

Differences in Muscle Activation and Joint Kinematics Between Deadlift Styles When Performed at High-Intensity Training Loads

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ABSTRACT

The purpose of this study was to compare the conventional (CDL), sumo (SDL) and hex-bar (HBD) deadlift actions at a high intensity training load across a wide range of leg and back muscles to explore which lift has the biggest impact on prime mover musculature. Twelve males (age: 19 ± 2 years; height: 1.81 ± 0.81 m; body mass: 85.64 ± 10.87 kg) performed 3 repetitions of HBD, CDL and SDL at a 90% 1RM intensity. Load lifted, EMG for the Erector Spinae Longissimus, Gluteus Maximus, Biceps Femoris, Semitendinosus, Rectus Femoris, and Vastus Medialis and knee and hip range were compared via effect size magnitude of change. The EMG results showed a general pattern of greater muscle activity, considered a large effect, during the HBD compared to the CDL and SDL, possibly due to the greater absolute load lifted during the HBD. The only anomaly to this was greater EMG activity for the bicep femoris within the CDL compared to the HBD, large effect, and the SDL, moderate effect. This finding was attributed to the greater hip flexion seen in the start position for the CDL compared to other lifts. These findings suggest that the HBD would be the preferred deadlift technique for total muscle recruitment and load lifted for high intensity (90% 1RM) training regimes. However, the CDL would be the preferred lift if bicep femoris muscle activity were a specific targeted requirement.

Keywords: deadlift technique, EMG, training recommendations

INTRODUCTION

The deadlift exercise is considered a key movement modality employed in a wide range of exercise regimes, particularly to challenge posterior chain function^{1,2}. The posterior chain musculature, comprising the gluteal, hamstring and triceps surae muscle groups, as well as the posterior portion of the trunk³. It is seen as an essential component for a number of actions in both sporting and everyday life⁴ and in particular, underpins human running and jumping actions¹. Because of the posterior chain's importance to human locomotion and its susceptibility to injury⁵, development through training is of great importance to practitioners interested in human function.

Research examining posterior chain training has broadly agreed that hip-dominant resistance exercises are the most frequently used and optimal training modality^{6-8,1,2}. However, the most effective exercise selection for developing the posterior chain is yet to be established¹.

The deadlift is considered a hip dominant exercise, frequently utilised in development of

athletic function. There are a number of ways this exercise can be performed, with the most common techniques being conventional, sumo and hexagonal/trap bar (hex-bar) styles⁹. The aim of each of these lifts is to displace a load from the floor to a standing position via a predominantly hip and knee extension action⁹. However, each style has a unique technical model consisting of a different kinematic sequence for each lift¹⁰.

The conventional deadlift promotes a start position with greater flexion at hip and knee and greater torso inclination compared to the sumo deadlift¹¹. The sumo style's more upright torso and more extended hip and knee position is caused by a narrower barbell grip and a wider stance position¹¹. The hex-bar deadlift has only been compared to the conventional deadlift to date, but was found to have a more upright torso, with a more flexed hip and knee in the start position of the lift¹⁰. This is due to the grip changing from in front of the lifter in the conventional version, to more laterally in the hex-bar, due to the hexagonal shape of the bar¹¹. However, despite these obvious technical differences and the popularity of these lifts within resistance training regimes, research comparing the lifts' muscle activation patterns and kinematics is limited. The existing research is dominated by research comparing sumo and conventional deadlifts^{12-15,9}, with little work exploring differences to the hex-bar deadlift, despite its growing popularity in the exercise industry.

