prime movers did not differ between conditions, activation of the shoulder (bicep, latissimus dorsi, pectoralis major, rhomboids, and serratus anterior) and trunk (erector spinae and rectus abdominus) stabilizers was increased when pressing with an unstable load and flexible barbell. However, rotator cuff musculature (supraspinatus, infraspinatus, and subscapularis) did not change across conditions. Interestingly, the SU condition was effective only in increasing the activation of the latissimus dorsi and erector spinae as compared to the SS condition. Furthermore, the EQ condition exhibited a large (59.0 and 25.0%) increase in CoP anterior-posterior excursion as compared to the SS and SU conditions, respectively. In comparing the 2 unstable conditions, it seems that the use of the flexible barbell in the EQ condition is necessary to elicit the most shoulder and trunk stabilizer muscle activity. Furthermore, the EQ condition provided a greater challenge to overall stability, as measured through CoP excursion, and a greater RPE than the SU condition. Our findings along with the findings of others (16) suggest that ULT may be a useful training tool to increase activation of stabilizing musculature during upper extremity exercises.

Despite similar loading strategies (kettlebells suspended by elastic bands), the EQ condition generated increased muscle activity in more stabilizing muscles than the SU condition. In addition, during the EQ condition, the biceps, latissimus dorsi, pectoralis major, rectus abdominus, and serratus anterior were more active than during the SU condition. This would suggest that the use of the Earthquake bar plays a substantial role in activating shoulder and trunk stabilizing musculature. Although the movements are different, our findings of increased bicep activation are consistent with Ostrowski et al. (16), who examined bench pressing with an unstable load. Although Ostrowski et al. (16) found differences only in biceps brachii and left middle deltoid between stable and unstable conditions, we found increases in multiple stabilizing muscles, which is likely due to the overhead press being inherently more unstable than the bench press.

Surprisingly, there was no increase in activation for the supraspinatus, infraspinatus, and subscapularis across conditions. The lack of increased activation may be due to (a) glenohumeral ligamentous structures providing enough support to not require increased activation of the rotator cuff muscles, (b) rotator cuff muscles were highly active across all conditions, or (c) participants used a strategy of controlling the bar with larger scapular stabilizers and prime movers that are capable of greater force development than the rotator cuff muscles. As our study showed increased activation of the scapular stabilizers during the EQ condition, it is likely that a different control strategy was used during the EQ condition as compared to the SU or SS conditions. This would be consistent with previous findings by Lawrence et al., (12) who found that a different control strategy was used when bench pressing with an Earthquake bar as compared to bench pressing with a typical setup. In short, the bench pressers constrained the activation of their stabilizer muscles more during an unstable load, which effectively allowed them to "stay tighter" with the unstable load. Although it is at this point unknown if the subjects during the overhead press were attempting to "stay tighter" by constricting their activation patterns, it does appear that they were using more muscle activation from both shoulder and trunk stabilizers to maintain control of the barbell.

Center of pressure excursion was measured as a way to determine whether overhead pressing with an unstable weight would be challenging to postural stability and control, which has been shown to be a valid measure in young adults (8). Although differences between SU and SS conditions were insignificant ($p = 0.053$), this is likely due to our study being slightly underpowered to expose those differences. The large increase in CoP excursion during the EQ condition suggests that this activity might also challenge whole-body stabilization instead of relying just on local shoulder and trunk structures to control the barbell. Transmitting the instability through the shoulders and torso to the ground demonstrates another strategy used to control unstable loads. Although we did not measure muscle activation of plantarflexors and dorsiflexors, the increased movement of the CoP suggests that those muscles were more active during the unstable conditions. Similarly, Lawrence and Carlson (11) found that squatting with an unstable load increased activation of the soleus muscle as compared to squatting with a stable load. To fully understand how pressing unstable loads overhead challenges whole-body stabilization, activation of the lower extremity muscles should also be measured. We also found that while the SS condition resulted in a "moderate" difficulty rating on the modified Borg scale, the SU condition was rated as "somewhat hard" and the EQ as "hard." As the overall load was the same across all conditions, it would seem that the instability of the unstable conditions is what drove the differences in the rating of perceived exertion. One of the limitations of this study was the small sample size and that the participants in the study had similar demographics (healthy men aged between 20 and 30 years, with limited experience with the Earthquake Bar, which may limit the generalizability of the results). Another limitation was that maximal voluntary isometric contraction of the muscles was not assessed, limiting the ability to determine the magnitude of activation during each condition.

Practical Applications

Our findings suggest that ULT may be useful in performance and rehabilitation settings to challenge scapular and trunk stabilizer muscles and whole-body stability. The Earthquake bar may be an effective tool to activate stabilizing muscles of the shoulder and trunk during an overhead press while using light loads. Unstable load overhead pressing could be implemented if the athlete needs a more challenging exercise than what can be provided with normal overhead barbell press and the trainer is not wanting to increase the load of the barbell. Also, by eliciting higher magnitude excursions in CoP, ULT can be used as a part of balance and proprioception training. It should be noted that subjects perceived unstable overhead pressing as more difficult than pressing with a standard free weight, therefore more rest or recovery may be needed between sets.

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