ISOMETRIC STRENGTH BETWEEN OLYMPIC AND HEXAGONAL BARBELLS AND RELATIONSHIP TO COUNTERMOVEMENT JUMP

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ABSTRACT

The hexagonal barbell is a commonly used implement for strength and power development. However, as it is a relatively novel tool, little is known of the performance differences between a hexagonal (hex) bar and an Olympic bar. Therefore, the purpose of this study was to compare isometric performance between hex bar and Olympic bar at the mid-thigh and deadlift position. Isometric performance was then compared to dynamic performance via countermovement jump. Twenty resistance trained men (age = 24.05 ± 2.09 years, ht = 178.07 ± 7.05 cm, mass = 91.42 ± 14.44kg) volunteered to participate. Participants performed isometric mid-thigh pulls (MTP) and isometric deadlifts (DL) utilizing the Olympic bar (OL) and both low (LH) and high (HH) handles on the hex bar. Isometric performance was then compared to dynamic countermovement jump (CMJ) performance. Joint angle was recorded for all pulls and the countermovement portion of the jump. MTP force variables were greater than DL for all lifts, with the only difference between bars seen at RFD 50ms, where HH produced greater RFD than LH. MTP joint angles were more extended than DL angles, and the strongest correlation between isometric and dynamic performance was seen between DL PGRF and CMJ impulse. The findings are likely due to the biomechanical characteristics of the MTP and DL as well as the similarity in joint angle between the DL and CMJ positions.

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CHAPTER 1

INTRODUCTION

The deadlift is a full-body strength exercise that is frequently performed in resistance training settings. It is most frequently used for strength and power development, as it allows for the use of heavy loads which generate large muscular forces (13). The exercise requires the lifter to grasp the barbell in a position similar to a squat, then elevate the load in a continuous motion through extension of the lower back, hip, knee, and ankle joints. It is crucial that the barbell remain close to the body throughout the lift, ensuring that the load remain closer to the lifter's center of gravity (23).

There are many variations of the deadlift exercise. One such variation is the hex bar deadlift. The hex bar enables athletes to perform the deadlift movement while the load is positioned closer to their body, as the lifter is actually inside the frame of the bar. The hex bar also enables the lifter to keep a more erect posture, reducing strain on the lumbar spine (15). However, little research has been done on the hex bar and its comparison to conventional deadlifts using an Olympic bar. To our knowledge, only one study to date has examined the hex barbell in comparison to the Olympic barbell, finding that the hex bar deadlift produced greater peak force, peak velocity, and peak power, as well as a greater 1- repetition maximum (RM) (23).

The isometric mid-thigh pull is a static movement in which an athlete generates maximum force against a stationary bar positioned at mid-thigh position (1, 20). Rather than recording dynamic performance variables, isometric peak force and rate of force development are easily measured. The isometric mid-thigh pull has several advantages to gross measures of strength, such as reduced chance of injury, minimal fatigue, and small chance of technical error (8). While isometric peak force has been shown to correlate well with dynamic variables, this appears to only be the case in movements with similar joint positions (1, 18). Therefore, peak force produced during an isometric mid-thigh pull correlates well with weightlifting movements, such as the second pull of the clean, yet correlation to a dynamic deadlift movement is yet unknown.

The hex bar is now commonly used in many strength and conditioning settings. In order to properly employ the hex bar deadlift in a training program, further research is needed to examine how the hexagonal barbell compares to the straight barbell. Therefore, the purpose of this study was to compare isometric performance between straight and hexagonal barbells, and the relationship to dynamic performance.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

There are a many variations of popular exercises in a resistance training setting. By changing the mechanics of a resistance training movement, the characteristics of the movement will be altered in response. When biomechanics are altered, this can alter force, velocity, and power production. This concept is highly evident in the deadlift exercise. The deadlift requires the lifter to grasp the barbell at mid-calf level, in a position similar to the bottom of a squat. The load is then elevated in one continuous motion through extension of the lower back, hip, knee, and ankle joints. There are a multitude of variations of the deadlift, one of which is performed with the use of a hexagonal barbell. By allowing the lifter to execute the movement from inside the frame of the bar, performance characteristics differ from those of the conventional deadlift. As deadlift characteristics are altered with the use of a hex bar, it is likely that the hex bar will alter other performance variables as well, such as peak isometric force and rate of force development. As one of the most accepted methods of measuring RFD is the isometric mid-thigh pull performed with a straight bar, the use of a hex bar for isometric pull may likely alter RFD characteristics.

The deadlift is a full-body strength exercise that is frequently performed in resistance training settings. It is most frequently used for strength and power development, as it allows for the use of heavy loads which generate large muscular forces. The exercise requires the lifter to grasp the barbell at mid-shank level in a position similar to a squat, and then elevate the load in a continuous motion through extension of the lower back, hip, knee, and ankle joints. Typically, individuals are able to lift larger loads in the deadlift than in other free-weight exercises. A variety of deadlift styles exist, with a novel style being the deadlift performed with a hexagonal barbell. Due to the position of the body when performing the hex bar deadlift, this variation may provide numerous kinetic and kinematic advantages.

