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Research article

Anthropometrical Determinants of Deadlift Variant Performance

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Abstract

The barbell deadlift is a popular exercise and one of the three lifts in competitive powerlifting. While muscle activation has been tested between the sumo (SDL) and conventional deadlift (CDL), the relationships between anthropometrics and deadlift performance in the two styles is not yet known. The purpose of this study was to investigate the relationships between anthropometrics and SDL versus CDL performance (SDL:CDL strength ratio). Forty-seven (n = 28 male, n = 19 female) deadlift naïve subjects participated in this study. Anthropometric measurements were arm and hand length, wrist and ankle girth, seated height, thigh length, and lower leg length. Deadlift instructions for the two styles were provided on day 1 and 2. On day 3 and 4, deadlift 1RM was tested for the SDL or CDL in random order, and then deadlift repetitions to volitional fatigue with 60% of 1RM were measured. No significant differences between CDL 1RM and SDL 1RM were found. The only significant correlation found between the anthropometric predictors and the SDL:CDL strength ratio was an inverse relationship with the sitting height to total height ratio ($r = 0.297$, $p = 0.043$). Total repetitions to volitional fatigue was higher in females compared to males for both lifts ($p = 0.041$). Our findings suggest that the sumo deadlift may be slightly mechanically advantageous for deadlift naïve individuals with longer torsos, while the conventional deadlift may be better suited for those with shorter torsos.

Key words: Deadlifting performance, anthropometry, sumo deadlift, conventional deadlift.

Introduction

The barbell deadlift is a popular exercise employed to increase the strength of the posterior kinetic chain in athletes, recreational weight lifters, and the elderly, and is also one the three lifts tested during competitive powerlifting. The barbell deadlift is performed with two different styles in powerlifting competitions: conventional deadlift (CDL) and sumo deadlift (SDL). The CDL requires the lifter to stand with feet approximately hip width apart, flex at the hips slightly more than at the knees, grasp the bar just outside the knees, and then lift the bar to standing using the hip and knee extensors. The SDL, on the other hand, requires the lifter to stand with the feet wider than shoulder width apart, bend equally at the knees and hips, grasp the bar inside the knees, and then lift the bar to a standing position using the hip and knee extensors (Belcher, 2017).

Several studies have demonstrated that body height, arm and leg lengths may influence how an individual performs a CDL (Hales, 2010; Mayhew et al., 1993). Furthermore, anecdotal evidence has suggested that individuals with a longer arm length and limb length relative to height may be more efficient at deadlifting (Lockie et al., 2018b; Mayhew et al., 1993). In contrast, Mayhew et al. (1993) (found that shorter limb lengths had a positive effect on the CDL when performed by collegiate football players; however, full anthropometrical profiles were not reported. To the best of the authors' knowledge, only one study has examined the relationship between body structure and deadlifting performance (Lockie et al., 2018b). Lockie et al. (2018b) investigated the relationship between anthropometric profile (height, arm length and leg length) and CDL as well as high-handle hexagonal bar deadlift (HDL) performance. In men, only leg length correlated positively with absolute, but not relative 1RM CDL strength, suggesting that longer-legged men can deadlift more weight but do not have a biomechanical advantage relative to body mass. Secondly, height correlated negatively with relative, but not absolute HDL strength, suggesting taller men have a biomechanical disadvantage in the HDL relative to body mass regardless of relative leg or arm length. In women, no anthropometric variable correlated with any measure of absolute deadlift strength in either variation and no variable correlated with any absolute or relative strength measurement in the HDL. In contrast, for the CDL, height, leg length and arm length all negatively correlated with relative strength, but the ratio of arm-to-leg length did not, suggesting it is biomechanically beneficial for women to be short and have short limbs for CDL performance. In a second study, Lockie et al. (2018a) found individuals using the HDL had a significantly higher 1RM when compared to the CDL, likely attributable to a shorter lift distance and higher starting height, resulting in less total work required to lift the weight compared to the CDL.

