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Stability of Resistance Training Implement alters EMG Activity during the Overhead Press

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ABSTRACT

International Journal of Exercise Science 11(1): 708-716, 2018. Kettlebells often replace dumbbells during common resistance training exercises such as the overhead press. When performing an overhead press, the center of mass of a dumbbell is in line with the glenohumeral joint. In comparison, the center of mass of the kettlebell is posterior to the glenohumeral joint. Posterior displacement of the kettlebell center of mass may result in less stability during the pressing motion. The purpose of this study was to examine muscle activity during an overhead press with resistance training implements of differing stability. Surface electromyography (EMG) for the anterior deltoid and pectoralis major was analyzed for 21 subjects. Technique and pace of the overhead press were standardized and monitored. Filtered EMG data were collected, normalized, and average peak amplitude as a percentage of MVIC was calculated for each repetition. A repeated-measures analysis of variance was used to compare EMG values for the anterior deltoid and pectoralis major across implements. A statistically significant increase in normalized EMG activity ($p < .05$) was identified in the anterior deltoid when using the dumbbell (63.3±13.3%) compared to the kettlebell (57.9±15.0%). In this study, EMG activity was augmented in the anterior deltoid when using the more stable implement, the dumbbell.

KEY WORDS: Kettlebell, dumbbell, muscle activation, anterior deltoid, pectoralis major

INTRODUCTION

Over recent years, the popularity of the kettlebell (KB) as a resistance training implement has grown steadily (3). While exercises exist that are unique to the KB, there are also exercises in which the KB is used as a substitute for more traditional resistance training implements, such as the barbell and dumbbell (DB). This substitution is important to note because there is a lack of scientific literature examining the efficacy of the KB during traditional resistance training exercises. This gap in the literature is relevant due to the potential implications of the differences between the KB and more traditional resistance training implements.

One of the distinctive features separating the KB from more traditional implements is its uneven distribution of mass. For example, the mass of a DB is distributed equally on either side of the handle, whereas the mass of a KB is located inferior to the handle. Therefore, during a traditional resistance training exercise such as the overhead press, the mass of the DB is in line with the glenohumeral (GH) joint (Figure 1). However, the center of mass of a KB is posterior to the GH joint during the overhead press (Figure 2).

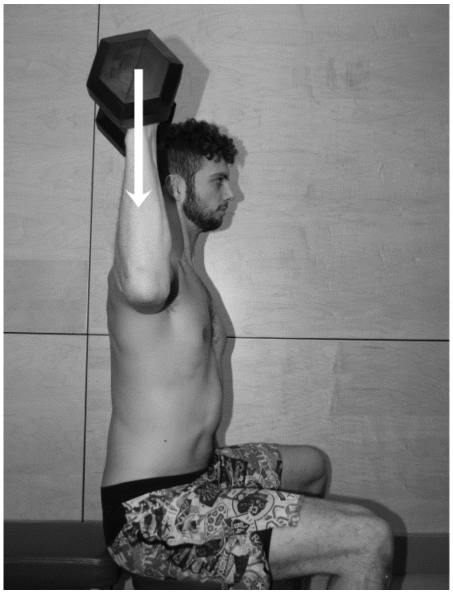

Figure 1. Estimated COM when in the start position of the dumbbell overhead press.

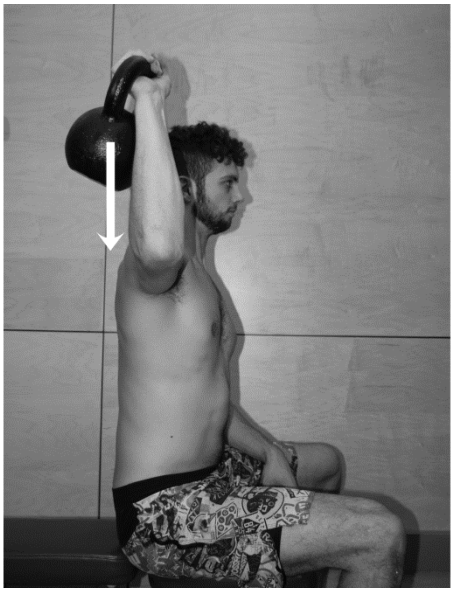

Figure 2. Estimated COM when in the start position of the kettlebell overhead press.

The difference in the distribution of the mass during an overhead press has led the authors of this study to identify the KB as a less stable implement when compared to the DB. Previous studies have examined the effect of changes in stability during common resistance training exercises. These studies have examined different resistance implements (2,5,10-12,16), body positions (13), and surfaces (1,4,5,7,14,15), or a combination of these variables. One of the specific exercises that has been examined is the overhead press (5,13,15). Saeterbakken and Fimland examined the anterior, middle, and posterior deltoid during an overhead press (13). The authors compared the barbell and dumbbell overhead press when seated and standing. The authors observed significantly higher activation in the anterior deltoid with the less stable implement. In contrast, Kohler, Flanagan, and Whiting did not note a significant difference in activation of the anterior deltoid when comparing the dumbbell press to a barbell press in a seated position (5). These varying findings might be the result of comparisons made based on unmatched loads.