Biomechanical Characteristics of the Deadlift

The deadlift's ability to generate large muscular forces makes this exercise ideal for strength enhancement, developing strength in the back, legs, hips, and torso (13). However, these large internal forces may not always be beneficial, as the deadlift has the potential to generate large compressive forces in the lumbar spine. High lumbar compressive and shear forces have been reported during the deadlift (13, 16). In performing the conventional deadlift, L4/L5 compressive forces of 14,350 N to 17,192 N were recorded during national competitive powerlifting (7), with extreme disk compression values ranging to as high as 36,400 N. The potential for such immense compressive loads on the lumbar spine increases the risk of injury when performing the deadlift. Additionally, large joint forces are produced at the hip, knee, and ankle joints, ranging from 1,450 N to 1,550 N (5).

To help attenuate the exceedingly large internal and external forces that accompany the deadlift exercise, lifters should maintain the barbell close to the body throughout the entire movement (23). By maintaining bar path close to the body, the overall resistance of the external load will be decreased, through reduction of the moment arm at individual joints (23). It is crucial that the barbell remain close to the body throughout the lift, ensuring that the load stays closer to the lifter's center of gravity. This will aid in decreasing the moment at the lumbar spine (23).

<u>Variations of the Deadlift</u>

There are many variations of the deadlift exercise outside of the conventional deadlift. One such variation is the sumo deadlift. The sumo deadlift is performed with the feet further apart than in the conventional deadlift, and with the feet turned outward and the arms positioned inside the knees (12). Because of the closer positioning of the body relative to the barbell, the range of motion of the exercise is decreased, as is bar path. In a comparison of the conventional and sumo deadlift, Escamilla et al. reported that during the conventional deadlift, there is 20-25% greater vertical bar displacement than the sumo deadlift (12). Additionally, when examining biomechanical parameters of the conventional and sumo deadlift, sumo style employs a more upright trunk position and less hip flexion at liftoff, while conventional style extends the hips, knee, and shank throughout a greater range of motion (12). Further, center of mass displacement is significantly less in sumo deadlift compared to conventional deadlift style (12). This is likely attributed at least partially to not only the more upright trunk, but the greater stance width of sumo deadlifts. Escamilla et al. reported 100% greater stance width, 20% closer hand width, and 10% less vertical bar distance in the sumo deadlift compared to conventional (11). The closer center of mass and more upright trunk position found in the sumo deadlift may aid in decreasing spinal loads, thereby lessening the chance for injury

(12). Indeed, when compared to the conventional deadlift, Chowlewicki et al. found an 8% decrease in L4/L5 shear force in the sumo deadlift (7).

Another variation of the deadlift exercise is the straight-leg deadlift. Unlike the conventional deadlift which is initiated from a position with both hips and knees flexed, the knees remain nearly fully extended throughout the straight-leg deadlift. The straight-leg deadlift more specifically targets the hamstrings than the conventional deadlift, increasing hamstring activity while decreasing quadriceps activity (12, 28). When examining EMG activity of the biceps femoris and semitendinosus, Wright et al. found the highest muscle activity in both the leg curl and straight-leg deadlift exercise (28). Erector spinae activity is also increased, as the spine is in a more flexed position (12). Bezerra et al. found increased lumbar multifidus EMG activity during the straight-leg deadlift as opposed to the conventional deadlift (2). While these findings indicate that straight-leg deadlift training may be beneficial if the aim is to target the lower back or hamstring musculature, this also may potentially increase the risk of injury, as muscle activity of this region is increased while the spine is in a more vulnerable position (7).

The sumo deadlift therefore provides a variety of biomechanical advantages while still allowing for the development of large muscular forces, ideal for generating strength and power. However, because of the wide-stance and closeness of the body to the bar, flexibility may be an issue for some lifters. In contrast, the straight-leg deadlift requires less flexibility throughout the lower body, but also has less potential for heavy loading as the back is placed in a potentially more dangerous position. Therefore, for the development of large external forces, it appears that the ideal deadlift variation should maintain bar path close to the body as well as proper biomechanical considerations, such as ability to correctly grasp and lift the bar maintaining correct body position.

The Hexagonal Barbell

A barbell in the shape of a hexagon was created to assist in maintaining the external load closer to the body. The deadlift performed with a hex bar enables the lifter to perform the deadlift movement from inside the bar frame. The hex bar also enables the lifter to keep a more erect posture, reducing the moment arm and strain on the lumbar spine (15). Yet little research has been done on the hex bar and its comparison to conventional straight-bar deadlifts using an Olympic bar. To our knowledge, only one study to date has examined the hex bar in comparison to the Olympic bar. Swinton et al. examined the kinetic and kinematic variables of the deadlift performed with the straight barbell and the hex bar across submaximal loads (23). Subjects were able to lift a higher 1 repetition maximum load when using the hex bar. Across all submaximal loads, significantly greater peak force, peak power, and peak velocity values were found for the hex bar deadlift when compared to the straight bar deadlift. Further, the hexagonal design of the hex bar, which allows the lifter to be positioned inside its frame, altered the moment arm at a variety of joints, resulting in lower peak moments at the lumbar spine, hip, and ankle, yet resulting in greater flexion at the knee joint. The use of the hex bar reduced horizontal displacement away from the body by 75% compared to the straight barbell. These findings indicate that while the hex bar deadlift may allow a heavier load via advantageous positioning, a straight bar deadlift is superior for targeting lumbar musculature. Additionally, as the hex bar deadlift more evenly distributes the load across the body, it may be the better choice if injury is a concern (23).