Hales (2010) proposed that athletes with long arms should use the CDL and those with shorter arms would be better suited to use the SDL. From a biomechanical perspective, McGuigan and Wilson (1996) reported that the SDL offered a mechanical advantage over the CDL due to greater trunk extension and less torque at the lumbar spine, in addition to a shorter lift distance. Differences in muscle activation and biomechanics have been studied between the two styles with minimal differences in EMG activity in the lower limbs or hip extension range of motions reported in 3D analysis (Belcher, 2017; Camara et al., 2016), and informal conversations with competitive power lifters suggest a clear preference for one style over another. Nonetheless, to our knowledge, there is no research investigating the relationships between height and arm length and leg

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length between the CDL and SDL.

This is of importance to strength and conditioning coaches who are trying to find what style (e.g. sumo or conventional) may be most appropriate for athletes who are being introduced to the deadlift exercise, and holds implications in inexperienced powerlifters and recreational lifting community members who are trying to maximize their deadlift performance. Therefore, the purpose of this study was to investigate the interaction between limb and torso measurements and deadlift performance in the SDL and CDL in deadlift naïve males and females. We hypothesized that greater performance in the CDL versus SDL would be positively correlated with longer relative arm and shorter relative femur lengths.

Methods

Deadlift naïve subjects were recruited for this study to minimize a confounding effect of previous deadlift experience with a particular style on deadlift performance. Subjects were taught how to perform the conventional (CDL) and sumo deadlift (SDL) styles over the course of two training sessions. Anthropometric measurements included subject height, weight, upper arm, forearm, hand length, wrist and ankle girth, seated height, thigh length, and lower leg length. Subjects were then tested for counter movement vertical jump (CMJ) and abdominal crunch performance to investigate if a relationship between deadlift performance and the power to mass ratio (measured in proxy via the CMJ) or anterior core performance (measured via the abdominal crunch) existed. During the third and fourth sessions, subjects performed a 1 repetition maximum (1RM) test of either the CDL or SDL followed 5 minutes later by repetitions to fatigue of the corresponding style deadlift with 60% 1RM. The deadlift styles tested in session 3 and 4 were randomized (via coin flip). The anthropometrical variables were used to predict deadlift strength (see statistical procedures).

Participants

Participants were a convenience sample of 47 volunteers (n = 28 male, n = 19 female) recruited from a university population (Table 1). Subject inclusion criteria included being between the ages of 18-35 years old, without any reported musculoskeletal disorders, free from consumption of anabolic steroids or any other illegal agents known to increase muscle size within the past year, and were currently engaged in a structured resistance training program that did not involve deadlifting. Subjects were instructed to avoid taking any performance-enhancing supplements during the study period and avoid strenuous exercise two days prior to testing. All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Coastal Carolina University (#2016.08).

Table 1. Participants characteristics

Height (m)	1.73 ± .09
Weight (kg)	77.6 ± 21.0
Age (years)	21.7 ± 3.0
Resistance Training Experience (months)	11.0 ± 14.3

Procedures

Subjects reported to the lab on four separate occasions at the same time of day (± 2 hours) to account for diurnal variations in performance. Table 2 illustrates the testing days and associated tests/activities performed on each day. Session 1 and 2 were separated by 48 hours, session 2 and 3 were separated by 48-72 hours, and session 3 and 4 were separated by 72-96 hours.

Anthropometrics: Height was measured using standard anthropometry and body mass was measured using a calibrated scale. All lengths were measured using a Gulick tape measure. Upper arm length was measured as the distance between the acromion process and the olecranon process. Forearm length was measured as the distance between olecranon process and the radial styloid process. Wrist girth was measured as the minimal girth distal to the radial styloid process. Hand length was measured on the anterior surface of the hand as the distance between the scaphoid carpal and distal tip of the third distal phalange. To measure seated height subjects sat on an adjustable unpadded stool set to a height that places the hips and knees at 90 degrees of extension. The distance between the top of the head and the chair was recorded as torso height. Upper leg length was measured as the distance between the superior border of the greater trochanter and the lateral tibial condyle. Lower leg length was measured with the subject standing barefoot and was recorded as the distance between the lateral tibial condyle and the floor. Finally, ankle girth was recorded as the minimal girth measurement of the region just superior to the malleoli.

