

AN EXAMINATION OF MUSCLE ACTIVATION AND POWER CHARACTERISTICS WHILE PERFORMING THE DEADLIFT EXERCISE WITH STRAIGHT AND HEXAGONAL BARBELLS

KEVIN D. CAMARA, JARED W. COBURN, DUSTIN D. DUNNICK, LEE E. BROWN, ANDREW J. GALPIN, AND PABLO B. COSTA

Department of Kinesiology, Center for Sport Performance, California State University, Fullerton, California

ABSTRACT

Camara, KD, Coburn, JW, Dunnick, DD, Brown, LE, Galpin, AJ, and Costa, PB. An examination of muscle activation and power characteristics while performing the deadlift exercise with straight and hexagonal barbells. *J Strength Cond Res* 30(5): 1183–1188, 2016—The deadlift exercise is commonly performed to develop strength and power, and to train the lower-body and erector spinae muscle groups. However, little is known about the acute training effects of a hexagonal barbell vs. a straight barbell when performing deadlifts. Therefore, the purpose of this study was to examine the hexagonal barbell in comparison with the straight barbell by analyzing electromyography (EMG) from the vastus lateralis, biceps femoris, and erector spinae, as well as peak force, peak power, and peak velocity using a force plate. Twenty men with deadlifting experience volunteered to participate in the study. All participants completed a 1 repetition maximum (1RM) test with each barbell on 2 separate occasions. Three repetitions at 65 and 85% 1RM were performed with each barbell on a third visit. The results revealed that there was no significant difference for 1RM values between the straight and hexagonal barbells (mean $\pm$ SD in kg = 181.4 ± 27.3 vs. 181.1 ± 27.6 , respectively) ($p > 0.05$). Significantly greater normalized EMG values were found from the vastus lateralis for both the concentric (1.199 ± 0.22) and eccentric (0.879 ± 0.31) phases of the hexagonal-barbell deadlift than those of the straight-barbell deadlift (0.968 ± 0.22 and 0.559 ± 1.26), whereas the straight-barbell deadlift led to significantly greater EMG values from the bicep femoris during the concentric phase (0.835 ± 0.19) and the erector spinae (0.753 ± 0.28) during the eccentric phase than the corresponding values for the hexagonal-barbell deadlift (0.723 ± 0.20 and 0.614 ± 0.21) ($p \leq 0.05$). In addition, the hexagonal-barbell deadlift demonstrated

significantly greater peak force ($2,553.20 \pm 371.52$ N), peak power ($1,871.15 \pm 451.61$ W), and peak velocity (0.805 ± 0.165) values than those of the straight-barbell deadlift ($2,509.90 \pm 364.95$ N, $1,639.70 \pm 361.94$ W, and 0.725 ± 0.138 m·s⁻¹, respectively) ($p \leq 0.05$). These results suggest that the barbells led to different patterns of muscle activation and that the hexagonal barbell may be more effective at developing maximal force, power, and velocity.

KEY WORDS electromyography, vastus lateralis, biceps femoris, erector spinae, peak power, peak force, peak velocity

INTRODUCTION

The deadlift exercise is widely used by athletes of many sports, as well as recreational lifters, to enhance power and strength (20). The exercise is a multijoint movement that activates several large muscle groups. Research has shown that, compared to other free weight exercises, the deadlift involves the lifting of heavier loads (1,10). The ability to lift heavier loads elicits a larger stimulus to adapt, making it ideal for enhancing muscular strength, which contributes to power (20). The movement requires grasping a barbell while in a squatting position and then elevating the barbell by extending the hips, knees, and ankles. When the hips are fully extended the concentric portion of the movement has ended. The barbell traveling downward until it reaches the floor or starting position completes the eccentric portion of the deadlift. The movement begins with the barbell starting at the midleg level and should remain close to the leg, thighs, and hips as the barbell elevates (1). It is vital that the barbell remain close to the lower extremities throughout the lift to reduce the moment arm of the barbell at the individual joints, decreasing the resistance of the external load (7).

In comparison with other strength exercises, such as the squat, the deadlift has received comparatively little research interest (2,4,5,9,11,13,19). A common belief is that the deadlift and back squat have similar movement patterns and that it is acceptable to relate theories and new findings between the 2 exercises. However, this was shown to be false through

Address correspondence to Jared W. Coburn, [jacoburn@fullerton.edu](mailto:jcoburn@fullerton.edu).
30(5)/1183–1188

Journal of Strength and Conditioning Research
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a kinematic analysis showing different movement patterns between the 2 exercises (8). Clearly, further research is needed to better understand the deadlift and optimize its use in training.