While kinematic and kinetic variables of body position undoubtedly play a role in the larger 1RM values obtained when performing the hex bar deadlift, grip position may also impact this result. The conventional deadlift is performed with a pronated or alternated grip, while the handles on a hex bar require a neutral grip. While examining a variety of push and pull tasks, Domizio et al. found that there was increased forearm extensor muscle activity during pronated grip when compared to neutral grip (10). Because of this increased muscle activity during pronation, it is possible that fatigue is greater in a pronated position versus neutral position. Further, deadlift 1RM differences could be attributed to differences in bar thickness of a straight barbell and a hex bar. Ratamess et al. examined strength performance of a variety of free-weight exercises, including the deadlifting, using bars of different thicknesses, such as an Olympic bar, a 2-inch thick bar, and a 3-inch thick bar (22). For the deadlift exercise, the highest 1RM values were obtained using the bar with the smallest diameter (Olympic bar). If the thickness of the hex bar handles is less than that of the Olympic bar, improved gripping ability may provide an advantage over straight bar deadlift.

Isometric Pull

One of the many components of the hex bar not yet examined is its use in the isometric mid-thigh pull. The isometric mid-thigh pull test (traditionally performed with a straight bar) is a compound, closed-chain isometric test in which athletes pull as quickly and forcefully as possible against a stationary bar positioned at mid-thigh. (1, 20). The IMTP has been shown to correlate well with dynamic 1RM strength (1,20). However, the strength of the relationship between isometric and dynamic strength tests appears to depend partially on similarity of joint position between isometric test and the associated dynamic movement (1,18).

The IMTP is designed to approximate the body position at the start of the second-pull of the snatch or clean, and has accordingly been shown to correlate strongly with weightlifting performance variables (1). A study by Beckham et al. examining IMTP in relation to various weightlifting variables showed strong relationships between isometric peak force and weightlifting performance (1). Further, although peak RFD showed no correlation, average RFD was strongly correlated to weightlifting performance. In a study examining isometric strength and dynamic performance in professional rugby players, West et al. also found a significant relationship between relative peak force of the IMTP and dynamic performance (27). In examining the IMTP in relation to dynamic mid-thigh pulls at various intensities, Kawamori et al. found no correlation at light loads, yet a trend toward stronger relationships between isometric and dynamic peak force as the external load increased (18). However, none of the aforementioned studies found any significance between any variable and peak RFD.

The hex bar is a tool designed primarily for performing variations of the deadlift exercise. Therefore, if a hex bar were to be used for an isomeric pull, the pull should begin from a position similar to that of a deadlift rather than a clean or snatch movement. Multi joint isometric movements have been shown to have good reliability and strong relationships with variables of dynamic movements which require large forces, such as a deadlift (1, 8). Further, optimal loading for peak performance in lower-body exercises has been shown to vary depending on the movement (9). Therefore, dynamic deadlift performance may show stronger correlations with an isometric movement more similar to it, such as the isometric deadlift, as opposed to the IMTP. As the IMTP has been shown to be highly reliable and a very efficient measures of maximum strength, the hex bar isometric deadlift may show strong correlations to dynamic deadlift strength.

As the deadlift exercise is increasingly used for power development (24), training to generate maximum force in the deadlift position may be beneficial. In examining deadlifts performed explosively with and without the inclusion of chain resistance, Swinton et al. found that the deadlift can be used to generate large force and power values when performed explosively (24). If the goal of the deadlift is power, exerting maximum force in minimum time (i.e. having a greater RFD) from the start of the deadlift position could have much carry over to training settings.

As the hex bar has not been examined in these parameters, the effect of hex bar use on isometric performance is yet unknown. The hex bar is now commonly used in many strength and conditioning settings. In order to properly employ the hex bar deadlift in a training program and understand how it compares to the conventional deadlift, further research is needed on how the use of the hex bar compares to that of a straight bar.

CHAPTER 3

METHODS

Experimental Approach to the Problem

This study used a repeated measures approach to compare isometric performance between two different bars (Olympic, OL; hex), two different hand positions on the hex bar (low handles, LH; high handles, HH), and two different lifts (mid-thigh pull, MTP; deadlift, DL). Subjects were required to attend 3 days of testing 24-48 hours apart and performed both lifts, utilizing all bars and lift positions: MTP OL, MTP LH, MTP HH, DL OL, DL LH, DL HH. The order of conditions was counterbalanced.

Subjects

Twenty resistance-trained males (age = 24.05±2.09 years, height = 178.07 ± 7.05cm, mass = 91.42 ± 14.44 kg) with at least one year experience performing the deadlift volunteered to participate. They were free from any musculoskeletal injuries. Before data collection, all subjects were notified of potential risks and gave written informed consent, approved by the University Institutional Review Board.

Procedures

Set-Up

For the MTP OL, the bar was fixed in a power rack at mid-thigh level, and secured with the use of straps. A goniometer was used to ensure that the knee angle was 135 degrees. Hands were positioned outside the knees, using a self-selected grip. For the hex bar, the bar was secured at the same rack height as OL for LH, and maintained for the HH grip. For the isometric DL, standard plate height was used for position of all bars. Knee angle was not controlled.