In reviewing current literature, no published study has examined the KB as a less stable implement during an overhead press. Further, only one study (15) has published findings that report differences in EMG activity when identical absolute loads were utilized in variations of the shoulder press exercise. Uribe and colleagues matched exercise load while altering surface stability (Swiss ball v. bench). Currently, no study has matched exercise load while altering implement stability during the overhead press. Therefore, the purpose of this study was to examine EMG activity when performing an overhead press with an evenly matched KB v. a DB. More precisely, the authors of this study examined EMG activity of the anterior deltoid (AD) and pectoralis major (PM) muscles. It was hypothesized that there would be greater EMG activity in a prime mover (AD) and less activity in a stabilizing muscle (PM) when utilizing the more stable implement, the DB.

METHODS

Participants

Twenty-three apparently healthy college-aged students volunteered to participate in this study. For inclusion in the study, participants were required to have completed an upper-level collegiate course that taught the scientific basis of resistance training. A general overview of each participant's previous shoulder health was also required. Participants were excluded from the study if they self-reported reduced shoulder range of motion or current shoulder injury. This study was approved by the Slippery Rock University Institutional Review Board. Prior to beginning the study, all participants read and signed an informed consent document. Of the initial 23 participants, only 21 (Table 1) were able to meet the requirements of data collection.

Table 1. Participant characteristics

	Female (N = 7)	Male (N = 14)
Age (y)	21.4 ± 0.5	20.9 ± 0.7
Height (cm)	167.3 ± 7.5	174.7 ± 5.4
Weight (kg)	69.7 ± 20.4	79.2 ± 12.1
1RM Press (kg)	24.7 ± 7.2	66.8 ± 12.7

Note. 1RM Press = maximal weight lifted in one repetition test

Protocol

Each participant attended two research sessions for this study, pre-testing and data collection. During the pre-testing session, informed consent was obtained, and subjects completed a form that collected demographic information, medical history, and denoted the completion of the resistance training course. When cleared, each participant completed a one-repetition max (1RM) test on a shoulder press machine (Shoulder Press, Technogym USA Corp, Fairfield NJ). The standard protocol outlined by the National Strength and Conditioning Association (3) was followed. Twenty-five percent of the 1RM was calculated and used to select the load for data collection. This selection was rounded up to the nearest 5-pound interval when necessary. Since the 1RM procedure was bilateral and the testing procedure was unilateral, 25% of the 1RM was selected as a safe load that could be achieved by all participants.

Upon selection of the load, subjects were required to practice the one-arm overhead press motion. To achieve consistency, researchers coached and cued each participant as they performed practice repetitions. Each repetition began in a standardized start position and proceeded through the prescribed range of motion at a predetermined pace to qualify as acceptable. The start position (Figure 1) utilized a neutral spine which required subjects to maintain normal curvature in the lumbar, thoracic and cervical regions. The GH joint was abducted 90 degrees and laterally rotated so that the forearm was placed in a vertical position. The elbow was flexed 90 degrees. Each participant was required to complete one overhead press beginning and ending in the start position to standardize the range of motion. Each press was observed from the sagittal and frontal planes to assess proper exercise technique and ensure safety. Participants were required to maintain a standardized pace with a two-second concentric phase followed by a two-second eccentric phase. A metronome set to 60 beats per minute provided auditory feedback. Participants were required to practice the overhead press until both technique and pace were accurate.

Before leaving the pre-testing meeting, participants were advised not to perform any upper-body resistance training until after completing the subsequent data collection session. Each data collection session was conducted a minimum of 48 hours after the pre-testing session.

Instrumentation: Surface EMG of the AD and PM was sampled at a rate of 1000 Hz using the Bagnoli-4 EMG system (Delsys, Boston MA). Raw EMG data were amplified and band-pass filtered (20 and 450 Hz) with the gain set to 1,000. Data were A/D converted using a National Instruments data acquisition system and collected using EMG Works acquisition software (Delsys, Boston MA).

A DE-2.1 differential surface EMG sensor (Delsys, Boston MA) was placed over the AD and PM. The AD electrode was placed 1 finger breadth below the anterior distal aspect of the acromion process (9). The PM electrode was placed four finger breadths inferior to the clavicle and medial to the anterior axillary border (7,9). One reference electrode was placed over the contralateral acromioclavicular joint. The EMG sensors are internally shielded to reject ambient electrical noise and have two silver bar contact points (1cm x 1mm) spaced 1cm apart.

