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ORIGINAL RESEARCH

CORE MUSCLE ACTIVITY DURING THE CLEAN AND JERK LIFT WITH BARBELL VERSUS SANDBAGS AND WATER BAGS

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ABSTRACT

Purpose/Background: While the traditional clean and jerk maneuver implies simultaneous participation of a large number of muscle groups, the use of this exercise with some variations to enhance core muscle activity remains uninvestigated. The purpose of this study was to compare the muscle activity during clean and jerk lift when performed with a barbell, sandbag and a water bag at same absolute load.

Study Design: Descriptive, repeated-measures study

Methods: Twenty-one young fit male university students (age: 25 ± 2.66 years; height: 180.71 ± 5.42 cm; body mass: 80.32 ± 9.8 kg; body fat percentage: 12.41 ± 3.56 %) participated. Surface electromyographic (EMG) signals were recorded from the anterior deltoid (AD), external oblique (OBLIQ), lumbar erector spinae (LUMB), and gluteus medius (GM) and were expressed as a percentage of the maximum voluntary isometric contraction (MVIC).

Results: There were no significantly significant differences for AD muscle activity between conditions, whereas muscle activation values for OBLIQ (60%MVIC), GM (29%MVIC) and LUMB (85%MVIC) were significantly higher during the water bag power clean and jerk maneuver when compared with the other conditions.

Conclusions: The clean and jerk is an exercise that may be used to enhance core muscle activity. Performing the maneuver with water bags resulted in higher core muscle activity compared with sandbag and standard barbell versions

Level of Evidence: 3

Keywords: Muscle activation, olympic lift, resistance training, weight lifting

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INTRODUCTION

The clean and jerk is an Olympic lift that involves multi-joint movements while using fast movement velocity, typically used by athletes to improve muscular power.[1] Indeed, performance in the hang power clean has been correlated 20-m sprint, countermovement jump performance,[2] and several strongman tests.[3] As a result, power cleans are commonly used to assess and monitor the effectiveness of training programs, providing valuable power and strength information.[4] The clean and jerk exercise involves complex and synchronized neural recruitment patterns. As the barbell is elevated successively higher above the base of support,[5] simultaneous participation of a large number of muscle groups is required, balance disturbances occur, and thus a postural control challenge is provided. These facts suggest that the clean and jerk may be used to induce different muscle strength adaptations not only for athletic conditioning but also in the clinical setting. Significant positive associations have been found between the power clean and several core isometric endurance strength tests used in the clinical setting, such as trunk flexion (r = 0.396), back extension (r = 0.449), right flexion (r = 0.519) and left flexion (r = 0.460).[6] However, there is only one study evaluating electromyographic (EMG) activity during the clean and jerk, and data were measured only during different static phases of the movement[5] so results may differ when a dynamic condition is used for analysis of this movement. Moreover, the use of maximal speeds to perform the exercise can provide a greater increase in muscle activity compared with lower speeds[7] and could provide high challenges for the activation of postural muscles.

The clean and jerk is commonly performed using a barbell. However, during the last decade, performance of classic multi-joint strength exercises with additional instability elements have become popular[8] and have been studied with the purpose of understanding their use during rehabilitation.[8,9] The number of alternative unstable devices is growing and their use is common at fitness facilities and physical therapy centers. For example, the use of bag implements (water or sand filled) as a resistance training element has increased over recent years.[10] Sandbags or water bags may be used to perform different lifting movements and also to simulate contact and throws, requiring participation of a large number of muscles, facilitating specific adaptations in occupational tasks that require lifts and dragging objects or persons.[10] However, the use of sandbags in the scientific literature and their effect on EMG measures during exercise remain uninvestigated. The disruptive and unpredictable forces that are provided by sandbags or water bags require continuous body stabilization, especially when high speeds are used.