Studies exploring muscle activation within these lifts have utilised surface EMG analysis^{1,16,8}. There is a consensus that conventional and sumo deadlifts promote posterior chain (back and hamstring) activation, with the hex-bar deadlift being more quadriceps-dominant^{16-18,7,1}. However, this analyses have been questioned with studies demonstrating that the quadriceps is the most active muscle group in all deadlift styles, followed by the gluteals and hamstrings, despite the deadlift being thought of as a hip extension exercise^{10,19,20,8,21}. The contradictions between some of the deadlift research could be due to an inability to describe actual training practices, particularly when strength is the aim of the training plan. Deadlift research into muscle activation tends to use multi repetition schemes, ranging from six to 12 repetitions. For instance, Escamilla et al¹⁶ indicated that the sumo deadlift was more quadriceps rather than posterior chain dominant. However, their use of 12RM as a load does not represent a lifting strategy designed to promote strength, with much higher intensities and lower lift

volumes a prerequisite for strength training¹⁰. This is particularly important if certain muscles are being targeted, as frequently lift technique will change as loads are increased closer to maximum lifting strategies⁹. This could potentially mean that muscle activation patterns will change from sub to maximal loads, meaning the musculature trained during a strength regime may be different to that trained in a lighter muscular endurance based session.

Escamilla et al¹⁰ compared conventional and sumo deadlift muscle activation across a range of back extensor, hip extensor, knee extensor and ankle plantar flexor muscles. They showed that there was an increase in vastus lateralis and vastus medialis activity in the sumo lift due to the increased knee range of motion utilised within this lift style. However, this research can be critiqued in a number of ways. Four repetitions were analysed at a 12 RM intensity (approximating 60% of 1RM). This intensity and volume does not represent a lifting regime suitable for strength or muscular endurance training and may not represent the recruitment profiles actually seen in real training scenarios²². EMG was reported at 90° joint angles, rather than through different phases of the lift from lift off to lock out, as most deadlift research reports^{23,24,11,21,9,10}. This means, as participants had different anthropometric characteristics; EMG was collected at different phases of the lift, making definitive observation of muscle activity potentially invalid.

Although the conventional deadlift is considered a more hamstring and back (posterior chain) dominant exercise, with the sumo and hex-bar action more quadriceps (anterior) dominant, this has yet to be validated by a direct comparison of all three deadlift styles at an intensity appropriate to actual strength training practices. This is particularly important, as Cholewicki et al⁹ showed changes in lift technique with higher intensity lifts. Therefore, this study aims to compare the conventional, sumo and hex-bar deadlift actions at a high intensity training load across a wide range of leg and back muscles to explore which lift has the biggest impact on prime mover musculature.

METHODS

Research design

This study implemented a within-participant, randomised, counterbalanced and repeated measures design. With participants required

to perform three interventions consisting of a conventional (CDL), sumo (SDL) and hex-bar deadlift (HBD).

Participants

Twelve males (age: 19 ± 2 years; height: 1.81 ± 0.01 m; body mass: 85.64 ± 10.87 kg) were invited to participate in this study. Details of experimental methods and procedures were provided via a participant Information Sheet and informed consent was obtained. Participants were injury-free for the previous six months, established via a health screen form. All participants had a minimum of one year gym experience, including performing maximal (100% 1RM) CDL, SDL and HBD. Appropriate gym clothing was worn, with each lift being conducted barefoot without socks. Lifting belts, lifting suits and knee wraps were not permitted. The study was approved by the University of Bedfordshire's Research Ethics Committee.

Data collection

Data collection was conducted at the participants normal lifting facility over three sessions separated by 72 hrs, to help minimise fatigue. Participants were required to continue regular eating habits, with no supplementation products taken pre-testing, post-testing or during the 72 hr interval between sessions. Familiarisation with testing procedures was completed 72 hrs before the first data collection session; including EMG set up and technical competency of the SDL, CDL and HBD. A UK Strength & Conditioning Association accredited Strength & Conditioning coach assessed lift competency. No participant was excluded due to incorrect lift technique.