Day 1: Familiarization

Upon arriving at the lab, subjects read and signed an informed consent document. Body mass and height were obtained using an electronic scale (ES200L; Ohaus Corporation, Pinebrook, NJ, USA) and stadiometer (Seca, Ontario, CA, USA). Prior to testing, subjects performed a dynamic warm-up consisting of 10 meters of walking knee hugs, walking lunges, and Frankenstein walks. They then performed a countermovement jump (CMJ). An EPIC jump device was positioned next to a force plate. Subjects' reach was measured with the dominant hand. While standing on the plate, subjects performed 3 CMJ trials, with 1 minute rest between attempts. While 3 trials was the minimum performed, subjects continued to perform trials until they could no longer successfully hit the vanes of the device. After the completion of CMJ trials, subjects held still in the bottom position of a countermovement, and ankle, knee, and hip angles were recorded.

Subjects were then measured and fitted to all bars for both lift positions. For the MTP OL condition, a handheld goniometer was used to ensure 135 degree knee angle. This bar height was recorded and maintained for MTP LH and HH conditions. Before initiation of pulls, subjects were given lifting straps to secure their hands to the bar. They then performed a warm up of 5 pulls at 50% effort, 3 pulls at 75% effort, and 1 pull at 90% effort, with 1 minute rest between sets and 3 minutes rest between conditions. They were then instructed to pull against the bar as hard and fast as possible for 5 seconds, throwing their weight back onto their heels while pulling. They performed two to three trials of each bar condition, with 1 minute rest, until a consistent effort was shown. Ankle, knee, and hip angles were recorded for all bars and lifts.

Day 2-3: Testing

Subjects followed the same warm-up procedures as Day 1. They then performed three repetitions each of an isometric MTP or DL, utilizing all bars. They were given 1 minute rest between trials and 3 minutes between conditions. On Day 3, they followed the same procedures, utilizing whichever lift had not been tested on Day 2.

For all tests, subjects stood on an Advanced Mechanical Technologies force plate (AMTI, Watertown, MA) sampling at 1000 Hz. All data were collected and analyzed with custom LabVIEW (v2013, National Instruments, Austin, TX) software. Isometric peak ground reaction force (PGRF), rate of force development (RFD), RFD every 50ms to 250ms, and S-gradient RFD (SRFD) were measured. CMJ jump height, GRF, peak velocity (PV), peak power (PP), and impulse were recorded.

Statistical Analyses

A 2 x 3 (lift by bar) repeated measures ANOVA analyzed all isometric force variables. The average of the three trials was used for analysis. Significant interactions were followed-up with two 1 x 3 ANOVAs, one for each lift.

Pearson correlations were run between all CMJ variables and isometric force variables.

A 2 x 3 x 3 (lift by bar by joint) repeated measures ANOVA analyzed joint angle. Significant interactions were followed-up with two 3 x 3 (bar by joint) repeated measures ANOVA, one for each lift. Further interactions were followed-up with three 1 x 3 repeated measures ANOVA, one for each bar.

CHAPTER 4

RESULTS

For PGRF, there was no interaction or main effect for condition. However, there was a main effect for lift, with MTP being greater than DL (Table 1).

For RFD, there was no interaction or main effect for condition. However, there was a main effect for lift, with MTP being greater than DL (Table 1).

For RFD at 50ms, there was an interaction. Follow-up demonstrated that for MTP, HH was greater than LH, but there were no differences between OL and LH or HH (Table 1). There were no differences for DL.

For RFD at 100ms, there was no interaction or main effect for condition. However, there was a main effect for lift, with MTP being greater than DL (Table 1).

For RFD at 150ms, there was no interaction or main effect for condition. However, there was a main effect for lift, with MTP being greater than DL (Table 1).

For RFD at 200ms, there was no interaction or main effect for condition. However, there was a main effect for lift, with MTP being greater than DL (Table 1).

For RFD at 250ms, there was no interaction or main effect for condition. However, there was a main effect for lift, with MTP being greater than DL (Table 1).

For SRFD, there was no interaction or main effect for condition. However, there was a main effect for lift, with MTP being greater than DL (Table 1).

CMJ GRF showed significant correlation to PGRF of MTP OL, MTP LH, DL OL, DL LH, and DL HH (Table 3). There was no significant correlation between CMJ GRF and PGRF of MTP HH. CMJ GRF was significantly correlated with RFD 150 of LH, showing no significant correlations with RFD 150 of MTP OL, MTP HH, DL OL, DL LH, or DL HH (Table 7). RFD 200 of DL OL was significantly correlated with CMJ GRF, with no significant correlation with RFD 200 of MTP OL, MTP LH, MTP HH, DL LH, or DL HH (Table 8). RFD 250 of DL OL was significantly correlated with CMJ GRF, with no correlations with RFD 250 of MTP OL, MTP LH, MTP HH, DL LH, or DL HH (Table 9). SRFD of MTP LH and MTP HH were significantly correlated with CMJ GRF, with no correlation with MTP OL, DL OL, DL LH, or DL HH (Table 10). There were no significant correlations between CMJ GRF and RFD, RFD 50, or RFD 100 for any bars or lifts.

CMJ PP was significantly correlated with PGRF of MTP OL, MTP LH, DL OL, DL LH, and DL HH (Table 3). There was no significant correlation between CMJ PP and PGRF of MTP HH. CMJ PP was significantly correlated with RFD of DL HH, with no significant correlation with MTP OL, MTP HL, MTP HH, DL OL, or DL LH (Table 4). CMJ PP was significantly correlated with RFD 200 of DL OL, with no significant correlation with RFD 200 of MTP OL, MTP LH, MTP HH, DL LH, or DL HH (Table 8). There was a significant correlation between CMJ PP and RFD 250 of DL OL, but no correlation with that of MTP OL, MTP LH, MTP HH, DL LH, or DL HH (Table 9). SRFD of MTP LH was significantly correlated with CMJ PP, with no significant correlations with MTP OL, MTP HH, DL OL, DL LH, or DL HH (Table 10). There were no significant correlations between CMJ PP and RFD 50, 100, or 150 for any bars or lifts.