Deadlift technique: In the first session subjects were taught to perform a hip hinge in the conventional and sumo positions by standing with their backs approximately 20 cm away from a wall. For the conventional position subjects stood with feet approximately hip width apart and for the sumo the feet were placed wider than shoulder width with the toes pointing outwards. Subjects stood tall with their shoulders back, chest up, and back straight. Subjects were next instructed to unlock the hips and sit back, and touch their hips to the wall (without resting on wall) while maintaining a neutral or slightly lordotic spine. Subjects were instructed to come back to standing by contracting the hamstrings and gluteal muscles while keeping a neutral spine and pushing the hips forward. Once subjects demonstrated proficiency in the hip hinge they were instructed to

Table 2. Tests associated with each session.

Day 1	Day 2	Day 3	Day 4
Anthropometrics Unloaded Deadlift Training	Loaded Deadlift Training	Lift Style Randomly Assigned Deadlift 1 RM Test Deadlift Repetitions to Fatigue with 60% 1RM	Deadlift 1 RM Test Deadlift Repetitions to Fatigue with 60% of Day 3's 1RM

perform the conventional and sumo style deadlifts using an unweighted PVC plastic pipe. The PVC pipe was placed on blocks that elevated the pipe to the standard Olympic weightlifting starting position (22.5 cm). Subjects were instructed to stand with their shins approximately 2-4 cm from the pipe, hinge at the hip and bend at the knee until they could grasp the pipe while maintaining a neutral spine. This movement was practiced 5 times per lift to ensure subjects were comfortable with the proper starting position. Next, subjects were instructed to lift the pipe by pushing their feet into the ground. As the bar passed the patella subjects were instructed to push their hips forward as they did during the concentric phase of the hip hinge.

In the second session the CMJ was measured with the Just Jump! Mat (Probotics, Huntsville, AL.) and abdominal crunch according to National Strength and Conditioning Association (NSCA) guidelines (Baechle et al., 2008). Subjects then began by practicing the conventional and sumo style deadlifts with the PVC pipe off the block. Once subjects demonstrated proficiency in technique they were progressed to practicing with an Olympic weightlifting bar (20 kg) for one set of 6 repetitions. For subsequent sets the repetitions were lowered to 2 and the load was progressed by 5-10 kg per set and ratings of repetitions in reserve were recorded (Zourdos et al., 2016). The deadlift session ended once subjects reported a repetitions in reserve of 4. The load lifted was recorded and used to calculate the estimated 1 RM (load ÷ 0.85) to determine the loads for the warmup sets during the 1 RM testing sessions.

Deadlift 1 Repetition Maximum (RM): Subjects reported to the lab having refrained from any exercise other than activities of daily living for at least 48 hours prior to testing. Repetition maximum testing and warmups were consistent with recognized guidelines as established by the NSCA (Baechle et al., 2008). Subjects performed a general warm-up prior to testing that consists of light cardiovascular exercise lasting approximately 5-10 minutes. A specific warm-up set of the given exercise of 5 repetitions was performed at ~50% 1RM followed by two sets of 2-3 repetitions at a load corresponding to ~60 and then ~80% 1RM. Subjects then performed sets of 1 repetition of increasing weight for 1RM determination beginning with 90% of the estimated 1 RM. Three to 5 minutes rest were provided between each successive attempt. All 1RM determinations were made within 5 attempts. Subjects used lifting straps to minimize grip strength as a limitation to deadlift performance. When subjects could no longer lift the weight while maintaining a neutral spine the test was terminated and the highest load lifted was recorded. Two fitness professionals including one NSCA Certified Strength and Conditioning Specialist supervised all testing sessions. Subjects were verbally encouraged, but were not informed of their prior performance (i.e.: subjects on testing day 4 were not told what their 1 RM was from day 3).

