Short Communication

Isometric Strength of Powerlifters in Key Positions of the Conventional Deadlift

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Objectives: To determine if force differences exist between isometric pulling positions corresponding to key positions of the deadlift.

Design: Cross-sectional evaluation of isometric strength

Methods: 14 powerlifters performed isometric pulls on a force plate at 3 key positions related to the deadlift (at the floor, just above the patella, and 5-6 cm short of lockout) and in the mid thigh pull position (MTP). A 1x4 repeated measures ANOVA was used to ascertain differences between the various pulling positions tested. Bonferroni-adjusted paired samples t-tests were used post-hoc.

Results: Forces generated at each bar height were significantly different ($F(3,39) = 51.058$, $p<0.05$, $\eta^2=0.80$). Paired samples t-tests showed significant differences between positions, revealing a trend of greater force generation at increasing heights for positions corresponding to the deadlift. Force generated in the mid thigh pull position was significantly higher than any other position.

Conclusion: In positions corresponding to the deadlift, force generation increases at higher bar heights.

(*Journal of Trainology* 2012;1:32-35)

Key words: powerlifting ■ strength testing ■ performance monitoring ■ maximum strength ■ isometric mid thigh pull

Powerlifting is a sport made up of three events, the squat, bench press and deadlift. For each event, the ultimate goal is to lift as much weight as is possible. In the deadlift, a lifter lifts the barbell off of the floor until standing upright. The lift is finished upon extending the knees and hips with scapula retracted. Two styles of the deadlift are used in competition. The sumo style uses a wide foot stance, upright posture, and a grip width that is narrower than the feet.[1] Conversely, the conventional style deadlift uses a narrow foot stance, generally a more bent-over posture, and a grip outside of the legs.

Three key phases have been identified in the literature for the conventional deadlift.[2-4] The first phase, or lift-off, occurs when the lifter first applies force to the bar and the bar rises off of the floor. The second phase, knee passing, occurs when the bar moves from below to above the knee. The third phase, or lift completion, occurs when the lifter transitions into a full upright position. While these specific regions of the deadlift are known, little has been done to examine how each position might contribute to deadlift performance. The most disadvantageous position represents a limiting factor in overall performance, thus identification of this position may lead to better training prescriptions.

To the authors' knowledge, no literature exists that assesses the force generation capabilities of lifters in these phases of the deadlift, however in a number of studies examining the isometric mid thigh pull (MTP), a weightlifting-specific position, a variety of athletes produced high levels of peak forces.[5-7] Peak force measured in these studies showed moderate to strong relationships with dynamic mid-thigh pulls, jumps and a number of other dynamic measures. Therefore, since little is known about the force generation capabilities of lifters in the key phases of the deadlift, the purpose of the study was to evaluate the isometric maximum strength of powerlifters in bar positions corresponding to key phases of the deadlift and also to compare those positions to the MTP, given the strong relationship the MTP shares with a variety of dynamic measures.

Methods

Experimental Approach to the Problem

Data obtained in an athlete monitoring program were assessed using a repeated measures design to assess peak force production differences between key positions of the deadlift. A repeated measures ANOVA and paired t-tests were used to assess force differences between positions.

Athletes

Fourteen competitive powerlifters who could deadlift a minimum of 2.5 x body mass (BdM) using the conventional style using only a belt or competed regularly volunteered for this investigation. Based upon training history questionnaires all subjects reported that they did not regularly perform weightlifting movements or their variants. Some lifters reported using the sumo style most often in competition (n=4),

Received October 17, 2012; accepted November 12, 2012

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but all lifters reported training regularly using the conventional style (n=14, age range: 18-39, height: 178.6±9.8cm, BdM: 109.9±20kg, conventional deadlift 1-RM: 248.5±18kg). Each subject was screened by questionnaire for injury prior to testing. Athletes were informed of all testing procedures and possible risks, and voluntarily signed an informed consent document as outlined by University Institutional Review Board policy.

Warm-up procedures

The warm-up routine was a standardized protocol with a small amount of possible modification (within the specified range) to more closely match the typical warm-up routine of the lifter. Warm-ups were as follows: 2-5 repetitions at 35% of 1-RM, followed by 90 seconds rest, 2-3 repetitions at 50% 1-RM, followed by 120 seconds rest, 1-2 repetitions at 65% 1-RM, followed by 150 seconds rest, then 1 repetition at 75% 1-RM, followed by 180 seconds rest. Warm-up loads were determined using the athletes' belt-only conventional personal records.