Muscle activity

Muscle activity was analysed via surface electromyography (EMG; Biometrics Ltd, Cwmfelinfach, Gwent, Wales, UK) of the Erector Spinae Longissimus (ES), Gluteus Maximus (GM), Biceps Femoris (BF), Semitendinosus (ST), Rectus Femoris (RF), and Vastus Medialis (VM) muscles. Analysis was conducted on the dominant side of each participant (defined as their writing hand). Detection sites were prepared by first shaving and then cleaning with an alcohol wipe, optimising electrode skin contact and minimising artefact interference (< 55 k Ω). An earth electrode was attached to the lateral malleolus of the dominant leg with an R206 Earthing Strap. Electrodes were

attached with T350 Adhesive Pads following the guidelines of Hermens and Freriks²⁵. Electrodes were placed in pairs with a 2 cm spacing along the longitudinal axis of the muscle belly, parallel to the superficial fibres, while the muscle was under contraction. Surface pre-amplified (1k) SX230 electrodes with a 1000 Hz sampling frequency and 3 V channel sensitivity were attached directly via a USB port into an eight-ordered elliptical DLK900 Datalink filter (550 Hz) with muscle activity directly measured using analogue inputs by a PC using Datalink Software.

Muscle activity was normalised as a percentage of maximal voluntary isometric contraction (%MVIC), as recommended by Burdon et al²⁶. For each individual muscle, MVC was collected at the start of each testing session. Quadriceps musculature was recorded in a seated 70° knee extension position for RF and VM, with participants actively attempting to extend their knee²⁷. For the hamstrings musculature, BF and ST, a 70° knee flexion position was used, with participants flexing against an immovable object²⁸. The 70° extension and flexion knee joint angles were measured using a universal goniometer. Gluteus Maximus MVC was performed with participants lying prone with the knee slightly flexed and a standardised hip flexion angle of 20°. Participants actively attempted to extend their hip in an upwards motion²⁹. For the ES MVC, a roman chair was used positioning the hip at 45° of flexion, with the trunk parallel to the ground, participants actively extended their hip and trunk simultaneously³⁰. All MVIC's were performed for 5 seconds and repeated three times, with a rest period of 2-5 minutes between efforts, guided by participant's feedback RPE.

Kinematics

To measure hip and knee joint angles (°) Electron Goniometers (SG Series Goniometer) were synchronised in conjunction with EMG via J1000 lead and directly ported into DLK900 Datalink Filter. Before application, sites for goniometer placement were prepared by shaving and swabbed with an alcohol wipe, optimising goniometer attachment by facilitating good skin contact. The goniometers were attached by T350 Adhesive Pads, on the lateral aspect of the participant's non-dominant leg. Goniometer positioning was standardised, with participants stood in the anatomical position. The knee goniometer was attached 4 cm distally from the lateral epicondyle with the hip goniometer 4 cm distal from the greater trochanter²⁵. Kinematic

data was sampled at 200 Hz with a pre-set 2000 mV excitation output.

Deadlifts

Before each session, a warmup consisting of 10 minutes steady state cycling at 80 W (Watt Bike, Pro, Cranlea) was performed prior to a range of full body mobility exercises, after which lift type was allocated randomly. Deadlift actions were standardised by the use of universal weightlifting straps (preventing grip strength being a lift limitation) and a pronated overhand grip for the CDL and SDL and a neutral grip for the HBD. Start position foot position and knee angle were self-selected by the participant, but standardised between their 90% and 100% lifts. One repetition maximum (1RM) lift performance was established first, with three repetitions at 90% 1RM measured after a 60 minute rest period.

All lifts were performed on a weightlifting platform using a 20 kg weightlifting barbell for the CDL and SDL and a hex bar for the HBD, loaded using weightlifting plates (Eleiko, Halmstad, Sweden). The start position for all lifts (CDL Figure 1 a, SDL Figure 1 c and HBD Figure 1 e) was with the load resting on the floor. In one movement, participants lifted the barbell through a simultaneous hip and knee extension while preserving a neutral spine/flat back position. Lifts were completed (finish position) when the hips and knees reached an anatomical neutral standing position at approximately 180° (CDL Figure 1 b, SDL Figure 1 c and HBD Figure 1 f). The main difference between the HBD and other lifts was the load position. The CDL and SDL were performed with the load positioned in front of participants, causing the grip to be anterior to the lifter, while the HBD was performed with participants stepping inside the hex bar and lifting with arms positioned laterally (Figure 1 e).

