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Relationships Between Hex Bar Deadlift One-Repetition Maximum and Maximal Isometric Pulls

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ABSTRACT

International Journal of Exercise Science 15(4): 45-57, 2022. This study sought to determine relationships between hexagonal barbell (HBB) deadlift one-repetition maximum (1-RM) and force-time characteristics of maximal isometric pulls. Twenty-three healthy adults (13 men [8 trained], 10 women [4 trained]) completed three visits consisting of a familiarization and anthropometrics session, a HBB deadlift 1-RM session, and a performance session with three maximal isometric pulls at three positions: lift-off (FLOOR), knee-passing (KNEE), and mid-thigh (MT). Correlation analyses assessed relationships between 1-RM and force-time characteristics at each position with significance set a priori at $\alpha \leq 0.05$. Correlation coefficients between 1-RM and force-time characteristics at all positions presented large to very large relationships to peak force (PF; r = 0.695-0.879, $p \leq 0.001$), large to very large relationships to all time-specific force variables (r = 0.506-0.812; $p \leq 0.014$), moderate to very large relationships between rate of force development (RFD) time-bands (r = 0.430-0.752; $p \leq 0.041$), and large to very large relationships to impulse (r = 0.575-0.778; $p \leq 0.004$). Collectively, more very large effect sizes (r = 0.7-0.89) were observed at FLOOR (n = 8) and KNEE (n = 6) than MT (n = 0). PF at FLOOR and KNEE presented as strongest predictors of maximal strength in the 1-RM HBB deadlift. The observed differences between positions may be due to exercise-specific disadvantageous positions commonly observed as isometric sticking points. Coaches should consider incorporating isometric pulls from the lift-off or knee passing positions as it appears to be better related to maximal strength than the isometric mid-thigh pull.

KEY WORDS: Isometric mid-thigh pull, maximal strength testing, peak force, performance testing

INTRODUCTION

Conventional deadlifting consists of a standard Olympic barbell being lifted from the floor by performing hip, knee, and ankle extension until the torso is fully erect and subsequently eccentrically lowered to the floor (20). Given the recruitment of large muscle groups and the ability to impose high total loads, the deadlift is frequently used to develop strength and power (20). A common variation to conventional deadlifting utilizes a hexagonal barbell (HBB) which uses a more upright posture, thereby reducing stress on muscles of the posterior chain (i.e.

erector spinae and biceps femoris) (7, 33), and providing an increased safety of the spine and low back (15, 32).

In addition to potentially enhanced safety, improved peak force (PF), velocity, and power during submaximal HBB deadlift have been reported in comparison to conventional deadlifting (7, 24, 33). Using the HBB, Swinton and colleagues (33) observed greater maximal strength when compared to conventional deadlift in powerlifters, while Camara et al. (7) observed no differences in maximal strength in resistance trained men. Differences in training status may have led to these discrepancies, as powerlifters produced a HBB deadlift one-repetition maximum (1-RM) of approximately 81 kg more than resistance trained men (7, 33).

Researchers and practitioners have begun using maximal isometric testing to examine performance and adaptation to training stimuli (9, 19). When compared to traditional maximal strength assessments (i.e. RM protocols), isometric testing is considered potentially safer due to the biomechanical simplicity, reduced fatigue, and improved time-efficiency (9). Additionally, multi-joint isometric tests have demonstrated greater relationships to dynamic movements and are preferred over single-joint isometric tests (16). The isometric mid-thigh pull (IMTP) is a multi-joint isometric test that has been previously used extensively in research. The IMTP consists of participants pulling against an immovable bar located at a position that mimics the second pull position of the clean exercise (9). Unlike the 1-RM, the use of the IMTP allows the assessment of PF, time-specific force values, and rate of force development (RFD) (11, 14, 17–19). Previously, trained individuals experienced with the IMTP have shown this test to be highly reliable with low variability and low measurement error (5, 11, 12, 14, 18). To the authors' knowledge, only one study has utilized a sample of inexperienced weightlifters and found that reliable data were able to be collected from the mid-thigh position (5).