Strength and conditioning professionals typically include the deadlift in their programs to strengthen the legs, hips, back, and torso musculature (1,20). Variations of the deadlift are also often performed to alter the movement patterns and muscular requirements of the exercise. One popular variation is the hexagonal-barbell deadlift. The hexagonal design of the barbell is theorized to shift the stress from the lower back, hips, and hamstrings to the quadriceps femoris. Theoretically, this would be a more advantageous position and reduce external forces and injuries to the lumbar spine. However, little research exists on performing deadlifts with a hexagonal barbell (Figure 1) (6,14).

To date, one study has compared the hexagonal barbell with a straight barbell during the deadlift exercise. The results indicated that the hexagonal barbell reduced stress on the lumbar region while enhancing force, velocity, and power (16). To our knowledge, however, no previous studies have simultaneously examined muscle activation and power characteristics while performing the deadlift exercise with a straight vs. hexagonal barbell. Therefore, the purpose of this study was to further investigate the hexagonal barbell in comparison with a straight barbell while performing the deadlift, through an analysis of electromyography (EMG), force, velocity, and power characteristics.

METHODS

Experimental Approach to the Problem

A repeated-measures design was used to compare the effects of deadlifting with 2 different barbells on EMG (vastus lateralis, bicep femoris, and erector spinae) and force plate

data (peak force, power, and velocity). Participants visited the laboratory for 3 testing sessions. Each session began with a dynamic warm-up consisting of knee pulls, walking lunges, and alternating leg swings. The first 2 sessions consisted of 1 repetition maximum (1RM) testing with each barbell in a randomized order. The third session consisted of 3 repetitions with submaximal loads of 65 and 85% 1RM for each barbell, with the order of barbells randomized for each participant. We chose these 2 loads to determine whether the 2 barbells had different effects when using loads associated with power (65% 1RM) vs. strength development (85% 1RM).

Subjects

Twenty men, 19 to 27 y, (mean $\pm$ SD age = 23.3 ± 2.1 y, height = 176.8 ± 7.6 cm, body mass = 89.9 ± 18.3 kg,) who performed three days per week of resistance training, including deadlifting once per week for the past year, volunteered to participate in the study. Participants were disqualified from the study if they were not capable of lifting one and one half times their body weight with either bar. All procedures were approved by the University Institutional Review Board for Human Subjects and the participants signed informed consent forms before any testing. Participants were also instructed to avoid any lower-body resistance training 48 hours before each session.

One Repetition Maximum Testing

For deadlift 1RM testing, subjects were required to warm up for 10 repetitions at 50%, 5 repetitions at 70%, 3 repetitions at 80%, and 1 repetition at 90% of their predicted 1RM (1). Three minutes of rest were given between warm-up sets. During 1RM attempts, the weight was increased in increments of 5–20 pounds until the subjects were able to only complete 1 repetition successfully. If the subjects were not able to execute the lift successfully, the weight was reduced by 5–10 pounds. Subjects were given up to 5 single-repetition sets to determine their 1RM. All deadlifts were performed using a conventional stance. A lift was deemed successful if at the end of the ascent phase the participant stood erect with knees and hips extended, the torso upright, and the shoulder girdle retracted. During each condition, participants were allowed normal deadlifting shoes and chalk; however, these remained consistent for all conditions. No belts or straps were used.

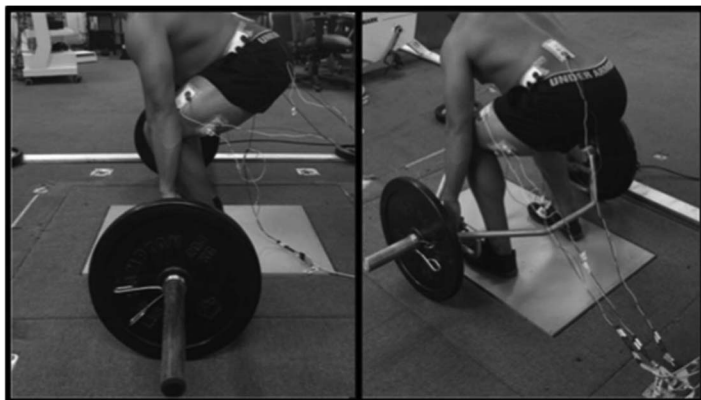


Figure 1. Deadlift performed with straight (left) and hexagonal (right) barbells.