CMJ impulse was significantly correlated with PGRF or all bars ad lifts: MTP OL, MTP LH, MTP HH, DL OL, DL LH, and DL HH (Table 3). RFD of DL OL and DL HH were significantly correlated with CMJ impulse; RFD of MTP OL, MTP LH, MTP HH, and DL HH were not (Table 4). RFD 150 of DL OL was significantly correlated with CMJ impulse, but RFD 150 of MTP OL, MTP LH, MTP HH, DL LH, and DL HH were not (Table 7). There were significant correlations between RFD 200 of MTP LH, DL OL, DL HH and CMJ impulse, but no significant correlations with RFD 200 of MTP OL, MTP HH or DL LH (Table 8). There were significant correlations between CMJ impulse and RFD 250 of MTP LH, DL OL, DL LH, and DL HH, but no correlations with that of MTP OL or MTP HH (Table 9). SRFD of MTP LH was significantly correlated with CMJ impulse, with no correlations between that of MTP OL, MTP HH, DL OL, DL LH, or DL HH (Table 10). There were no significant correlations between CMJ impulse and RFD 50 or RFD 100 for any bars or lifts.

There were no significant correlations between estimated jump height and isometric force variables for any bars or lifts. There were no correlations between CMJ PV and isometric force variables for any bars or lifts.

There were significant differences between joint angles at MTP and DL. At MTP, OL and HH ankle angles were significantly greater than LH ankle angle (Table 11). There was no difference between OL and HH ankle angle. HH knee angle was significantly greater than OL and LH knee angles (Table 12). There was no difference between OL and LH knee angle. HH hip angle was significantly greater than OL and LH hip angles, and OL hip angle was significantly greater than LH hip angle (Table 13).

At DL, OL ankle angle was significantly greater than LH ankle angle (Table 11). There was no difference between HH and OL or LH ankle angles. HH knee angle was significantly greater than LH knee angle (Table 12). There were no differences between OL knee angle and LH or HH knee angles. HH hip angle was significantly greater than OL an LH hip angles (Table 13). There was no difference between OL and LH hip angle.

There were significant differences between CMJ angles and ankle, knee, and hip joint angles at the MTP position. Ankle, knee, and hip joints were significantly more extended at MTP than CMJ (Table 14). At DL position, CMJ hip angle was significantly more extended than DL hip angle (Table 15). However, there were no differences between CMJ angles and ankle or knee angles at the DL position.

Table 1: Isometric Force Variables of MTP and DL by Bar

	MTP OL	MTP LH	MTP HH	DL OL	DL LH	DL HH	MTP (collapsed)	DL (collapsed)
PGRF	3196.28 ± 590.29	3177.48 ± 531.34	3102.47 ± 475.32	2461.08 ± 397.11	2541.21 ± 414.84	2540.58 ± 416.57	3158.74 ± 111.43*	2514.29 ± 90.45
RFD	2435.12 ± 1780.90	2826.38 ± 1887.94	2776.61 ± 1865.61	1926.54 ± 1181.35	1744.50 ± 851.58	1739.21 ± 1146.44	2679.37 ± 379.76*	1803.42 ± 217.68
RFD50	7563.20± 4200.25	6698.62± 2997.87	9126.26± 5774.18♦	6433.07± 3203.51	6245.03± 3508.39	6447.23± 3541.22		
RFD100	7427.52± 3272.27	7034.26± 2687.92	7978.16± 3317.69	6523.05± 2460.69	6245.03± 3508.39	6340.74± 2635.00	7479.98±620.85*	6369.61±572.58
RFD150	7657.68± 3162.04	6859.47± 2509.44	7119.18± 2673.70	5901.08± 1760.18	5707.88± 1844.30	5604.98± 1908.98	7212.11±563.76*	5737.98±378.45
RFD200	7486.89± 2525.88	7123.73± 2256.14	7095.08± 2137.48	5323.71± 1391.57	5175.94± 1452.47	5192.79± 1621.33	7235.23±475.16*	5230.82±311.46
RFD250	6583.57± 1852.97	6654.27± 1686.91	6503.91± 1513.99	4673.19± 1086.95	4572.77± 1133.30	4594.27± 1262.89	6580.58±342.23*	4613.41±242.37
SRFD	8063.01± 3331.22	7484.76± 2566.75	8694.14± 3881.19	6891.42± 2707.84	6783.98± 2976.41	6889.49± 2945.70	8080.64±642.25*	6854.97±612.15

*Significantly greater than DL (collapsed).

♦ Significantly greater than MTP LH.