Core strength is an important element in low back pain and rehabilitation,[11] related to both muscle endurance and motor control.[8] Wang et al[9] found in their recent meta-analysis that core training had greater effectiveness than general exercise in decreasing pain and improving physical function in patients with chronic low back pain in the short term. Instability resistance training has the aim of stressing and reprogramming feed-forward and feedback systems and may be useful to induce greater core activity when high loads cannot be used in the presence of injury-susceptible joints or as a first step before using high loads in untrained people.[8] Even low core muscular activity (EMG) values may provide an effective stimulus to promote motor control improvements and provide benefits in those with low back pain.[8] Hence, the use of the clean and jerk in the stable version and performed with more unstable devices (e.g., sandbags and water bags) may be novel and good methods to enhance core muscle activity and improve core strength. The perturbations provided by the unstable versions of the clean and jerk may provide additional stimulus for muscle recruitment and benefits for core training in comparison with the traditional stable version. With this in mind, the purpose of this study was to compare muscle activity during the standard clean and jerk and the same exercise performed with a sandbag and a water bag. The authors hypothesized that unstable clean and jerk lifting (sandbag and water bag versions) would demonstrate greater core muscle activity compared with the corresponding barbell exercise using the same absolute load of 20 kg.

METHODS

Participants

Young fit male university students (n = 21; age: 25 ± 2.66 years; height: 180.71 ± 5.42 cm; body mass:

80.32 ± 9.8 kg; body fat percentage: 12.41 ± 3.56 %) voluntarily participated in this study. Participants had a minimum of one year of resistance training experience, performing at least two sessions per week at moderate to vigorous intensity. In addition, participants had to be familiar with the clean and jerk exercise. None of the participants had musculoskeletal pain, neuromuscular disorders, or any form of joint or bone disease. All participants signed an institutional informed consent form before starting the protocol, and the institutions' review board approved the study (H1421157445503). All procedures described in this section comply with the requirements listed in the 1975 Declaration of Helsinki and its amendment in 2008.

Procedures

Each participant took part in two sessions: familiarization and experimental sessions both at the same hour during the morning. The first session occurred 48-72 hours (hrs) before the data collection in the experimental session. Several restrictions were imposed on the volunteers: no food, drinks or stimulants (e.g. caffeine) to be consumed two hrs before the sessions and no physical activity more intense than daily activities 12 hrs before the exercises. They were instructed to sleep at least eight hrs the night before data collection.

During the familiarization session, height (IP0955, Invicta Plastics Limited, Leicester, England), body mass and body fat percentages (Tanita model BF-350) were obtained. An assistant researcher showed the proper clean and jerk technique, in accordance with the NSCA guidelines.[12] Then, the participants were familiarized with the different conditions, movement amplitude, body position, and load that would later be used during data collection. Participants practiced the three exercises until they felt confident and the researcher was satisfied that proper form was achieved. The three different conditions (Figure 1, Figure 2, Figure 3) were performed with the same absolute load (i.e., 20 kg) since this was the maximal weight that could be achieved by either type of bag. The load of both bags was checked before starting each testing session.

The protocol started with a light warm-up, where each participant performed five minutes of mobility drills

Figure 1. *The clean and jerk exercise performed using a barbell.*

without ballistic movements and then performed five repetitions of traditional clean and jerk without additional load (i.e., only with a 10 kg barbell). The protocol continued with the preparation of participants' skin, and followed by electrode placement, MVIC collection and exercise performance. Hair was removed from the skin overlying the muscles of interest, and the skin was then cleaned by rubbing with cotton dipped in alcohol for the subsequent electrode placement, positioned according to established recommendations[13] on the anterior deltoid (AD), external oblique (OBLIQ), lumbar erector spinae (LUMB) and gluteus medius (GM), on the dominant side of the body. Pre-gelled bipolar silver/silver chloride surface electrodes (Blue Sensor M-00-S, Medicotest, Olstykke, Denmark) were placed with an interelectrode distance of 20 mm. The reference electrode was placed between the active electrodes, approximately 10 cm away from each muscle, according to the manufacturer's specifications. All signals were acquired at a sampling frequency of 1 kHz, amplified and converted