The IMTP has been associated with several dynamic movements important for athletic performance. Previously, PF and/or RFD at predetermined time bands during the IMTP have demonstrated relationships to vertical jump performance (34, 35), sprinting, change of direction, speed, and agility (34–36), total weightlifting performance (3, 17), as well as 1-RM performance in the power clean and bench press (28, 29), snatch, clean and jerk (3, 17), and back squat (26, 28, 29, 36). Deadlift 1-RM has been associated with IMTP PF (12), though the use of an older population (40 ± 8 years) that was chosen to resemble the current corps of astronauts and the use of uncommon exercise equipment (Advanced Resistive Exercise Device; ARED) may make generalizations to younger or athletic populations inappropriate.

While the IMTP is performed with an upright posture mimicking the second pull position of the clean, examination of isometric performance in disadvantageous positions of the deadlift may also produce relationships to dynamic performance. During the deadlift, lift-off and knee passing are two phases at which performance can be limited (21, 27). It may be beneficial to further examine the force-time curve characteristics of isometric pulls from these positions, in addition to the mid-thigh position. One study – utilizing powerlifters – has compared isometric PF at these phases of the deadlift, finding the lift-off position to generate the lowest PF, followed by knee passing, and lastly mid-thigh (4). The reliability of these positions via the coefficient of variation (CV) for PF was determined to be 1.2%, 2.0%, and 5.0% for lift-off, knee-passing, and mid-thigh, respectively (4). Unfortunately, other isometric force-time curve characteristics were not analyzed, limiting the breadth of the investigation.

The IMTP has been established as an effective alternative to monitor training adaptations in myriad dynamic movements. It is important to continue to understand the relationships present between the IMTP and different movements, such as the HBB deadlift, to allow trainers and coaches to routinely monitor their trainee's progression and provide safe exercise prescriptions. With a reliable alternative method to assess HBB deadlift 1-RM being warranted, the primary purpose of this investigation is to determine if any relationships are present between a HBB deadlift 1-RM and force-time curve characteristics of the IMTP in a generalized population. We hypothesized PF would present with the strongest relationship to maximal strength, and also that the later RFD (0-250ms) and time-specific force values (250ms) would be stronger correlates to 1-RM than all other variables. Additionally, we sought to determine whether isometric pulls performed from the floor, knee, or mid-thigh position present stronger relationships between a HBB deadlift 1-RM and previously mentioned force-time curve characteristics. We hypothesized that the force-time curve characteristics collected in the mid-thigh position would present with the strongest relationships to maximal strength when compared to the floor and knee positions.

METHODS

Participants

Twenty-three college-aged adults volunteered to participate in this investigation. Participants were generally healthy and free from disease, as determined by a self-reported medical history form. Descriptive characteristics are listed in Table 1. Participants were determined to be resistance trained if they self-reported training a minimum of three days per week for at least the previous six months. Exclusion criteria consisted of presenting with any cardiovascular, pulmonary, or metabolic diseases. Additionally, those with ongoing neuromuscular diseases or seizures, musculoskeletal injuries, a history of blood clots, or less than six months removed from surgery to the lower extremities were excluded from participating. Individuals that agreed to participate were made aware of any risks the study may include and provided a written informed consent followed by the completion of a medical history questionnaire to determine eligibility. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (30). This investigation was approved by the University's Institutional Review Board.

Table 1. Participant Descriptive Characteristics.

	Men	Women
Total *N* (Trained)	8 (5)	4 (6)
Age	23 ± 3	22 ± 4
Height (cm)	178.7 ± 5.9	164.2 ± 7.2
Weight (kg)	84.6 ± 12.6	63.3 ± 9.4
Body Fat (%)	13.2 ± 4.8	22.5 ± 4.7
HBB Deadlift 1-RM (kg)	162.62 ± 42.26	92.40 ± 18.83

Data presented as mean ± SD

Protocol

A correlational study design was implemented to determine the relationship between maximal strength recorded from a HBB deadlift 1-RM and force-time variables collected during a series of maximal isometric pulls. During Visit 1, a written informed consent and medical history questionnaire were obtained, and participants were familiarized with the isometric testing and deadlift procedures. Anthropometric measures and maximal strength during the deadlift, as assessed through a 1-RM, were determined during Visit 2; while isometric pulls were performed during Visit 3. Visits 1 and 2 were separated by at least 24 hours, while Visits 2 and 3 were separated by a minimum of 72 hours (Figure 1).