Table 2: CMJ Variables

Jump height (EPIC)	25.35 ± 3.38 cm
Estimated jump height	46.67 ± 7.69 cm
Average jump GRF	2390.58 ± 341.79 N
Average jump velocity	3.08 ± 0.23 N/s
Average jump power	5990.43 ± 1051.93 W
Average jump impulse	286.69 ± 45.13 J

Table 3: Correlation of Isometric PGRF with CMJ Variables

	EST JUMP HT	CMJ GRF	CMJ PV	CMJ PP	CMJ IMPULSE
MTP OL PGRF	0.57	0.50*	-0.20	0.45*	0.60*
MTP LH PGRF	0.19	0.48*	-0.12	0.48*	0.66*
MTP HH PGRF	0.20	0.39	-0.06	0.41	0.68*
DL OL PGRF	0.15	0.77*	-0.11	0.70*	0.85*
DL LH PGRF	0.18	0.77*	-0.13	0.67*	0.84*
DL HH PGRF	0.22	0.66*	-0.05	0.64*	0.81*

*$p < 0.05$.

Table 4: Correlation of Isometric RFD with CMJ Variables

	EST JUMP HT	CMJ GRF	CMJ PV	CMJ PP	CMJ IMPULSE
MTP OL RFD	-0.31	0.21	-0.16	0.00	-0.01
MTP LH RFD	-0.08	0.26	0.08	0.21	0.18
MTP HH RFD	-0.05	0.36	-0.16	0.17	0.26
DL OL RFD	0.04	0.43	0.10	0.42	0.52*
DL LH RFD	-0.85	0.34	0.03	0.25	0.36
DL HH RFD	0.27	0.41	0.32	0.50*	0.47*

*$p < 0.05$.

Table 5: Correlation of Isometric RFD at 50ms with CMJ Variables

	EST JUMP HT	CMJ GRF	CMJ PV	CMJ PP	CMJ IMPULSE
MTP OL RFD 50	-0.06	-0.07	-0.08	-0.07	0.06
MTP LH RFD 50	0.07	0.28	0.05	0.23	0.24
MTP HH RFD 50	-0.05	0.36	-0.16	0.17	0.26
DL OL RFD 50	-0.14	-0.02	-0.16	-0.09	0.06
DL LH RFD 50	-0.05	-0.09	-0.09	-0.17	-0.20
DL HH RFD 50	0.05	0.11	0.01	0.10	0.18

*$p < 0.05$.

Table 6: Correlation of Isometric RFD at 100ms with CMJ Variables

	EST JUMP HT	CMJ GRF	CMJ PV	CMJ PP	CMJ IMPULSE
MTP OL RFD 100	0.02	-0.01	0.01	0.03	0.12
MTP LH RFD 100	0.16	0.38	0.04	0.32	0.40
MTP HH RFD 100	-0.00	0.35	-0.18	0.16	0.29
DL OL RFD 100	-0.06	0.26	-0.11	0.17	0.35
DL LH RFD 100	-0.05	-0.09	-0.09	-0.17	-0.20
DL HH RFD 100	0.08	0.21	0.07	0.23	0.35

*p < 0.05.

Table 7: Correlation of Isometric RFD at 150ms with CMJ Variables

	EST JUMP HT	CMJ GRF	CMJ PV	CMJ PP	CMJ IMPULSE
MTP OL RFD 150	0.02	0.15	-0.02	0.14	0.24
MTP LH RFD 150	0.16	0.47*	0.05	0.23	0.24
MTP HH RFD 150	0.08	0.31	-0.07	0.24	0.42
DL OL RFD 150	0.03	0.40	-0.06	0.32	0.49*
DL LH RFD 150	0.05	0.13	0.06	0.10	0.16
DL HH RFD 150	0.16	0.20	0.17	0.31	0.41

*p < 0.05.

Table 8: Correlation of isometric RFD at 200ms with CMJ Variables

	EST JUMP HT	CMJ GRF	CMJ PV	CMJ PP	CMJ IMPULSE
MTP OL RFD 200	-0.03	0.23	-0.16	0.17	0.32
MTP LH RFD 200	0.15	0.43	0.01	0.41	0.53*
MTP HH RFD 200	-0.05	0.25	-0.20	0.21	0.33
DL OL RFD 200	0.17	0.49*	0.02	0.45*	0.57*
DL LH RFD 200	0.11	0.23	0.06	0.22	0.34
DL HH RFD 200	0.19	0.21	0.15	0.32	0.46*

*p < 0.05.

Table 9: Correlation of Isometric RFD at 250ms and CMJ Variables

	EST JUMP HT	CMJ GRF	CMJ PV	CMJ PP	CMJ IMPULSE
MTP OL RFD 250	-0.06	0.27	-0.23	0.20	0.36
MTP LH RFD 250	0.16	0.40	-0.02	0.38	0.52*
MTP HH RFD 250	-0.09	0.21	-0.29	0.05	0.33
DL OL RFD 250	0.21	0.54*	0.03	0.50*	0.63*
DL LH RFD 250	0.12	0.31	0.02	0.27	0.45*
DL HH RFD 250	0.20	0.24	0.12	0.34	0.49*

*p < 0.05.

Table 10: Correlation of Isometric SRFD with CMJ Variables

	EST JUMP HT	CMJ GRF	CMJ PV	CMJ PP	CMJ IMPULSE
MTP OL SRFD	0.03	0.06	0.02	0.10	0.20
MTP LH SRFD	0.21	0.49*	0.15	0.48*	0.50*
MTP HH SRFD	0.05	0.46*	-0.03	0.36	0.43
DL OL SRFD	-0.18	0.22	-0.19	0.10	0.28
DL LH SRFD	-0.00	0.18	-0.04	0.11	0.14
DL HH SRFD	0.05	0.24	0.03	0.26	0.36

*p < 0.05.