Deadlift repetitions to fatigue: Five minutes of rest separated the final deadlift 1 RM attempt and the test of repetitions to volitional fatigue. The load used for the repetitions to fatigue test corresponded to 60% of the 1 RM from the session 3 deadlift 1 RM test. Subjects performed as many repetitions as possible with a 1-2 second concentric and 1-2 second eccentric tempo. Subjects were allowed to use lifting straps to minimize grip strength as a limitation to deadlift performance. The test was terminated when subjects could no longer maintain the tempo or perform the exercise with proper deadlift technique and a neutral spine. Subjects were verbally encouraged, but were not informed of their prior performance (i.e.: subjects on testing day 4 were not told what their repetitions completed from day 3).

Statistical analysis

All descriptive data is reported as the mean ± standard deviation. Paired sample t-tests were conducted to access if a learning effect took place by comparing the 1 RM and repetitions to fatigue completed during session three and four. Dependent variable distributions were assessed for normality with Shapiro-Wilk and Kolmogorov-Smirnov tests as well as manual inspections of M-estimators, histograms, steam-and-leaf plots and boxplots. All data were analyzed for the presence of outliers and homoscedasticity with the aforementioned plots in addition to Q-Q plots and standard deviations from the mean. Independence of residuals was assessed with the Durbin-Watson test. Normality of residual distributions was assessed graphically. Linearity of the relationship between the independent and dependent variables was assessed graphically. Multicollinearity was assessed with the Tolerance and Variance Inflation Factors (VIF) statistics. Since no previous data were available to establish priority of our predictors, a non-hierarchical multiple linear regression was performed to predict the ratio of sumo to conventional deadlift 1RM with all anthropometrical measurements as independent variables. Additionally, Pearson correlations were performed between the predictors and the ratio of sumo to conventional deadlift 1RM (SDL:CDL). We observed during testing that females tended to perform more repetitions to fatigue with 60% 1RM than males. Therefore, a mixed factorial repeated measures ANOVA was conducted *post hoc* to investigate the interaction between deadlift style (within subject factor) and gender (between subject factor). Statistical significance was set at $p \leq 0.05$ and all data was analyzed using the IBM Statistical Package for Social Sciences 20.0.

Results

There were no significant differences between SDL 1RM and CDL 1RM ($p = 0.493$) (Table 3); there was a significant ($p < 0.001$) correlation ($r = 0.980$) between the two. There was no effect of order (session three vs. session four) on deadlift 1 RM performance ($p = 0.477$) or repetitions to fatigue ($p = 0.119$).

Anthropometric prediction of deadlift variation strength

The only significant correlation between the anthropometric predictors and SDL:CDL strength ratio was the sitting height to total height ratio, $r = 0.297$, $p = 0.043$ (See Table 4 for all correlations). The full regression model performed with all anthropometric predictors did not significantly predict the SDL:CDL strength ratio ($p = 0.303$) and there was considerable multicollinearity, most severely for the insignificant lower leg to thigh ratio, so this variable was removed from the model. Model 2 was still insignificant (p

= 0.288), but did not suffer from multicollinearity (all VIFs < 2.410 and tolerances > 0.415). Removal of insignificant predictors in order of p-value, highest to lowest, resulted in a final model with sitting height to total height as the sole remaining predictor. This model significantly predicted the ratio of SDL:CDL strength, $F(1,45) = 4.338$, $p = 0.043$, $\beta = -0.392$, $R^2 = 0.154$ (Figure 1).

Table 3. Performance results.

Vertical Jump (cm)	47.5 ± 10.3
Crunches	40.0 ± 29.0
Sumo Deadlift (kg)	116.4 ± 35.6
Conventional Deadlift (kg)	115.6 ± 35.5
SDL Repetitions to Fatigue	20.8 ± 6.4
CDL Repetitions to Fatigue	20.7 ± 8.9

Table 4. Correlations (r) between anthropometric predictors and the sumo to conventional deadlift ratio.