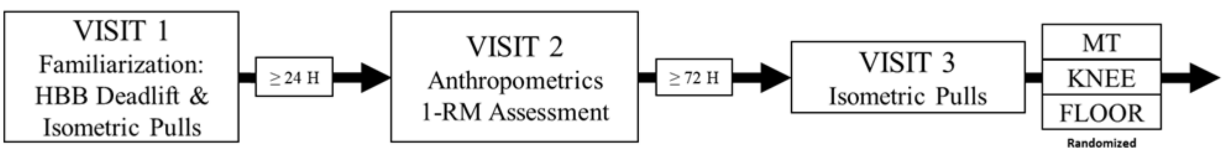

Figure 1. Study Design: Participants completed three visits to the Exercise Performance and Recovery Lab. On Visit 1, participants first provided a written informed consent, followed by a medical health history questionnaire, and finally a familiarization with the hex barbell deadlift and the isometric pulls. At least 24 hours later, Visit 2 consisted of anthropometrics and hex barbell deadlift one-repetition maximum assessment, while Visit 3, at least 72 hours after Visit 2, consisted of a series of isometric pulls at the floor, knee, and mid-thigh positions in a randomized order.

Familiarization: After participants provided a written informed consent and were deemed eligible during Visit 1, all participants were familiarized with the HBB deadlift which included technique instruction and the performance of one to three sets of three to ten repetitions, depending on the needs of the participant. Participants were then familiarized with each of the isometric pulls using a straight Olympic barbell and the use of lifting straps. Bar heights were measured and recorded for replication during Visit 3. Lastly, a submaximal isometric pull was performed at each of the three positions.

Anthropometrics: Height, weight, and body fat percentage was determined for each of the participants during Visit 2. Height and weight were assessed using a digital physician scale (Health-o-Meter 500KL, McCook, IL). The seven-site skinfold assessment was completed using Lange skinfold calipers (Beta Technology, Santa Cruz, CA) and previously established procedures (31).

1-RM Assessment: The HBB deadlift 1-RM assessment was modified from NSCA guidelines (20), and overseen by a Certified Strength and Conditioning Specialist (CSCS). The HBB deadlift was performed using Olympic weight plates (Rogue Fitness, Columbus OH), with midpoint of the bar 22.5cm from the ground. Participants completed a standardized general warm-up consisting of five minutes of cycling on a Schwinn Air Dyne (Nautilus Inc., Vancouver, WA), 10 bodyweight squats, and 10 body weight lunges. Participants were then allotted three specific warm-up sets of the HBB deadlift: one set of no more than 10 repetitions at 50% of their estimated 1-RM, one set of no more than five repetitions at 65% of their estimated 1-RM, and one set of no more than three repetitions at 80% of their estimated 1-RM. Participants were given one minute of rest in between warm-up sets. A three-to-five-minute rest break was provided before each maximal effort attempt. The CSCS increased the load depending on the difficulty of the previous attempt. No more than five attempts were permitted. The greatest load lifted with proper form, as judged by the CSCS was deemed the 1-RM. Proper form was determined as lifting the load from the floor to an erect torso position and subsequently lowering the weight in a controlled fashion, whilst maintaining a neutral spine through the completion of the exercise (20).

Isometric Pull Assessment: All isometric pulls were performed in a Squat Stand (Rogue Fitness, S-Series, Columbus OH) outfitted with bilateral force plates (PASCO Scientific, Roseville, California, USA) and an immovable straight Olympic barbell (Rogue Fitness, Columbus, OH) using inverted J-hooks and tightened straps (Figure 2A). The equipment utilized allowed for bar heights to be changed in 2.5cm increments.

The first bar height (FLOOR; Figure 2B) was measured as 22.5cm above the platform to the center of the barbell, corresponding to deadlift lift-off (4). The mid-thigh position (MT; Figure 2C) was determined as the mid-point between the center of the patella and the anterior superior iliac spine (11). The final position (KNEE; Figure 2D) was determined as the mid-point between the floor and mid-thigh positions which was located just superior to the patella (4). Hip and knee angles were self-selected, measured, and recorded immediately prior to the first repetition at each position. Prior research has demonstrated a hip angle of 140-150° and knee angle of 125-145° in the mid-thigh position to produce the most optimal results (9); therefore if posture was outside this range, the researcher would correct the stance for MT only. To our knowledge, no standard hip and knee angle for isometric pulls from the floor or knee exist, thus the participants were permitted to maintain a posture of choice. The order of completion was randomized for each participant prior to their visit to ensure that there was no effect of order.

Table 2. Average Hip and Knee Angle at Each Position.