Table 11. Ankle Joint Angles

	OL ANKLE	LH ANKLE	HH ANKLE
MTP	82.50±3.62♦	79.80±5.15	84.60±4.55♦
DL	76.15±5.42♦	71.00±7.22	73.60±7.61

♦Significantly greater than LH.

Table 12. Knee Joint Angles

	OL KNEE	LH KNEE	HH KNEE
MTP	135.00± 0.00	134.85±0.67	148.80±10.43*
DL	99.85±14.14	97.10±13.17	104.15±12.36♦

*Significantly greater than OL and LH
♦Significantly greater than LH

Table 13. Hip Joint Angles

	OL HIP	LH HIP	HH HIP
MTP	129.20±12.82♦	123.70±12.61	150.85±17.53*
DL	52.70±6.75	49.70±10.24	60.25±7.96*

♦Significantly greater than OL and LH.
*Significantly greater than LH.

Table 14. Comparison of MTP and CMJ Joint Angles

	CMJ	OL MTP	LH MTP	HH MTP
ANKLE	75.00±6.24	82.50±3.62*	79.80±5.15*	84.60±4.55*
KNEE	93.50±27.39	135.00±0.00*	134.85±0.67*	148.80±10.43*
HIP	80.00±13.33	129.20±12.82*	123.70±12.61*	150.85±17.53*

*Significantly greater than CMJ angle.

Table 15. Comparison of DL and CMJ Joint Angles

	CMJ	OL DL	LH DL	HH DL
ANKLE	75.00±6.24	76.15±5.42	71.00±7.22	73.60±7.61
KNEE	93.50±27.39	99.85±14.14	97.10±13.17	104.15±12.36
HIP	80.00±13.33	52.70±6.75*	49.70±10.24*	60.25±7.96*

*Significantly less than CMJ angle.

CHAPTER 5

DISCUSSION

The purpose of this study was to compare isometric performance between Olympic and hexagonal barbells at the mid-thigh and deadlift positions, and compare isometric performance to dynamic performance via countermovement jump. The major findings were that MTP force variables were greater than DL for all lifts, HH MTP RFD at 50ms was greater than LH, MTP joint angles were more extended than DL angles, and the strongest correlations between isometric and dynamic performance were seen between DL PGRF and CMJ impulse. These may be due to biomechanical differences between the MTP and DL, the joint angles of the movements, and the need to maximize force during explosive efforts, such as during isometric pulls.

MTP was found to be greater than DL for all force variables. Isometric MTP is a commonly used assessment to measure performance due to its similarity with the 2nd pull of the clean. Characteristic of this position is a knee angle of 130-140 degrees and an upright trunk, commonly referred to as the power position as it represents the point during weightlifting movements where the highest forces and power outputs are achieved (1, 17). In comparing power production between weightlifting and powerlifting exercises, Garhammer (14) reported average power output in the deadlift was one-half to one-third that developed during the snatch or clean, attributed to the lower vertical velocities generated throughout the deadlift. Additionally, in a review of existing studies on power output during weightlifting and powerlifting, Garhammer reported that power output testing has more potential as a tool for predicting performance in weightlifting movements rather than powerlifting movements. (14) The current study examines two separate movements that are classically considered weightlifting specific (MTP) and powerlifting specific (DL). The deadlift is commonly employed to generate maximum strength, whereas the clean is employed to generate maximum power (17, 23, 24). Despite the overlap, it has been repeatedly demonstrated that the development of strength and power are distinct qualities (20). Further, previous research has shown that the joint angle of isometric tests significantly impacts the relationship to dynamic performance (1, 18); therefore, the higher power production during weightlifting movements would result in greater outputs during the isometric task of similar position.

The difference between MTP and DL may also be due to the biomechanical differences between the positions. The conventional deadlift at heavy loads is commonly viewed as the most challenging movement for the lumbar spine (23). Indeed, in examining elite powerlifters, Cholewicki found the loads on the lumbar spine to range from 14,350 to 17,192N during the deadlift (7). In contrast, as mentioned above, the 2nd pull position of the MTP is often referred to as the power position (17). At MTP, the greater extension of angles at the ankle, knee, and hip allow for a more advantageous length-tension relationship of the muscles involved than during the DL position. The greater a muscle shortens, the less tension it is capable of generating (12, 13). As the muscles are more optimally overlapped, greater force is able to be instantaneously developed at MTP rather than DL.

Due to the dimensions of the force plate, participants were required to perform the DL with a conventional stance. While all participants had experience performing the deadlift with a hex bar, many were powerlifters who employed a sumo-style deadlift when performing dynamic deadlifts with an Olympic bar. The change in stance for purposes of data collection may have impacted some lifters' force production. During the sumo-style deadlift, the feet are positioned further apart and turned outward, with the hands positioned inside the knees (11, 12, 13). Due to the differences in biomechanical positioning, Escamilla et al found that sumo-style deadlifts resulted in 25-30% less mechanical work (12 OR 13). Additionally, Cholewicki et al. observed a 10% reduction in L4/L5 moment and 8% reduction in L4/L5 shear force when employing the sumo deadlift versus conventional (7). As subjects were giving a maximum isometric contraction, the difference in forces on the body during the conventional stance may have affected their force generating capability.