Predictor	Pearson Correlation	Significance
Arm to height ratio	.037	.807
Arm to sitting height ratio	-.088	.556
Thigh to height ratio	-.093	.533
Lower leg to thigh ratio	-.015	.920
Lower leg to height ratio	-.182	.220
Sitting height to height ratio	.297	.043
Abdominal crunches	.156	.296
Counter movement jump	.025	.871

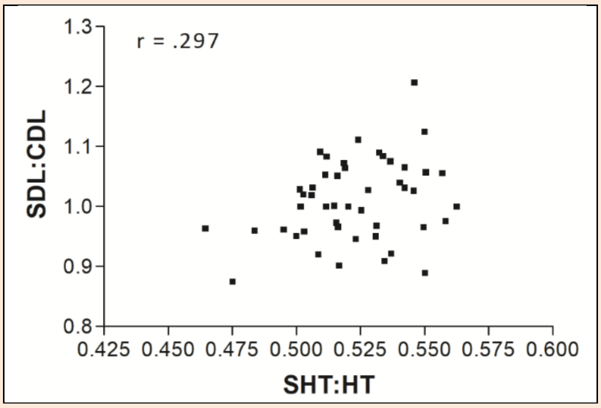

Figure 1. Scatterplot relationship between sitting hight to height ration (SHT:HT) and sumo deadlift to conventional deadlift ratio (SDL:CDL)

Gender differences

There were no significant interactions between gender and deadlift style ($F = 0.104$, $p = 0.748$). However, a significant ($F = 4.438$, $p = 0.041$) main effect for gender was found. Total repetition performance was higher in women for both exercises (Table 5).

Table 5. Repetitions to fatigue.

	SDL Repetitions	CDL Repetitions
Male	19.4 + 4.6	18.9 + 7.2
Female *	23.3 + 8.1	23.5 + 10.2

SDL: Sumo deadlift; CDL: Conventional deadlift. * Significantly different than males for total repetitions

Discussion

To our knowledge, this was the first study to explore the relationships between sumo and conventional deadlift performance and the anthropometrics of sitting height, arm length, and leg length in deadlift naïve subjects. We utilized naïve subjects because pilot testing with experienced deadlifters revealed a preferred deadlifting style predominantly employed in training. Consequently, had a difference in SDL vs. CDL performance been found, it would be more difficult to discern whether this performance difference was a result of varying anthropometrical ratios or due to the principal of specificity. By using deadlift naïve subjects we better able to control for both specificity of training and standardize deadlifting technique between subjects, allowing for greater insights into the relationship between deadlifting performance and anthropometrics.

We hypothesized that greater performance in the CDL versus SDL would be positively correlated with longer relative arm and shorter relative femur lengths. The only relationship we found was between sitting height relative to total height and a greater SDL. Therefore, we reject our initial hypothesis. On the surface our findings disagree with Hales (2010) who recommended those with longer arms (measured from humeral head to distal most tip of third phalange) would be better suited for the conventional deadlift while those with shorter arms would be better suited for the sumo deadlift, regardless of torso length. Hales (2010) defined long arms as a proportion equal to or greater than 38% of total height. In the present study, the arm proportion was 44.5 + 1.9%, defining all subjects as having long arms. However, the arm lengths were measured using a proximal point of the acromium process in the present study, not the humeral head, which may have led to a slight overmeasurement of arm length. Regardless, there was a high degree of homogeneity in relative arm length of the subject pool, which may have reduced our ability to detect the relationship between relative arm length and the SDL:CDL strength ratio.

We also hypothesized that individuals with relatively shorter thighs would perform better in the CDL compared to SDL. We formed this hypothesis because longer thigh lengths would require the individual to start the lift with a greater degree of hip flexion and torso angle, especially in the CDL, thereby reducing leverage and requiring greater erector spinae strength. On the other hand, during the SDL, the hip abduction and laterally rotated feet effectively shortens the length of the thigh in the sagittal plane (Demers et al., 2018), thereby reducing the degree of hip flexion necessary to grasp the bar in the starting position. In partial support of this hypothesis, Demers et al. (2018) reported individuals with longer relative thigh lengths (compared to lower leg length) may potentially benefit from adopting a wider stance when back squatting. Our results did not support our hypothesis. We did not find a correlation between thigh length relative to lower leg length and the SDL:CDL strength ratio, nor did thigh length predict the difference in deadlift strength. In contrast to the arm proportion, there was a higher degree of heterogeneity in the thigh to lower leg length ratio (0.93 ± 0.09) in the sampled population. The discrepancy in our results compared to those reported by Demers et al. is likely due to differences in mechanics between the squat and the deadlift. Demers et al. suggested that when individuals with longer thighs use a wider stance, it reduces the reliance on ankle dorsiflexion to achieve depth in the squat. In the deadlifts, however, tibial translation angles are small and dorsiflexion is likely not a limitation.