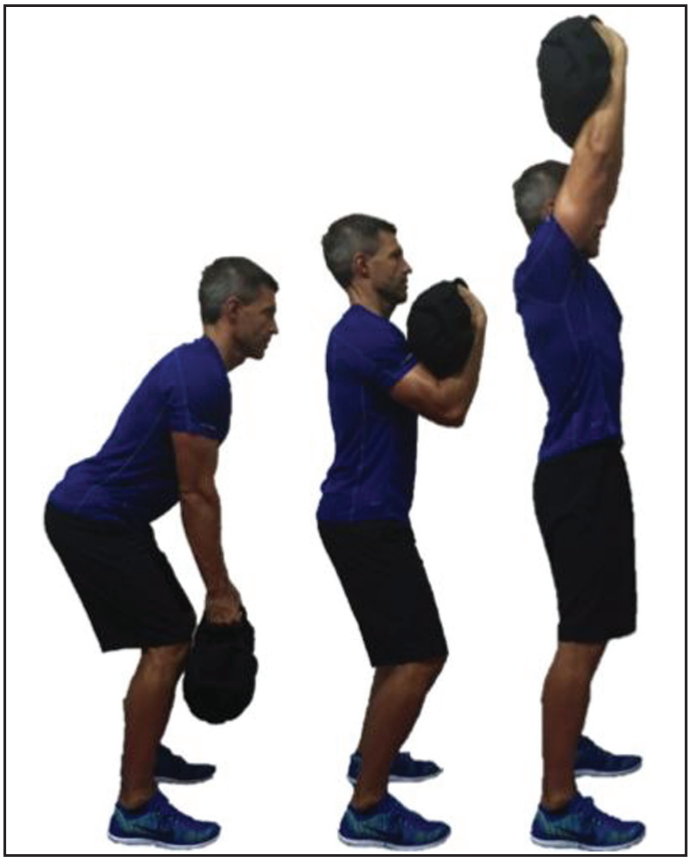

Figure 2. *The clean and jerk exercise performed using the sandbag.*

Figure 3. *The clean and jerk exercise performed using the water bag*

from analog to digital. All records of myoelectrical activity (in microvolts) were stored on a hard drive for later analysis. To acquire the surface EMG signals produced during exercise, an ME6000P8 (Mega Electronics, Ltd., Kuopio, Finland) biosignal conditioner was used. Prior to the exercise performance described below, two five second MVICs were performed for each muscle and the trial with the highest EMG was selected. Participants performed one practice trial to ensure that they understood the task. One minute of rest was given between each MVIC and verbal encouragement was provided to motivate all participants to achieve maximal muscle activation. Positions during the MVICs were based on standardized muscle testing procedures for the 1) AD,[14] 2005), 2) OBLIQ,[15] 3) LUMB,[16]4) GM[16] and were performed against a fixed immovable resistance (i.e., Smith machine). Specifically, 1) deltoid flexion at 90º in a seated position with erect posture and no back support, 2) a trunk curl up at 40º with arms on chest and pressing against the bar in an oblique direction with the participant lying on the bench, with the feet flat on the bench and the knees bent at 90˚, 3) trunk extension with the participant lying on the bench and pelvis fixated, the trunk was extended against the bar, and 4) hip abduction at 30º against the bar with the participant positioned sidelying on their nondominant limb.

Participants performed the clean and jerk in accordance with established exercise technique guidelines.[12] The upward movement of the bar was performed in one continuous motion without interruption as explosive as was possible. 1-second rate for descent to the clean and 1-second rate more for descent to the initial position was used before starting the subsequent repetition. Cadence of the descent movement was controlled with the use of a metronome set at 60 bpm (Ableton Live 6, Ableton AG, Berlin, Germany). Visual and verbal feedback was given to the participants in order to maintain the range of movement and hand distance during the data collection. Each participant performed three consecutive repetitions in the three conditions, with two minutes resting between exercises.