The 1RM testing loading strategy was informed by Grgic et al³¹ systematic review of 1RM testing protocols²⁹. Sequentially heavier lifts were attempted with the percentage of 1RM attempted estimated, via a Borg scale (CR-10), based on participants' perceived effort (RPE). Rest periods were calculated as < 5 RPE = 1-2 minutes; 5-8 RPE = 2-5 minutes; > 8 RPE = 5 minutes. The first set allowed comfortable completion of 5-10 repetitions, at a perceived 50% of 1RM, with set two at 80% of perceived 1RM for 3 repetitions. The participants then continued adding additional loads of 5-10% perceived 1RM, completing 1 repetition, with 100% 1RM achieved within a maximum of seven sets.

1RM load lifted was recorded and used to calculate the 90% training load.

After the 60 minute rest, participants re-warmed using the initial warm up protocol. As progression to the 90% 1RM testing, the participants performed a first set of 5-10 repetitions, at a calculated 50% 1RM and a second set at 80% 1 RM for 3 repetitions. The third set was at 90% of calculated 1RM for three repetitions, with muscle activity and knee and hip kinematics recorded during this set.

A cool down was completed after data collection, consisting of a 10-minute cycle on a Watt Bike (Watt Bike, Pro, Cranlea) at 80 W. Non-developmental static stretches were performed to minimise muscle soreness and fatigue. Stretches were held for 2 x 10 s, for the major muscle groups used in the lifts.

Data analysis

Raw waveform muscle activity of the ES, GM, BF, ST, RF and VM for three 90% 1RM repetitions was rectified and exported as root mean squared (RMS) values. EMG was averaged over the ascent phase of each lift repetition and calculated and normalised as a percentage of the maximum voluntary isometric (%MVIC) values attained pre-data collection. The ROM for each joint was calculated by subtracting start position peak flexion from peak extension at the finish position.

Statistical analysis

Statistical analysis was completed using IBM Statistical Package for Social Science, version 26 (SPSS Inc., Chicago, IL). Statistical assumptions and data normality were checked using Q-Q plots and all variables were considered normally distributed. Central tendency and dispersion were reported as means $\pm$ standard deviation (SD). For each deadlift variation, Coefficient of Variance (CoV) of the three repetitions completed at 90% 1RM was calculated and an average for all participants is provided in Table 1. The majority of data examined within this study was considered to have an acceptable level of reliability, with a CoV of <15%³².

The muscle activity for ES, GM, BF, ST, RF and VM, kinematic variables at hip and knee and loads lifted were compared between lift types at 90% 1RM. Percentage differences between lift types were calculated, with the magnitude of any change was calculated and reported as Cohens *d* values, with effect size thresholds of 0.0-0.19 (Trivial), 0.2- 0.49

(Small), 0.5 – 0.79, (Moderate) and > 0.8 (Large)³².



Figure 1. Conventional (a & b), Sumo (c & d) and Hex Bar (e & f) deadlift techniques

Table 1. Mean (n = 12) Coefficient of Variance for each variable

Variables	Deadlift Variation		
	CDL (CoV%)	SDL (CoV%)	HBD (CoV%)
Muscle Activity			
Erector Spinae (%)	8.8	11.5	16.9
Gluteus Maximus (%)	9.1	7.6	12.8
Bicep Femoris (%)	2.4	2.7	5.4
Semitendinosus (%)	21.6	9.4	14.5
Rectus Femoris (%)	15.4	20.5	12.0
Vastus Medialis (%)	6.2	8.0	7.1
Joint ROM			
Knee	7.0	2.9	7.8
Hip	2.7	5.9	1.5

Conventional Deadlift (CDL), Sumo Deadlift (SDL), Hex Bar Deadlift (HBD), Coefficient of Variance (CoV%)

RESULTS

Figure 2 presents the absolute loads lifted at 90% of 1RM in the HBD, SDL and CDL lift variations.