Isometric Testing Procedures

All isometric testing was completed in a custom designed power rack that allows fixation at any height. Athletes stood on a 91.4 x 91.4 cm force plate (Rice Lake Weighing Systems, Rice Lake, WI) to measure vertical ground reaction forces. Bar heights for each testing condition were chosen to correspond to the three key positions achieved in the deadlift and the isometric mid-thigh pull. For the first height, the center of the bar was placed at 22.5 cm from the floor to correspond to the position of the barbell in the start of the deadlift. The second bar position was placed immediately superior to the patella from standing. The third corresponded to the same body position as used in the MTP.[5, 6] The fourth position used the same bar height as the third, but with a self-selected body position corresponding to one that would be achieved in a deadlift. Pilot testing indicated that the fourth height results in a body position with the bar 4-6 cm from deadlift lockout. Intra-session test-retest reliability (intraclass correlation, coefficient of variation, respectively with 90% CI's for each) of peak force for each position was excellent: floor: 0.99 (0.98-1.0), 1.2% (0.9%-1.8%), knee: 0.98 (0.96-0.99), 2.0% (1.5%-2.9%), IMTP: 0.92 (0.80-0.96), 5.0% (3.8%-7.5%), lockout: 0.88 (0.70-0.94), 4.6% (3.5%-6.9%).

Each condition was performed in order, 1-4, to maintain standardization among athletes and result in a uniform fatigue. Pilot testing indicated that forces and perceived difficulty increased as the athletes used the higher bar positions, thus the order was chosen to correspond to what was likely least fatiguing to most fatiguing. The conditions were separated by 10 minutes of rest, during which time the athletes remained seated. Athletes were secured to the bar using lifting straps and athletic tape. Each subject assumed the position he would be using for the pull condition, and once body position was stabilized (verified by visual monitoring of both the athlete and force trace), the athlete was given a countdown. Nominal pre-tension was allowed to minimize slack in the subject's body prior to the pull (monitored by force-trace and instruction to the lifter) to ensure that little or no vertical acceleration of the athlete occurred. The subject performed two warm-up attempts separated by 90-120 seconds, each at a subject-estimated 50% and 75% of maximum. The athletes then performed 2 to 3 maximal attempts for 3-4 seconds each, separated by 2-3 minutes. The attempt was terminated when a plateau or consistent decrease in force was observed. A third trial was only performed if a ≥250N difference in PF was observed between trials, a countermovement was observed, or if the athlete did not follow directions.[6]

The highest observed force from each pull obtained using a custom analysis program (National Instruments, Austin, TX) was designated peak force (PF). PF measurements from both trials were averaged. Peak force was allometrically scaled (APF) using the equation [$y=result \cdot BdM^{-2/3}$].[6,8]

Analog data from the force plate were amplified and conditioned (low-pass at 16 Hz; Transducer Techniques, Temecula, California). An AD converter (DAQCard-6063E, National Instruments, Austin, TX) allowed for collection at 1000 Hz and further low-pass filtering using a software-based 4th Order Butterworth filter at 100 Hz.

Statistical Analysis

For the purpose of comparing kinetic measures at each of the four pulling positions, a repeated measures ANOVA (RM ANOVA) was used for each dependent variable considered, using Bonferroni adjusted paired t-tests (p=0.008) for post-hoc analysis. RM ANOVA and post-hoc tests were performed for unscaled and allometrically scaled force. Alpha was designated at p=0.05. All statistical analysis was performed using SAS 9.2 (Statistical Analysis System, SAS Institute Inc., Cary, NC). Effect sizes were evaluated with the method of Hopkins.[9]

Results

PF and APF measures can be found in Table 1. There was a significant main effect for PF ($F(3,39) = 87.44$, $p<0.0001$), with η^2 of 0.871. APF measures were significant for main effect ($F(3,39) = 88.23$, $p<0.05$) with η^2 of 0.872. Results of paired t-tests can be found in Table 1. Effect sizes of paired t-tests for PF and APF were as follows: floor vs. knee, 1.50, 1.97; floor vs. MTP 3.66, 4.22; floor vs lockout 3.04, 3.08; knee vs. MTP 2.10, 2.80; knee vs. lockout 1.40, 1.52; MTP vs. lockout 1.23, 1.27.