Our results suggest that the SDL may be mechanically advantageous for deadlift naïve individuals with longer torsos, while the CDL may be best suited for those with shorter torsos. This is likely because during the SDL the center of mass is positioned over and closer to the barbell compared to the CDL, allowing for a more upright torso, which reduces the moment arms of resistance at the knee, hip and especially the lumber joints (Escamilla et al., 2000; Escamilla et al., 2002). Research has also indicated the hip extensors do not exceed the force exhibited by the erector spinae muscles in the SDL, possibly due to greater quadriceps femoris activity, making it easier to maintain lumbar lordosis (Escamilla et al., 2000; Escamilla et al., 2002).

Finally, we found no gender differences in repetition performance at 60% of 1RM between the CDL or SDL. However, we did observe absolute repetition performance to be higher in females for both deadlifts. These findings are in agreement with previous studies that reported higher acute fatigue resistance in females compared to males at a given relative intensity (Salvador et al., 2009) especially during sub-maximal (60-80% maximum) dynamic contractions (Hicks et al., 2001; Hunter, 2014). There are several mechanisms that may explain greater deadlift fatigue resistance in females, including a greater proportion of type I muscle fibers, greater proportion of fat oxidation during exercise, and greater muscle perfusion resulting in greater metabolite clearance, which leads to reduced peripheral afferent inhibition to the motor neuron pool, thus attenuating voluntary activation (for review, see Hunter, 2014).

Limitations

Several limitations within this study exist. First, we did not measure flexibility or ROM deficits, which may contribute to differences the SDL:CDL strength ratio. For example, greater hip adductor flexibility is necessary to accomplish a sumo deadlift, and therefore limited hip adductor ROM may have compromised sumo deadlift performance in some subjects and added variability to the results. Second, although the order of the deadlift styles was randomized, the two styles are unique in regards to mechanics, and we found no differences between deadlift 1 RM on session 3 versus session 4, we cannot fully discount that a learning effect may have taken place between the first and second deadlift testing sessions.

Conclusion

In conclusion, our findings demonstrate no overall difference between sumo and conventional deadlift 1RM in deadlift naïve individuals. However, our results suggest that individuals with longer relative torsos may gain an advantage, at least in regards to 1RM performance, by adopting the sumo stance. These findings have important implications to strength and conditioning coaches who are trying to determine which style is most appropriate, especially for those athletes who are new to deadlifting. Thus, it might be appropriate for powerlifting coaches to measure sitting height and torso length prior to prescribing a specific deadlift style (sumo versus conventional). Additionally, we found that women demonstrated greater fatigue resistance during a repetition to failure test with 60% 1RM. Therefore, coaches who are prescribing a specific number of repetitions based off a percentage of the 1RM (i.e.: 15 repetitions with 65% 1RM) may need to adjust the load upward to accommodate greater strength-endurance observed in females.

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The experiments comply with the current laws of the country in which they were performed. The authors declare no conflict of interest

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Key points

- Minimal differences exist in hip range of motion and lower limb muscle activation between the conventional and sumo deadlifts; however, little is known about how differences in limb lengths and ratios effect performance between the two lifts.
- In this study, we found that individuals with greater torso to total height ratios had higher 1 repetition maximums when the deadlift was performed with the sumo compared to conventional styles.
- Additionally, we found that women demonstrated greater fatigue resistance during a deadlift repetition to failure test with 60% of the 1 repetition maximum.

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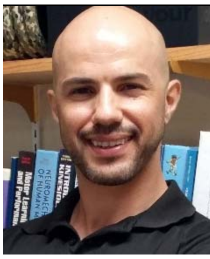

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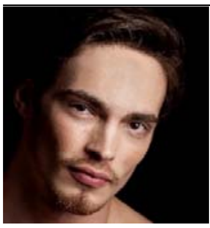

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