Bar Position	Hip Angle (°)	Knee Angle (°)
FLOOR	59.13 ± 6.36	100.70 ± 13.89
KNEE	95.17 ± 8.12	130.74 ± 8.93
MT	140.13 ± 4.77	142.91 ± 4.22

Data presented as mean ± SD

Testing began with the standardized general warm-up previously detailed. Next, participants performed three trials at each of the three positions for a total of nine maximal effort isometric pulls. Participants were secured to the bar using lifting straps as previously suggested by literature (3). Participants were instructed to place their feet centrally on each force plate and to "push their feet into the ground as hard and as fast as possible" which has been suggested to maximize RFD and PF (22). After maintaining appropriate positioning, as determined by the technician, participants completed a two-second stationary weighing period. Participants were then provided a firm "Pull!" signal to begin a six-second maximal effort while receiving strong verbal encouragement through completion. Participants were given three minutes of rest between trials. If there was an obvious, visible countermovement prior to initiation of the pull, the trial was discarded, and an additional trial was performed. The force plates were tared prior to the beginning of each attempt. The coefficient of variation (CV) for the three pulls completed at each position were calculated. CVs above the minimum acceptable reliability of 15% for force-time characteristics (18), or 5% for PF (4), were re-examined and the two closest values were chosen for analysis to negate the impact of outlier values. This methodology was chosen to counteract anticipated variability in force-time characteristics in an untrained population at positions not previously determined to be reliable. Average CVs are reported in Table 3.

Force-Time Curve Analysis: Vertical ground reaction forces collected from the force plates were unfiltered and sampled at 1,000 Hz. The normal force from each force plate was summed for a total force, and all force-time curve data recorded were analyzed using a customized Microsoft Excel spreadsheet (Microsoft Corp., Redmond, WA, USA). The onset of contraction threshold was set at a vertical ground-reaction force of five standard deviations above the average body weight (13). Body weight was determined as the average force over the first one-second of stationary weighing period prior to the start of the isometric pull. If the onset of contraction threshold criteria was met prematurely (i.e., producing negative RFD), trials were discarded, and the remaining two pulls were used for further analysis. All force-time characteristics were analyzed using the first five seconds of the maximal isometric pull. The maximum instantaneous force generated during the pull was reported as the absolute PF. Time-specific force values at 50, 100, 150, 200, and 250ms (F50, F100, F150, F200, F250) and time-specific force values normalized to PF (F50%, F100%, F150%, F200%, and F250%) were determined for each trial (10) and RFD at pre-determined time bands of 0-30, 0-50, 0-90, 0-100, 0-150, 0-200, and 0-250ms from the onset of contraction were determined for each trial. These time-specific force curve characteristics have been suggested by previous literature to demonstrate the highest reliability from the mid-thigh position (18). RFD was calculated using the equation: Rate of Force Development (RFD) = ΔForce / ΔTime. Additionally, impulse (IMP) at 100, 200, and 300ms were calculated as the average force generated over each time interval.

Table 3. Coefficients of Variation (CVs) for Each Position.

VARIABLE	FLOOR	KNEE	MT
PF	3.3	3.6	3.1
F50	15.2*	13.2	11.2
F100	11.2	10.5	10.5
F150	7.2	6.0	10.7
F200	8.7	7.1	11.5
F250	8.8	6.3	9.4
F50%	15.0	14.4	12.7
F100%	12.1	12.6	9.5
F150%	8.3	8.7	8.8
F200%	8.2	9.2	9.6
F250%	8.5	7.0	7.6
RFD 0-30ms	19.3*	23.1*	13.8
RFD 0-50ms	19.4*	15.0*	14.2
RFD 0-90ms	12.8	14.1	11.7
RFD 0-100ms	12.1	13.4	11.6
RFD 0-150ms	8.5	8.7	12.0
RFD 0-200ms	8.8	8.6	12.2
RFD 0-250ms	10.7	9.0	11.8
IMP100	12.6	13.7	11.3
IMP200	7.6	6.6	10.4
IMP300	7.8	5.7	10.1

Data presented as mean percentage. * Denotes CV > 15%. RFD: rate of force development; PF: peak force; F50: force at 50ms; F100: force at 100ms; F150: force at 150ms; F200: force at 200ms; F250: force at 250ms; F50%: force at 50ms normalized to peak force; F100%: force at 100ms normalized to peak force, F150%: force at 150ms normalized to peak force; F200%: force at 200ms normalized to peak force; F250%: force at 250 normalized to peak force; IMP100: impulse over 100ms; IMP200: impulse over 200ms; IMP300: impulse over 300ms.