Experimental Trials Testing Procedure

This testing session was separated by a minimum of 48 hours from the previous session. Data collection then consisted of 3 repetitions at 65% and 3 repetitions at 85% with each barbell. Participants were instructed to perform each repetition with maximal velocity during the concentric phase of the lifts, then to lower the bar under control during the eccentric phase. The order of bars was randomized. All repetitions were performed with 3 minutes of rest, and 5 minutes of rest was given between lifts with each bar.

Electromyography

Electromyography data were collected during each visit. Before collection, each participant's skin was prepared for EMG electrode placement by shaving the hair on the skin, mild abrasion, and cleaning with isopropyl alcohol. Electromyography data were collected and stored on a personal computer (Dell Latitude D610; Dell, Round Rock, TX, USA). Three separate bipolar (3.5-cm center-to-center) surface electrode (BIOPAC EL500 silver-silver chloride; BIOPAC Systems, Inc., Goleta, CA, USA) arrangements were placed over the biceps femoris, vastus lateralis, and erector spinae (longissimus) muscles, with the reference electrodes placed over the iliac crest. The biceps femoris electrodes were placed at 50% of the distance along the line between the ischial tuberosity and the lateral epicondyle of the tibia. Electrodes for the vastus lateralis were placed 2/3 of the distance on the line from the anterior superior iliac spine to the lateral side of the patella. For the erector spinae (longissimus), 2 electrodes were placed at a width of 2 fingers, lateral from the spinous process of L1. All measurements were taken on the left side of the participant's body. The EMG signals were preamplified (gain 1,000 $\times$) using a differential amplifier (EMG 100C, bandwidth = 1–500 Hz; BIOPAC Systems, Inc., Santa Barbara, CA, USA).

The EMG signals were band-pass filtered (fourth-order Butterworth) at 10–500 Hz. The amplitudes of the signals were expressed as root mean square values. All analyses were performed with custom programs written with LabVIEW software (version 7.1; National Instruments, Austin, TX,

USA). The EMG values for the experimental condition repetitions were normalized to the EMG values achieved during the concentric phase of the straight-barbell 1RM tests. These normalized EMG values for the 3 repetitions performed with each load (65 and 85% 1RM) were then averaged before data analysis. Intraclass reliability values exceeding 0.9 were found for EMG amplitude values.

Force and Velocity

A velocity transducer (Model V-80-L7M; UniMeasure, Inc., Corvallis, OR, USA) was attached to the end of each barbell. An AMTI force plate (Watertown, MA, USA) was used to collect force data. Both the linear velocity transducer and the AMTI force plate were connected to a desktop computer running custom LabVIEW data collection and analysis software (version 2013; National Instruments Corporation). As with the EMG data, the 3 repetitions performed with each load (65 and 85% 1RM) were averaged before data analysis. Intraclass values between 0.8 and 0.9 for force plate measures have previously been reported from our lab.

Statistical Analyses

A 2 (barbell: straight and hexagonal) $\times$ 2 (phase of movement: concentric and eccentric) $\times$ 2 (load: 65 and 85% 1RM) $\times$ 3 (muscle: vastus lateralis, biceps femoris, and erector spinae) repeated-measures analysis of variance (ANOVA) was used to analyze the normalized EMG amplitude data for each muscle. Follow-up tests included ANOVAs and paired *t*-tests with Bonferroni corrections as appropriate. Three separate 2 (barbell: straight and hexagonal) $\times$ 2 (load: 65 and 85% 1RM) repeated-measures ANOVAs were used to determine differences for peak force, power, and velocity between barbells. An alpha level of 0.05 was used to determine statistical significance. IBM SPSS Statistics 21 was used to perform all statistical analyses.