The HBD (140.67 ± 5.74 kg) load lifted was 3% greater, with a moderate effect size ($d = 0.68$) compared to the CDL load (136.46 ± 6.69 kg) and 2% greater, with a small effect size ($d = 0.49$) compared to the SDL load lifted (137.81 ± 6.02 kg). The 1% increase in load lifted for the SDL compared to the CDL load was considered a small effect size ($d = 0.38$).

Muscle Activity Comparisons Between Muscles and Lift Types

Table 2 presents %MIVC muscle activity for each muscle (ES, GM, BF, ST, RF and VM) during the CDL, SDL and HBD lift variations.

Erector spinae muscle activity indicated that the HBD had 35% greater muscle activity, with a large

effect size ($d = 2.24$), compared to the CDL and 29% greater activity, with a large effect size ($d = 1.84$), compared to the SDL. The 6% greater activity within SDL condition compared to the CDL was rated as a moderate effect size ($d = 0.53$).

Gluteus maximus muscle activity indicated that the HBD had 19% greater muscle activity, with a large effect size ($d = 1.0$), compared to the CDL and 22% greater activity, with a large effect size ($d = 1.16$), compared to the SDL. The 3% greater activity for the CDL vs SDL conditions was rated as a small effect ($d = 0.23$).

Biceps femoris muscle activity indicated that the CDL had 2% greater muscle activity, with a moderate effect size ($d = 0.53$) compared to the SDL and 10% greater activity, with a large effect size ($d = 2.74$) compared to the HBD. The SDL condition had a 7.5% greater muscle activity compared to the HBD lift, also considered a large effect size ($d = 2.44$).