Statistical Analysis

Both sexes and training statuses were combined during analysis. Normality was assessed using Shapiro-Wilk's test. All data was determined to be normally distributed with the exception of RFD 0 - 30ms, which was subsequently removed from analysis. Pearson's product-moment correlations were performed to assess the relationship between HBB deadlift 1-RM and force-time curve characteristics. Significant correlations were defined a priori at $a \leq 0.05$. Effect size thresholds of 0.1, 0.3, 0.5, 0.7, and 0.9 were interpreted as small, moderate, large, very large, and extremely large as previously suggested (8, 23). Post-hoc power analysis was calculated using G*Power (Version 3.1.9.4; Düsseldorf, Germany), while all other statistical analyses were performed using SPSS Statistics (IBM, Armonk, NY).

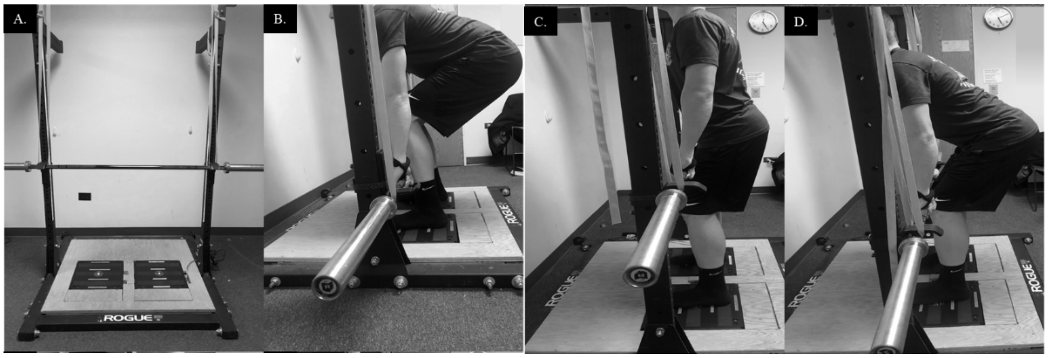

Figure 2. Photo depicting (A) the isometric pull equipment, (B) a participant in position for an isometric pull from the FLOOR, (C) a participant in position for an isometric pull from the MT, and (D) a participant in position for an isometric pull from the KNEE.

RESULTS

Correlation coefficients between HBB deadlift 1-RM and each force-time curve variable are depicted in Table 4. The correlation coefficients between 1-RM and PF at FLOOR and KNEE presented with very large effect sizes (r = 0.879, 0.827; respectively), while PF at MT presented with a large effect size (r = 0.695).

Correlation coefficients between 1-RM and time-specific force values presented with moderate to very large relationships (r = 0.506–0.812). FLOOR and MT demonstrated a stepwise increase in effect size from early time points (F50: r = 0.543, 0.506; FLOOR and MT, respectively) to late time points (F250: r = 0.812, 0.652; FLOOR and MT, respectively). In contrast, KNEE demonstrated very large effect sizes at intermediate time points (F100: r = 0.773; F150: r = 0.724). All time-specific force values normalized to PF were not related to 1-RM across all positions ($p \geq 0.131$).

Relationships between 1-RM and RFD for all three positions presented with the lowest effect sizes at the early time-band (0 - 50ms: r = 0.459–0.555). RFD 0-200 and 0-250ms at FLOOR demonstrated very large relationships to 1-RM (r = 0.736, 0.752; respectively). RFD 0-90, 0-100, and 0-150 at KNEE demonstrated large to very large effect sizes (r = 0.682, 0.704, and 0.691; respectively). RFD 150, 200, and 250ms at MT demonstrated large relationships to 1-RM (r = 0.593–0.595).

The effect sizes between IMP variables and 1-RM were large at KNEE over 100ms (r = 0.659), very large at FLOOR and KNEE over 200ms (r = 0.711, 0.754; respectively), and very large at FLOOR and KNEE over 300ms (r = 0.778, 0.710; respectively). Post-hoc power analyses indicated that all but two (RFD 0-50ms - FLOOR: 1-β = 0.77; RFD 0-50ms – MT: 1-β = 0.74) significant relationships exceeded a power (1-β) of 0.8.

Table 4. Correlation Coefficients between 1-RM and Force-Time Characteristics.