Data analysis

All raw EMG signals obtained during MVCs as well as during the exercises were digitally filtered using 1) high-pass filtering at 10 Hz, and 2) a moving root-mean-square (RMS) filter of 500 ms. For each individual muscle, peak RMS EMG of the three repetitions performed at each level was determined, and the average value of these three repetitions was then normalized to the maximal RMS EMG obtained during MVIC.

Statistical Analyses

A two-way repeated measures analysis of variance (Proc Mixed, SAS version 9, SAS Institute, Cary, NC) was used to determine if differences existed between exercises and muscles. Factors included in the model were *Exercise* (3 exercises) and *muscle* (4 muscles), as well as *Exercise* by *muscle* interaction. Normalized EMG was the dependent variable. Values are reported as least square means (SE) unless otherwise stated and p-values < 0.05 were considered statistically significant.

RESULTS

AD muscle activity showed no statistically significant differences between conditions. OBLIQ ($p < 0.01$), GM ($p < 0.05$) and LUMB ($p < 0.05$) muscle activation values were higher in the water bag clean and jerk when compared with the other conditions. Complete results and muscle activations values expressed as a %MVIC are represented in Table 1.

DISCUSSION

The main finding of the current study was that clean and jerk lifting with water bags provided greater core muscle activation than traditional barbell version or the sandbag version. This is the first study to compare the level of muscle activity during different variations of resistance offered during the clean and jerk lift. However, other multi-joint exercises on stable and unstable surfaces have been investigated. Willardson, Fontana and Bressel[17] found the same OBLIQ muscle activation during the deadlift, vertical shoulder press and the squat when the exercises were performed with the same absolute load on a BOSU and on a stable surface. Same muscle activation patterns were found in some studies that used relative loads (loads previously measured for each of the different conditions). For instance, Saeterbakken & Fimland[18] found the same OBLIQ muscle activity when participants performed a squat at a one-repetition maximum (RM) under different unstable/stable conditions. In another study with relative intensities (10RM), differences between the barbell shoulder press and the dumbbell counterpart (which the authors considered an unstable load) were nonexistent.[19] However, when the barbell exercise was performed on a Swiss ball, decreased activation was found in comparison with the version performed on a bench, probably due to the higher force production that was found during the most stable conditions.[19] In contrast to the unstable moving objects used during the present study (sandbag or the water bag), previ-

Table 1. *Mean muscle activation between conditions (n = 21)*

	Traditional	Sandbag	Water bag
AD	70±6.1 (61-81)	69±5.5 (61-80)	77±5.7 (68-88)
OBLIQ	26±4.7 (16-35)	27±4.9 (18-37)	60±7.9 (51-70)*
LUMB	74±4.0 (66-85)	70±4.2 (62-81)	85±4.9 (76-96)*
GM	23±2.4 (15-34)	22±2.3 (14-33)	29±2.3 (22-40)*

Data are expressed as least square means ± SEM (Confident intervals) in percentage of the maximum voluntary isometric contractions (MVIC). AD= anterior deltoid; OBLIQ= external oblique; LUMB= lumbar erector spinae; GM= gluteus medius.
*Difference between conditions statistically significant at $p \leq 0.05$

ously mentioned studies used unstable platforms or surfaces that served as a base upon which to perform the exercise rather than unstable implements. In the current study, it seems that instability provided by the sandbags was not enough to produce muscle activation alterations. Asymmetrical movements may produce alterations in loading[20] that may specially affect OBLIQ activation because of their role as a rotator and trunk stabilizer.[21] In this study, the water bag could have provided greater asymmetrical disturbances during the exercise due to the fluidity of the water, especially during the final moments of the exercise.