RESULTS

There was no significant difference in deadlift 1RM values between the straight and hexagonal barbells (mean $\pm$ SD in kg = 181.4 $\pm$ 27.3 vs. 181.1 $\pm$ 27.6, respectively). For

TABLE 1. Normalized electromyography (EMG) amplitude values (mean $\pm$ SD) for the straight and hexagonal barbells, collapsed across 65 and 85% 1 repetition maximum loads.*

	Straight barbell		Hexagonal barbell	
	Concentric	Eccentric	Concentric	Eccentric
Vastus lateralis	0.968 $\pm$ 0.22	0.559 $\pm$ 1.26	1.199 $\pm$ 0.22†	0.879 $\pm$ 0.31†
Biceps femoris	0.835 $\pm$ 0.19‡	0.347 $\pm$ 0.11	0.723 $\pm$ 0.20	0.315 $\pm$ 0.10
Erector spinae	0.989 $\pm$ 0.26	0.753 $\pm$ 0.28‡	0.880 $\pm$ 0.27	0.614 $\pm$ 0.21

*All concentric normalized EMG amplitude values exceed corresponding eccentric values.

†Significantly greater normalized EMG amplitude value for hexagonal vs. corresponding straight barbell value ($p \leq 0.05$).

‡Significantly greater normalized EMG amplitude value for straight vs. corresponding hexagonal barbell value ($p \leq 0.05$).

TABLE 2. Peak ground reaction force, power, and velocity for straight and hexagonal barbells, collapsed across 65 and 85% 1 repetition maximum loads.*

	Straight barbell	Hexagonal barbell
PGRF (N)	2,509.90 ± 364.95	2,553.20 ± 371.52†
PP (W)	1,639.70 ± 361.94	1,871.15 ± 451.61†
PV (m·s ⁻¹)	0.725 ± 0.138	0.805 ± 0.165†

*PGRF = peak ground reaction force; PP = peak power; PV = peak velocity.

†Significantly greater value for hexagonal vs. corresponding straight barbell value ($p \leq 0.05$).

normalized EMG amplitude (Table 1), there was no significant 4-way interaction ($p > 0.05$). There was, however, a significant 3-way interaction (barbell $\times$ phase $\times$ muscle) ($p \leq 0.05$). This was followed up with 2-way ANOVAs: (phase $\times$ muscle), 1 for each barbell; (barbell $\times$ phase), 1 for each muscle; (barbell $\times$ muscle), 1 for each phase. Significant interactions were then followed up with separate paired t -tests as appropriate. These results revealed that normalized EMG amplitude for the vastus lateralis was significantly greater with the hexagonal barbell than with the straight barbell, regardless of phase, whereas it was greater for the biceps femoris (concentric phase only) and erector spinae (eccentric phase only) with the straight bar than with the hexagonal bar ($p \leq 0.05$). For all 3 muscles and both barbells, the concentric phase demonstrated greater EMG amplitude values than the eccentric phase ($p \leq 0.05$).

For the force plate data (peak ground reaction force, peak power, and peak velocity), there were no significant 2-way (barbell $\times$ load) interactions ($p > 0.05$) (Table 2). There were, however, significant main effects for the barbell and load ($p \leq 0.05$). Peak ground reaction force, peak power, and peak velocity were all greater for the hexagonal barbell than for the straight barbell. In addition, peak ground reaction force was greater for the 85% 1RM load, whereas peak power and peak velocity were greater for the 65% 1RM load.

DISCUSSION

The purpose of this study was to examine the effects of performing the deadlift exercise (65 and 85% 1RM) with a hexagonal barbell vs. straight barbell on 1RM values, muscle activation, peak ground reaction force, peak power, and peak velocity. There were no significant differences in 1RM values between the bars. The EMG results revealed that the normalized EMG amplitude values from the vastus lateralis were significantly greater for the hexagonal barbell vs. straight barbell, during both the concentric and eccentric phases. More specifically, the hexagonal barbell led to a more quadriceps-dominant movement. Conversely, with greater normalized EMG amplitude values being evident from the biceps femoris and erector spinae muscles during the concentric and eccentric phases, respectively, the straight

barbell seemed to use more of the hamstrings and lower back. Furthermore, deadlifts with the hexagonal barbell demonstrated higher peak velocity, peak force, and peak power than deadlifts with the straight barbell.