VARIABLE	FLOOR		KNEE		MT	
	r	*p*	*r*	*p*	*r*	*p*
PF (N)	0.879#	≤ 0.001	0.827#	≤ 0.001	0.695*	≤ 0.001
F50 (N)	0.543*	0.007	0.584*	0.003	0.506*	0.014
F100 (N)	0.671*	≤ 0.001	0.773#	≤ 0.001	0.606*	0.002
F150 (N)	0.729#	≤ 0.001	0.724#	≤ 0.001	0.629*	0.001
F200 (N)	0.790#	≤ 0.001	0.622*	0.002	0.605*	0.002
F250 (N)	0.812#	≤ 0.001	0.650*	0.001	0.652*	0.001
F50% (%)	-	0.902	-	0.592	-	0.277
F100% (%)	-	0.537	-	0.251	-	0.131
F150% (%)	-	0.747	-	0.438	-	0.225
F200% (%)	-	0.897	-	0.816	-	0.487
F250% (%)	-	0.754	-	0.665	-	0.499
RFD 0-50ms ($N \cdot s^{-1}$)	0.478	0.021	0.555*	0.006	0.459	0.027
RFD 0-90ms ($N \cdot s^{-1}$)	0.601*	0.002	0.682*	≤ 0.001	0.519*	0.011
RFD 0-100ms ($N \cdot s^{-1}$)	0.631*	0.001	0.704#	≤ 0.001	0.539*	0.008
RFD 0-150ms ($N \cdot s^{-1}$)	0.699*	≤ 0.001	0.691*	≤ 0.001	0.595*	0.003
RFD 0-200ms ($N \cdot s^{-1}$)	0.736#	≤ 0.001	0.593*	0.003	0.593*	0.003
RFD 0-250ms ($N \cdot s^{-1}$)	0.752#	≤ 0.001	0.554*	0.006	0.594*	0.003
IMP100 ($N \cdot s$)	0.576*	0.004	0.659*	0.001	0.575*	0.004
IMP200 ($N \cdot s$)	0.711#	≤ 0.001	0.754#	≤ 0.001	0.613*	0.002
IMP300 ($N \cdot s$)	0.778#	≤ 0.001	0.710#	≤ 0.001	0.635*	0.001

* Indicates large effect size (*r* = 0.5 – 0.69); # Indicates very large effect size (*r* = 0.7 – 0.89)

DISCUSSION

This investigation sought to determine if any relationships are present between HBB deadlift 1-RM and force-time curve characteristics collected during isometric pulls from FLOOR, KNEE, and MT. The primary findings of the investigation were that (a) PF produced the largest correlation coefficients to 1-RM of all force-time curve characteristics analyzed, and (b) correlation coefficients observed between 1-RM and force-time curve characteristics at FLOOR were generally larger than those observed from KNEE and MT.

The relationships between PF and 1-RM were in agreement with previous research (3, 12, 17, 26, 28, 29, 36). PF was observed to be either a large or very large correlate of 1-RM at each position, and explained 77, 68, and 48% of the variance in HBB deadlift 1-RM from FLOOR, KNEE, and MT, respectively. De Witt et al. and Wang et al. found PF from MT position to explain 77% and 75% of the variance in the deadlift and back squat 1-RM, respectively (12, 36). The observed differences in the PF effects sizes between the current study and previous studies may be due to the use of different equipment, different training status, and/or different exercises. The equipment utilized by De Witt et al. (12) – a mechanical lever system attached to two vacuum cylinders – and the exercise selection (back squat) of Wang et al. (36) may present different biomechanical demands compared to the free-weight HBB deadlift utilized in the present investigation. Additionally, the participants who volunteered for this investigation were not required to be a member of an athletic team (36), or have any prior resistance training experience (12).

The utilization of multiple bar positions during maximal isometric pulls in the literature is scarce. PF values generated at the mid-thigh position have been observed to be greater than PF generated from the lift-off and knee positions (5, 25). Additionally, Malyszek and colleagues observed the mid-thigh pull to produce greater RFD values than from the lift-off position, however the authors failed to report a calculation for RFD and did not report reliability measures, making interpretations from these data challenging (25). The differences observed in our study from FLOOR and KNEE may highlight differences in force production capabilities at disadvantageous positions of the dynamic movement (i.e. deadlift) (21, 27). Collectively, the literature suggests that the observation of isometric PF at MT is a useful indicator of maximal strength in dynamic, multi-joint exercises; yet our investigation provides evidence that isometric pulls in positions other than MT can demonstrate different, or stronger relationships. This could suggest that force generated near the isometric sticking points of the deadlift (21, 32) are more predictive of 1-RM performance in the HBB deadlift, than produced at the mid-thigh.