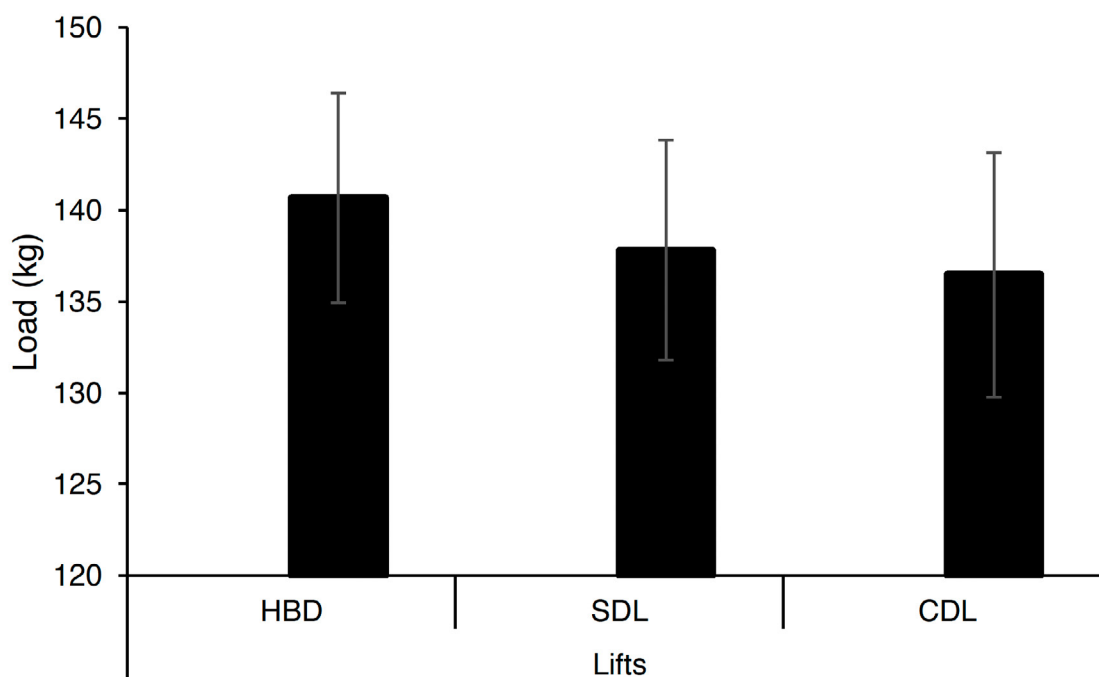


Figure 2. Means $\pm$ SD 90% 1RM loads for each lift variation

Table 2. Means ($\pm$ SD) Comparison of Normalised EMG for Analysed Muscles between Lift Types (N=12)

Muscle	Deadlift Variation		
	CDL	SDL	HBD
Erector Spinae (%)	114.61 $\pm$ 9.93	120.84 $\pm$ 13.21	149.45 $\pm$ 17.19
Gluteus Maximus (%)	136.92 $\pm$ 13.67	133.97 $\pm$ 12.03	155.84 $\pm$ 22.87
Bicep Femoris (%)	107.82 $\pm$ 4.74	105.51 $\pm$ 3.96	97.96 $\pm$ 1.86
Semitendinosus (%)	141.38 $\pm$ 9.57	132.12 $\pm$ 10.16	155.53 $\pm$ 20.24
Rectus Femoris (%)	86.02 $\pm$ 17.13	65.48 $\pm$ 10.58	119.41 $\pm$ 13.58
Vastus Medialis (%)	146.68 $\pm$ 18.83	136.29 $\pm$ 29.58	229.97 $\pm$ 36.35

Conventional Deadlift (CDL), Sumo Deadlift (SDL), Hex Bar Deadlift (HBD)

Semitendinosus muscle activity within the HBD lift had a 14% greater activity, with a large effect size ($d = 0.89$) compared to the CDL condition and a 23% greater activity compared to the SDL condition, considered a large effect ($d = 1.46$). The 11% greater muscle activity for the CDL vs SDL conditions was also considered a large effect ($d = 0.94$).

Rectus femoris muscle activity presented 33% greater EMG within the HBD condition vs the CDL condition and was considered a large effect size ($d = 2.16$), with the 54% greater activity compared to SDL also considered a large effect ($d = 4.43$). The 21% greater muscle activity for the CDL condition vs the SDL condition was also a large effect size ($d = 1.44$).

Vastus medialis muscle activity presented 93% greater EMG activity within the HBD condition compared to the SDL condition, considered a large effect ($d = 3.17$), as was the 83% greater activity compared to the CDL condition ($d = 2.88$). The 9% greater activity within the CDL vs SDL conditions was considered a moderate effect ($d = 0.53$).

Hip and knee joint angular kinematics

Table 3 presents the hip and knee joint kinematics for the CDL, SDL and HBD lifts at a 90% 1RM lift intensity.

The CDL start position had 7.9% greater hip flexion than the SDL, with a moderate effect size ($d = 0.53$), but 6.9% less hip flexion than the HBD, considered a small effect size ($d = 0.49$). The SDL condition had 14.3% less hip flexion than the HBD, calculated as a large effect ($d = 1.0$). The HBDs knee flexion was 11.4% greater than the SDLs start position knee flexion and 14.2% greater than CDL, both considered a large effect size ($d = 1.64$ and $d = 1.81$). There was a small increase in knee flexion in the SDL condition compared to the CDL, this 3.2% increase was considered a small effect ($d = 0.3$).

When ROM was compared, CDL had a 2.6% greater hip ROM than SDL, classified as a small effect size ($d = 0.21$) and 2.7% less hip ROM compared to HBD, considered a small effect size ($d = 0.41$). The HBD had 5.1% greater hip ROM compared to the SDL, considered a small effect ($d = 0.41$). The SDL condition had 2.6% greater knee ROM compared to the CDL and HBD, considered a moderate effect for CDL differences ($d = 0.71$), but a large effect size for HBD differences ($d = 1.81$).