EMG data were normalized (8) through the use of maximal voluntary isometric contractions (MVIC) of the AD and PM. Three MVIC were completed for each muscle. Published MVIC testing positions (6) were utilized. The AD MVIC was obtained with a shoulder press machine (Technogym USA Corp, Fairfield NJ). While in a seated position with both shoulders abducted to 90 degrees, subjects were instructed to perform a maximal contraction while abducting against an immovable resistance. The PM MVIC was obtained with subjects pushing against a fixed bar while supine. Their shoulders were abducted to 90 degrees with elbows flexed to 90 degrees. EMG data from the subsequent testing repetitions is represented as a percentage of the peak activity identified during the MVIC testing procedure.

Data collection: The data collection session began with each participant completing a five-minute warm-up on an arm ergometer (Technogym USA Corp, Fairfield NJ). Upon completing the warm-up, participants were prepared for placement of the EMG electrodes following standard skin preparation recommendations. The same researcher placed the double bar silver electrodes over the AD and PM for each participant. Following electrode placement, the MVIC procedure described above was conducted.

After completing the MVIC procedure, participants performed the single arm overhead press until five acceptable repetitions were recorded for each implement. On average subjects required 6.1±1.1 and 6.0±0.7 repetitions to achieve 5 acceptable repetitions for the DB and KB, respectively. The load for both the KB and DB was standardized to 25% of each participant's initial 1RM. As described earlier, participants were monitored for both technique and pace by two different researchers to identify acceptable repetitions.

The implement, KB or DB, was randomized for the first set. The second set was performed five minutes after the completion of the first set. For both sets, data were recorded for each individual repetition with a thirty-second rest between repetitions. For each repetition, subjects were cued by the same researcher. Subjects were asked to get in the ready position (Figure 1). Then, a second researcher placed the implement into the subjects hand and allowed the subject to hold the weight. Two seconds after taking the implement, the subject was asked to complete their repetition and then hold in the ready position until the implement was removed from their hand. Data were recorded for a total of seven seconds for each repetition. These data included two seconds of an isometric hold at the beginning, two seconds of a concentric up phase, two seconds for the eccentric down phase, and a one-second isometric hold at the end. Based on the criteria for an acceptable repetition, each set was terminated when five acceptable repetitions were recorded or if the subject reached ten attempts without five acceptable repetitions.

Statistical Analysis

Each participant's filtered EMG data were normalized via the MVIC procedures described above and are represented as a percentage of their MVIC. Average amplitude across the seven second repetition was calculated from the normalized signal and used in the statistical analysis. Data for the first three acceptable repetitions of each implement were recorded and averaged for use in the analysis. A 2x2 repeated measures analysis of variance was used to compare the dependent variables (muscle; normalized EMG (%) for AD and PM) across the independent variable (implement; KB or DB). When differences were noted, paired t-tests with a Bonferroni post hoc correction were used to identify the source of the difference. The a-priori p value was set at $p < 0.05$. Data were analyzed with SPSS version 21 for Windows (SPSS Inc, Chicago, IL).

RESULTS

A significant muscle*implement interaction was noted ($F = 4.52$, $p < .05$, $1\text{-}\beta = .526$, partial $\eta^2 = .184$). Simply, higher EMG activity was observed in the primary mover when using the more stable implement. More precisely, significantly greater EMG activity ($p < .01$, Table 2) was measured in the AD when performing the overhead press with a DB (63.3±13.3% MVIC) as compared to the KB (57.9±15.0% of MVIC).

Contrary to our hypothesis, muscle activity in the stabilizer was similar when using different implements. Specifically, no significant difference was noted in average EMG activity generated in the PM between the DB and KB conditions, respectively (31.0±20.0 v. 29.5±22.0 %, $p > .05$, Table 2).

A significant main effect of muscle was also determined, wherein the normalized EMG values for the AD were significantly higher than the PM across both implements (Table 2).

Table 2. Means and standard deviations for the anterior deltoid and pectoralis major.

	Muscle	Kettlebell	Dumbbell
Normalized EMG (%)	Anterior Deltoid	57.9(15.0)	63.3(13.3)*
	Pectoralis Major	29.5(22.0)†	31.0(20.0)†

Note. Normalized EMG = average peak amplitude of EMG signal normalized to MVIC
* $p < .05$, statistically significant difference between implement
† $p < .05$, statistically significant difference between muscle

DISCUSSION

This study examined differences in muscle activity when performing an overhead press with a KB v. DB. During this exercise, the center of mass for the KB is located posterior to the hand and thus, not in line with the GH joint creating a less stable implement. This posterior displacement of the KB mass may cause an external rotation torque that is not present when performing an overhead press with a DB. The main finding of this study was significantly greater EMG activity in the AD during the DB overhead press when compared to the KB overhead press. There was no significant difference in EMG activity of the PM when comparing the KB and DB overhead press.