The water bag condition was superior in enhancing LUMB muscle activation. Since this core muscle acts as a spine stabilizer,[11] it was expected that greater muscle activation levels would appear during conditions requiring higher postural control. However, it seems that when the same absolute load is used across conditions, greater LUMB activation is reached only when higher instability is induced and greater challenge to the postural control systems are provided. For example, similar LUMB muscle activation has been found during a deep squat on a Reebok core board[22] and a squat, deadlift or vertical shoulder press on a BOSU compared with the stable counterparts.[17] However, the absence of differences could be explained by the lower instability challenges provided by these devices. In fact, moderately unstable devices like the BOSU failed to enhance muscle activity during squats performed by highly resistance-trained participants.[23] In accordance with the current results, Anderson & Behm[24] found that unstable squats performed with the same absolute load provoked higher LUMB muscle activation compared to stable squats performed with the Smith machine and free weights. Indeed, as occurred in the current study, no significant differences were identified during conditions with lower instability difference (i.e., traditional and sandbag conditions). In general, different findings are reported in those studies that used a relative load, where the greater force production that is allowed during the most stable conditions seems to be a key factor for increasing LUMB muscle activity as was demonstrated during a barbell shoulder press at 10RM[19] and stable deadlifts at 70% of the maximum isometric force.[25] However, previous literature suggests that all the three options that were used in the current study may provide sufficient levels of muscle activity to improve motor control function.[8]

Similar muscle activation patterns were repeated for the GM, where only the water bag condition produced higher activity than the other conditions. Similar to the current results, Wahl and Behm[23] showed that some unstable surfaces did not produce higher muscle activity during squat exercises in highly resistance-trained individuals. More recently, no GM muscle activation differences were observed when participants performed a deep squat task with the same absolute load on a stable and unstable surface.[22] As in the previously mentioned studies, the addition of an unstable surface did not provoke significantly greater GM activation when compared with stable surfaces during either single limb stance or single limb squat exercises performed with only body weight.[26] However, positions or exercises that required higher postural control adjustments such as single limb stance or single limb squats demonstrated enhanced GM activity when compared with their double limb counterparts,[26] which highlights the role of this muscle as a hip and pelvis stabilizer.[27] These results and the current findings suggest that when an adequate degree of instability is achieved, higher GM activity may be reached when exercises are performed at the same absolute load.

Muscle activity of the AD was not significantly different across the different clean and jerk exercises. Likewise, stable/unstable conditions during the shoulder press exercise with a relative[19] or the same absolute load[28] showed an absence of differences. These results may be explained by the glenohumeral stabilizer function provided by this muscle[29] and the necessity of it being activated to stabilize during either unstable loads (as occurred in the current investigation) or unstable surfaces.[19] In addition, as was previously reported in other studies where the AD had a primary mover role during the exercise performance, it seems that stable conditions may provide greater or similar muscle activation levels as more unstable conditions.[30]

The use of non-injured participants may be the main limitation in the current study and thus caution should be taken when attempting to extrapolate these results to injured populations. However, the current study provides the first data about the use of unstable devices during the clean and jerk, indicating that there may be additional benefits to the use of such devices. However, sand and water bags are limited by the amount of weight that can be achieved in each. For example, in the current research the maximal allowed load of both bags was 20 kg. The authors decided that EMG evaluation with the same absolute load would provide valuable and applicable results for when these devices are available at physical therapy or training centers and there is no possibility to measure and calculate a maximal relative load. Future studies should be conducted to investigate the effectiveness of these exercises in relation to various injury conditions.

CONCLUSIONS

The results of the present study support the use of a low-load clean and jerk maneuver as an effective exercise to strengthening the core. These data illustrate that the clean and jerk performed with sandbags does not provide additional benefits to one performed with a bar. However, the clean and jerk performed with the water bag did increase core muscle activation compared to the other conditions. Thus, when barbell, sandbags and water bags with the same low loads are available to perform the clean and jerk exercise, greater core training stimulus would be achieved by using the water bag.

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