DISCUSSION

The aim of the present study was to compare the conventional, sumo and hex-bar deadlift actions at a high intensity training load across a wide range of leg and back muscles to explore which lift has the biggest impact on prime mover musculature.

The key findings from the present study showed the HBD had the biggest absolute load lifted at 90% of 1RM. With a greater erector spinae, gluteus maximus, semitendinosus, rectus femoris and vastus medialis muscle activity in the HBD compared to CDL and SDL conditions. The CDL had greater activity of the bicep femoris compared to HBD and SDL, and greater activity of the gluteus maximus, semitendinosus, rectus femoris and vastus medialis compared to the SDL. The SDL had greater muscle activity for the erector spinae compared to the CDL.

When muscle activity of the erector spinae were examined, the HBD showed more activity, with large effects, compared to the CDL (35%) and SDL (29%) lifts. This is an interesting finding as it refutes the commonly held view that the more upright torso position generally seen in the HBD should reduce the mechanical strain applied to the back musculature, leading to a decrease in erector spinae activity^{7,10}. Theoretically, a more upright torso requires less engagement of the back musculature to counteract torso flexion seen in deadlifts where the load is positioned in front of the lifter³³. This is

Table 3. Mean ($\pm$ SD) of Hip and Knee peak flexion and Range of Motion (N=12)

Muscle	Deadlift Variation		
	CDL	SDL	HBD
Hip PJF (°)	79.84 $\pm$ 11.74	73.50 $\pm$ 12.33	85.72 $\pm$ 12.16
Knee PJF (°)	60.80 $\pm$ 7.20	62.79 $\pm$ 6.20	70.86 $\pm$ 3.19
Hip ROM (°)	93.12 $\pm$ 11.71	90.73 $\pm$ 11.53	95.62 $\pm$ 12.51
Knee ROM (°)	109.42 $\pm$ 4.73	112.38 $\pm$ 3.55	109.5 $\pm$ 3.77

Hip joint peak flexion (Hip PJF), Hip joint range of motion (Hip ROM), Knee joint peak flexion (Knee PJF), Conventional Deadlift (CDL), Sumo Deadlift (SDL), Hex Bar Deadlift (HBD)

the fundamental difference seen between the HBD technique, where a more 'squat' action is possible due to the lifter sitting within the bar and load system and the CDL, where a 'hip hinge' position is required to help manoeuvre the barbell system around the knees during ascent. However, the SDL lift position is different, with the wider and externally rotated stance allowing a narrower grip than seen in the CDL, and a more upright torso position, where the bar is lifted more vertically through a squat action. This should decrease torso flexion and subsequent back musculature activity in a similar way to the HBD. These contradictory findings could be due to the absolute loads lifted. The HBD had the highest load and largest ES muscle activity, the SDL the second highest load and second largest activity, with the CDL lowest absolute load and smallest muscle activity. However, the idea that absolute load, rather than lift technique, may have the biggest impact on erector spinae activity needs to be viewed with some scepticism. Erector spinae EMG reliability was marginally above the 15% CoV threshold and, though the increase in load for the HBD had a moderate effect size compared to the CDL, all other differences had a small effect and should be viewed as such. Though this study looked at the same relative load in order to compare lifts at the same intensity, the absolute loads differed between lift types. It would be interesting to explore the effects of lift technique on EMG activity by using the same absolute load in these three DL types. It would be logical to assume that ES activity in the CDL should be higher at the same absolute load as the HBD and SDL as the torso starts in a greater inclined position¹¹ and must travel through a greater range. However, it is also worth remembering that the CDL lift would be working at a higher relative intensity than other lifts which may also impact EMG activity.