To our knowledge, only one previous study has examined deadlifts with a hexagonal barbell in comparison with a straight barbell (16). Although no significant difference in 1RM values between the bars were found in the present study, the participants in the study of Swinton et al. lifted an average of nearly 20 kg more with the hexagonal barbell compared than with a straight barbell (265.0 ± 41.8 vs. 244.5 ± 39.5 kg). These differences in findings may be a result of differences in the training experience of participants in the 2 studies. The participants of the present study consisted of resistance-trained men that had deadlifting experience (once a week for a minimum of 1 year). However, experience deadlifting with a hexagonal barbell was neither required nor common. The participants in the study of Swinton et al. consisted of competitive men powerlifters from the Scottish Powerlifting Association. Although no direct hexagonal-barbell deadlifting experience was reported, professional strength athletes, such as powerlifters and strongmen competitors, often use several variations of the deadlift, squat, and bench press to enhance their performance (15,18). Therefore, it is likely that these athletes had more deadlifting experience with a hexagonal barbell or other deadlift variations. Perhaps with more training experience with the hexagonal barbell, participants in the present study would have been able to lift more weight with the hexagonal barbell than with the straight barbell.

The EMG results of the present study are in agreement with the kinematic findings of Swinton et al. (16). Swinton et al. (16) concluded that the hexagonal barbell significantly increased the peak moment at the knee and reduced the peak moment at the lumbar spine and hip (16). The increased moment at the knee demonstrated with the hexagonal barbell should theoretically lead to increased muscle activation of the quadriceps femoris muscle group. This is precisely what was found in the present study, where normalized EMG amplitude data from the vastus lateralis was greater for deadlifts performed with the hexagonal barbell

than the deadlifts performed with the straight barbell. Furthermore, it has been demonstrated that there is an increase in the moment around the hip when deadlifting with a straight barbell vs. a hexagonal barbell (16). The results of the present study are in agreement with this finding because EMG amplitude from the biceps femoris during the concentric phase was greater for the straight barbell vs. hexagonal barbell. Finally, Swinton et al. (16) reported that the straight barbell increased the moment at the lumbar spine, which is consistent with the present study because significantly greater normalized EMG values in erector spinae were demonstrated while using the straight barbell during the eccentric phase.

As with the present study, the higher force, power, and velocity demonstrated with a hexagonal-barbell deadlift in comparison with the straight-barbell deadlift has been reported previously (16,17). The weighted vertical jump is a common movement frequently used to enhance power. The results of a study by Swinton et al. (17) suggested that the straight-barbell vertical jump method is an inferior technique to the hexagonal-barbell vertical jump method. With a 20% load, peak velocity, peak force, peak power, average power, and rate of force development were all increased with the hexagonal barbell. The design of the hexagonal barbell seems to allow the user to maintain a more advantageous position in the starting phase and throughout the movement allowing for enhanced velocity, force, and power. The hexagonal barbell may be a more effective method for not only enhancing force production for the deadlift exercise but also increasing explosive power when performing squat jumps (16,17). It should be noted that these suggestions are drawn from studies examining acute effects, whereas long-term training effects are unknown.

When analyzing the starting phase of the deadlift with a straight barbell, it has been shown that the hip is flexed the greatest followed by the knee, torso, and ankle (5,12,16). In contrast, the starting phase of a deadlift with a hexagonal barbell demonstrates an increase of knee flexion, with no difference among the hip, torso, or ankle joints (16). This suggests that the hexagonal barbell is a more quadriceps-dominant movement and distributes the external load more evenly among the hip, ankle, and torso. When comparing barbell paths between hexagonal and straight barbells, the findings of Swinton et al. further support this claim. Swinton et al. (16) concluded that the design of hexagonal barbell allowed the load to be positioned closer to the body using the horizontal distance from the ankle as the point of measurement. As the lift with the hexagonal barbell progressed, the average horizontal displacement away from the lifter was reduced by 75% and increased displacement toward the lifter by 22% (16). The ability to maintain the load closer to the lifter's center of gravity may explain the greater force, power, and velocity found in the present study.

PRACTICAL APPLICATIONS

The ability to manipulate joint range of motion and muscle activation through barbell selection is valuable information for practitioners. The conventional, straight-bar deadlift is a common exercise that is frequently performed within athletic and recreational weight rooms. However, when performed with heavy loads, it can be the most taxing exercise on the lumbar region (3). For individuals with lower-back injuries or pain, the results of this study suggest that the hexagonal barbell may be the better choice for barbell selection because of its ability to evenly distribute the load among all joints and reduce the moment at the lumbar spine. Conversely, if the goal of the training session is to emphasize strengthening of the lumbar region and hamstrings, the straight barbell seems to be the appropriate choice. Finally, the hexagonal barbell may be a more effective method for maximizing force, power, and velocity during the deadlift.

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