Discussion

Athletes produced different PFs at each position (floor, knee, MTP, lockout). The changing bar height resulted in different body positions for each pull, and thus a differing ability to apply force. Interestingly, positions directly related to deadlift performance (floor, knee, lockout) tended to increase force in the higher bar positions. PF and APF in the floor position were significantly less than both the knee and lockout positions (effect size of large to very large). There was also a significant

Table 1. Results of isometric testing and paired t-tests

Measure	Position	Mean	±	SD	Significance
Peak Force (N)	Floor	3380.0	±	377.0	†, ‡, §
	Knee	4093.0	±	559.0	*, ‡, §
	Mid-Thigh Pull	5829.0	±	867.0	*, †, §
	Lockout	4910.0	±	605.0	*, †, ‡
Allometrically Scaled Peak Force ($N.kg^{-1}$)	Floor	148.5	±	12.7	†, ‡, §
	Knee	179.8	±	18.6	*, ‡, §
	Mid-Thigh Pull	256.4	±	33.9	*, †, §
	Lockout	216.6	±	28.6	*, †, ‡

* = significantly different than floor position p <0.001
† = significantly different than knee position p <0.001
‡ = significantly different than MTP position p <0.001
§ = significantly different than lockout position p <0.001

difference between knee and lockout positions (with large effect size). This finding may be due to a number of reasons. Brown & Abani[2] found that horizontal hip moment to the bar center of mass (COM) decreased with higher bar positions in the deadlift. While Escamilla et al.[1] did not test for significant differences, they reported a trend of decreasing horizontal moment arm to the barbell COM at the ankle, hip and knee as the lifter ascended from lift-off to knee passing. This decreased moment at higher positions may allow for better mechanical advantage at the hip, thus increasing the resultant generation of upward force on the bar.

One confounding issue is the fact that two studies have found that the sticking region occurs at a point roughly around the knee.[1, 3] Because biomechanical disadvantage causes the sticking point to occur at a certain range of motion, the total force generating capability at that position should be reduced (net extensor moment and force applied to the bar). Therefore, based on the two aforementioned studies, the force generating capabilities of deadlifters at the knee position should be less than the floor position, not more, as was found in the present study. It is possible that anthropometric characteristics predispose one to certain sticking points, but no known research exists to assert this. Another possibility is that in the Escamilla et al.[1] and Hales et al.[3] studies the lifters were using a powerlifting deadlift suit. If this was the case, then the sticking regions of the lifts may be higher due to the assistance afforded the lifter by lifting suits.[10] Also possible is that the position used by athletes in the present study is different than what athletes use in a maximal deadlift. If the isometric pull allows for a more ideal body position than is attained during the deadlift, greater forces might be achieved, thus representing a possible limitation of this study. Further research should confirm this.

It is interesting that the MTP position allowed the lifters to produce the greatest amount of force, despite the lockout position being more similar in position to the deadlift. The lifters generally performed well in the lockout position (understandable given that they regularly train a movement that requires it, i.e. the deadlift, and do not regularly train in the MTP position); therefore the MTP position must provide a substantial mechanical advantage that overcomes even the frequent training in the deadlift-specific position. The greater

Figure 1. Example of lifter in MTP position (left) compared to lockout (right)

forces produced in the MTP position over the other three positions may be explained by a number of things. First, simple observation showed a marked difference in position even between the MTP and the position of second greatest force (lockout). The MTP position is rather upright, with the knees bent. Powerlifters, in mimicking the deadlift, are in a relatively straight legged position and somewhat bent over the bar. Figure 1 shows an example of the differing position for one of the athletes. The lockout position likely creates a greater moment on the lower back and hips, which may limit performance. The greater knee bend used in the MTP position probably provides a force-production advantage, as the powerful extensor forces of the quadriceps muscles are used to a greater extent. The gluteus maximus may also be in a more favorable position for resultant force production against the bar, assuming a smaller hip moment, as was found in Brown & Abani[2] and Escamilla et al.[1]

Conclusion

Powerlifters in this study generated substantially different amounts of force in each position. Changing mechanical advantages probably contribute to the difference in forces, but further research is needed to confirm this. Despite the advantage of regular training in the deadlift-specific positions (floor, knee and lockout), lifters still generated far more force in the MTP. The MTP appears to represent the position of greatest force output, even in lifters who train regularly in the other positions. Lower force production capabilities in the lower positions represent a limiting factor for deadlift performance, thus an emphasis in training of the lower ranges of motion of the deadlift may elicit greater gains.

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