The HBD also showed greater gluteus maximus activation when compared to both the CDL (%) and the SDL (%; both considered a large effect), a novel finding for the present study. This could be due to the larger loads lifted in the HBD, but is more likely to be linked to the deeper, more flexed hip joint in the HBD start position, by a moderate effect compared to the CDL and a large effect compared to the SDL. This led to a greater hip ROM in the HBD, though only by a small effect to both the CDL and SDL. This more flexed start position, greater hip ROM and greater load could have placed a greater mechanical stress on the hip musculature in the HBD ascent^{11,10}. This change in lift technique with the HBD is due to the hexagonal shape of the bar.

The hexagonal bar allows the lifter to 'sit back' in a deeper hip flexion position, rather than the more extended position seen in the CDL and SDL with the conventional bar. This is due to the hands being positioned in front of the lifter with the conventional bar, preventing excessive hip flexion at the start of the lift¹⁰.

It has been suggested^{34,33} that the CDL is a superior type of deadlift for training the hamstring musculature. The CDL lift technique sees the hip joint acting as a primary pivot for the thigh segment lever arm as the barbell is negotiated around the knee joint during the ascent⁹, leading to greater hamstring activation³⁴. The present study's findings partially support this understanding, with the CDL showing greater bicep femoris muscle activation than the SDL (large effect) and the HBD (moderate effect). However, when the semitendinosus activity was reviewed, the HBD has the largest activity (with a large effect compared to the CDL and SDL) and the CDL activity was greater than SDL (also considered a large effect). The reason for this difference in activity pattern for two muscles, which are major hip extensors, could be due to the CDL start position showing a more flexed hip than in the SDL. This could put more stress through semitendinosus as it assists in preventing thigh internal rotation, which is more prevalent in an increased hip flexion position. However, the reliability of EMG for the semitendinosus measures within the CDL can be questioned (>15% CoV) and this large variability cannot be discounted as the reason for this unexpected finding.

When quadriceps muscle activity was examined, the HBD had greater rectus femoris and vastus medialis activity when compared to the CDL and SDL, with large effects. This supports previous work^{35,34} which indicates that the HBD is a superior training modality for the quadriceps. The greater activation is probably due to the more flexed knee position at the start of the HBD, a large effect compared to both CDL and SDL, as well as the increased loads lifted in the HBD. This combination would put more mechanical stress through the knee joint, increasing quadriceps activation, in the HBD condition.

The present study showed minimal kinematic differences between the CDL and SDL, with differences calculated showing only small effects, except for the greater knee ROM in the SDL condition by a moderate effect. Previous studies have shown considerably greater differences,

with Escamillia et al²³ showing an increased in hip flexion in the start position of the SDL, with an greater ROM seen through the lift. Differences to the present study could be due to the participants examined. However Escamillia et al²³ tested elite power lifters using their preferred lift style, making comparisons to the present study problematic, due to evidence that elite lifters have different lift technique compared to non-elite³⁵. This potential issue is exacerbated by the SDL being the lift least used in training regimes within the present study's cohort.

In conclusion, the present study showed that the HBD had the biggest absolute load lifted at 90% of 1RM. There was greater erector spinae, gluteus maximus, semitendinosus, rectus femoris and vastus medialis muscle activity in the HBD condition compared to CDL and SDL. The CDL had greater activity of the bicep femoris compared to HBD and SDL, and greater activity of the gluteus maximus, semitendinous, rectus femoris and vastus medialis compared to the SDL. The SDL had greater muscle activity for the erector spinae compared to the CDL.

PRACTICAL APPLICATIONS

The results from this study suggest that the HBD would be the preferred deadlift technique for total muscle recruitment and load lifted for high intensity (90%) training regimes within a young adult male population with at least one year's experience of heavy lifting. However, the CDL would be the preferred lift if bicep femoris muscle activity were a specific targeted requirement within the same populations training regime.

CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

FUNDING

This study received no specific funding in order to be completed.

ETHICAL APPROVAL

The study was approved by the University of Bedfordshire's Research Ethics Committee.

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