As noted by Saeterbakken and Fimland, previous research has reported inconsistent EMG results when comparing exercises with differing levels of stability (13). However, these differences may be better understood through a clear comparison of the purpose of these studies. For instance, a subset of the literature has examined the effect of surface stability (e.g stable bench v. Swiss ball) on muscle recruitment (1,4,5,7,14,15). Most of these studies did not match for exercise intensity. One exception to this, Uribe and colleagues based both stable and unstable surface exercise intensity on a 1RM measurement in the stable condition (15). These studies, which examined surface stability (1,4,5,7,14,15), predominantly found that there were no significant differences in prime mover or stabilizer activation between unstable and stable surfaces. Exceptions included Sandu and colleagues, who found greater activation in the pec major muscle (a prime mover of the pushup) on the unstable Swiss ball (14), and Lehman who found greater activation of stabilizer muscles when the hands were placed on a Swiss ball during pushup variations (7).

A second subset of research, which aligns more closely with the purpose of this study, examined the effect of altering the stability of the resistance training implement (2,5,10-12,16) on muscle activation. Similar to the surface stability literature described earlier, most of the published literature in the area of implement stability did not match the absolute load between the conditions. Additionally, many of these studies did not observe differences in the activation of the prime movers (5,10-12,16) during exercises of varying stability. However, multiple studies reported greater activation in stabilizing muscles (5,10-12). The study most comparable to our protocol was the work of Dunnick and colleagues (2), who compared an identical moderate- to high-intensity load (60 and 80% of stable 1RM bench press) across implements of varying stability (i.e. barbell v. barbell with elastic-suspended kettlebells). Subjects in this study were experienced with weight training (≥ 1 year of training). Five muscles (prime movers and stabilizers) were examined across both conditions (stable v unstable) and intensities (60 and 80% 1RM) with authors reporting no significant differences in muscle activation (2). Considerations including the participant population, exercise intensity, choice of exercise plane, and means of altering stability may account for differences in our findings. Prior training experience was specifically identified by this group as a critical consideration when comparing the results of implement stability (2). Interestingly, in contrast to the studies described above, McCaw and Friday (10) noted an increase in prime mover activation (pectoralis major) during the ascent phase of a machine (stable) compared to a free-weight (unstable) bench press. This observation is similar to the results of the present study, which reports greater prime mover activation with the more stable implement.

As described above, much of the relevant literature to the present study examined prime movers and stabilizers across varying stability requirements and exercise intensities. Findings from this study, increased activity in the prime mover with the more stable implement, do not mimic much of the current literature. Variations in methodology might shed some light on this difference. The present study did not alter body position (e.g. seated v. standing) or stability of the base of support (e.g. Swiss ball v. bench). Further, this study matched the absolute load with subjects using the same exact weight for the KB and DB overhead press. This is in contrast to the majority of previous work, which used relative loads or altered exercise patterns as their experimental variables, in an attempt to compare muscle recruitment. However, comparable to other studies, exercise technique, range of motion, and tempo were controlled during the experimental procedure. To our knowledge, this protocol is the first to match absolute load while altering stability of the implement in a heterogeneous sample.

The present study did have limitations. The authors assumed exercise technique would remain consistent between repetitions with the KB and DB. The examination of exercise technique was limited to visual observation by researchers from the sagittal and frontal planes. More accurate technique analysis could be undertaken through the use of three-dimensional motion analysis during the overhead press. EMG data were collected and analyzed for only two of the active muscles during an overhead press. Data for the isometric, concentric, and eccentric phases of the overhead pressing motion were analyzed collectively during a seven-second repetition. The five repetitions were recorded individually as opposed to recording in a continuous set. Finally, the single arm load, 25% of the bilateral 1RM, may only represent a load appropriate for muscle endurance training (3). The above limitations could be addressed via a study design that examines a more comprehensive group of GH and scapular muscles. Also, each phase of the movement, concentric, eccentric, and isometric, could be examined independently. Previous literature has identified differences in EMG activity across the different phases of movement (1,9). Also, the utilization of a broader range of exercise volume and intensity may provide a deeper understanding of the implications of equipment selection.

The overhead press is a complex GH and scapular movement, and thus caution should be taken when interpreting the results of the present study. However, to the authors' knowledge, this is the first study to examine the use of a KB during an overhead press. A simple but effective methodology has been presented to compare resistance training implements of differing stability. Our primary findings suggest that there is a difference in muscle activity when using a KB in place of a DB during an overhead press. From these initial findings, we conclude that an individual looking to target primary movers may want to select a more stable implement during the overhead press. Based on this study, the DB yielded greater activation in the AD when compared to the less stable KB.

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