Despite the larger force variables for the MTP conditions, the strongest correlations between isometric performance and vertical jump variables were seen between DL PGRF and CMJ impulse. This is contrary to what was expected, as both the CMJ and MTP are classically utilized as measures of explosive performance, unlike the DL. Previous research has been conflicting in the relationship between isometric and dynamic performance. McGuigan found very strong correlations have been found between isometric MTP and vertical jump height, as well as correlations with 1RM squat and bench press (20). Thomas et al found isometric MTP performance does not significantly correlate with vertical jump peak velocity or jump height, yet does correlate with peak force and peak power (25). As in the present study, previous research has found no correlation with dynamic measures of performance and dynamic RFD (20, 25).

Several reasons can be suggested for the current findings. As mentioned above, multiple studies have found the strength of the relationship between dynamic tasks and isometric performance to be dependent on similarity of joint angle (1, 18). The lack of hypothesized correlation between MTP and CMJ could be attributed to the biomechanical characteristics of the two actions. While the MTP involves an active isometric muscle action, the CMJ involves an eccentric muscle action followed by a very brief isometric action and finally concentric muscle action (25). While MTP performance relies solely on maximal force production for performance, CMJ relies on both maximal force and velocity, a more complex relationship determining performance (25). Additionally, CMJ efficiently utilizes the stretch shortening cycle, unlike the isometric actions.

In the present study, MTP joint angles at the ankle, knee, and hip were significantly more extended than DL angles. It is commonly accepted that CMJ and MTP are initiated from a similar position, with the torso upright and ankles, knees, and hips slightly flexed. However, when examining the joint angles of the isometric assessments with those typical of the CMJ, the angles of the DL were more similar to CMJ angles than MTP angles. While ankle, knee, and hip angles were significantly more extended at MTP when compared to CMJ, there were minimal differences between DL angles and CMJ angles, with the only difference seen at the hip. This could explain the stronger correlation between DL and CMJ variables. Previous research has found the position of the knee during the first pull to be near the angle where knee extensor strength is approaching full capacity (26). In observing the CMJ, the degree of ankle and knee flexion during the countermovement more closely resembles DL than MTP, where joints are more extended.

Additionally, both the first pull of the DL and CMJ require the application of a large amount of force in a short period of time (26). During the dynamic DL, an explosive concentric contraction is required to move the load from the ground; this high reliance on rapid strength capability during liftoff is similar to that required to lift the body from the ground during CMJ (26). While rapid strength production is also required for MTP and dynamic weightlifting movements, subjects did not report on their weightlifting experience. Subjects were required to have experience with the deadlift, but not weightlifting movements.

Angle differences may be explained by the biomechanical characteristics of body position specific to each bar. At MTP, OL knee angle was ensured at 135 degrees, with LH and HH initiated from the same rack height. This produced no difference in knee flexion for OL and LH, yet less knee flexion for HH as the handles allow for the pull to begin from 4 inches higher. In the HH condition, the lifter initiated the pull from a position of almost full extension.

Despite the similarity of knee angle, differences did exist between the OL and LH conditions. During LH, the lifter is centered inside the frame of the barbell, making an effort to extend the flexed joints and produce force vertically. During OL, the lifter is positioned behind the barbell, allowing the lifter to throw their weight back on their heels during the pull. This causes force production not only vertically, but posteriorly/horizontally behind them, allowing for greater extension at the joints. As such, MTP angles of both ankle and hip at OL were significantly more extended than MTP ankle and hip angles at LH.

As there is a four-inch height difference in the HH condition, the lifter is centered inside the barbell with the joints almost completely extended. This allows for both MTP HH knee and hip angles to be significantly more extended than OL and LH knee and hip angles. However, HH ankle angle is significantly more extended than LH ankle angle, with no difference between OL and HH ankle angles. The more extended positioning is likely responsible for the greater RFD 50ms seen in HH rather than LH. As the lifter is more upright and near full extension during HH, they produce force via an initial rapid contraction.

The above biomechanical characteristics are similar for DL position, yet rather than controlling for knee angle, pulls were always initiated from standard plate height from the floor. There were no differences in DL knee angles for OL and LH, yet HH knee angle was significantly more extended, as the lifter is more upright with the higher set of handles. For the same reason, DL hip angle of HH was significantly more extended than OL or LH hip angles. However, only DL ankle angle for OL was significantly more extended than LH ankle angle, with no difference between OL and HH or LH and HH. This can likely be explained by the position of the lifter in relation to the barbell. At DL OL, the lifter was positioned behind the barbell, able to produce force in multiple planes, with more extension at the joints as mentioned above. Additionally, proximity to the barbell was not controlled at this position; the lifter simply had to be firmly strapped to the bar. At DL LH, the lifter was positioned inside the barbell in a fixed position, without being able to select their preferred distance from the bar as in the OL position. Therefore, ankle flexion was greater at LH than OL. The lack of difference between HH and LH can likely be explained by the position of the lifter inside of the barbell, as well as the differences in flexion at the other angles measured. Differences may not have occurred at the ankle angles because of the increased extension at the knee and hip angles, as both joints are generally much more mobile than the ankle joint.

The findings of the current study indicate that there is minimal difference in force output between hexagonal and Olympic barbells. Therefore, regardless of the bar selected, the position from which the pull is may play a role in force production. While pulls initiated from the mid-thigh had larger overall force outputs, an athlete interested in vertical jump performance may benefit by initiating pulling movements from the deadlift position as evidence by the high correlation with CMJ impulse. Due to similarity in joint angles between deadlift and CMJ, there may be a high carryover between the two movements.

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