While PF has been rigorously investigated, time-specific force values during an isometric pull can provide coaches and researchers with another aspect of force production near the onset of contraction. These data points are important for athletes who need to generate a large amount of force with limited ground contact times (< 250ms) (1). Relationships with maximal strength have not been as studied, possibly because maximal strength has been reported to be achieved in durations greater than 300ms (1). Our findings are in agreement with previous studies observing force at 250ms to be the strongest predictor of maximal strength (3, 36). Conversely, De Witt et al. failed to find significant correlations between time-specific force values (30 - 250ms) and deadlift 1-RM (12). Thus, it may be necessary to further investigate the relationships between time-specific force values and maximal strength.

RFD is an alternative method of analyzing force production as it relates to performance. Andersen & Aagaard suggested that analyzing RFD time-bands as early (< 0-100ms) or late phases (> 0-100ms) may provide information as to whether RFD was influenced by fiber type composition (early phase), or muscle cross-sectional area and maximal strength (late phase) (1, 2). Our observations at FLOOR and MT agrees with previous work examining relationships between late-phase RFD time-bands and 1-RM (3, 36), though the literature is limited, and inconsistencies in the measurement of RFD exist. Future studies, should aim to follow the RFD recommendations set forth by Haff et al. to allow for more consistent results, as well as a more complete understanding of the relationships between RFD and maximal strength (18).

The relationship between isometric impulse and maximal strength has not been extensively examined in the literature. To the knowledge of the authors, our findings provide the first evidence of a relationship present between impulse and 1-RM strength in a multi-joint exercise. As the lift-off position represents a common sticking point (21, 27), the ability to sustain a large amount of force over a longer time period (300ms vs 100ms) in this position may indicate an ability to generate sufficient force to move through a sticking point to improve maximal deadlift performance. Further research examining maximal strength and impulse is warranted with attention paid to positions representative of isometric sticking points.

As this was a correlational analysis designed to provide generalized data on a diverse group of young adults, we chose to combine the trained and untrained men and women into one data set. This approach is particularly important currently with the newly developed United States Army Combat Fitness Test (ACFT), which incorporates a HBB deadlift and will be completed by a diverse group of cadets (6). These findings could therefore provide commanding officers as well as trainers and coaches general guidelines necessary to safely monitor training adaptations for a varied population. However, consequentially, the variability observed at FLOOR and KNEE during early time-specific characteristics exceeded the 15% CV cut-off for acceptability (18), and are limitations to this investigation. Despite a familiarization session, the inexperienced participants may not have been able to generate force as rapidly, and consistently, as those with training experience, as Andersen and colleagues suggest that early RFD is influenced by intrinsic muscle properties like fiber-type composition that the untrained population will not be able to maximize (2). Therefore, a purely trained and experienced sample would be expected to produce lower average CV values for the observed force-time characteristics, though limiting the generalizability of the data. Another potential limitation of this study is the lack of reliability measures for the HBB 1-RM. In an untrained population, it is possible that a confirmation 1-RM may produce different results, which may affect the findings of the study. The timing of events for our study attempted to allow time for muscle recovery prior to isometric performance testing, and the addition of a second 1-RM test may have exacerbated muscle soreness. Lastly, post-hoc power analyses indicated that all but two significant relationships exceeded a power (1-β) of 0.8, indicating that though most of our tested relationships were appropriately powered, some tested relationships were under-powered, and may require larger sample sizes.

One of the proposed benefits to isometric testing from the mid-thigh is the reduced time needed to collect reliable, force-time curve characteristics (12). Due to the previously mentioned method to maintain reliable measures, the time necessary to conduct three trials in each position during isometric tests will not be as time efficient as previously described in literature; however, the benefits of improved safety and reduced fatigue are still present.

The results from this investigation demonstrate that isometric pulls from the floor may present a novel derivative of the established IMTP when examining an HBB deadlift. Specifically, the examination of PF, late-phase RFD time-bands, and late-phase time-specific force values may provide the most insight into HBB deadlift 1-RM performance. Future studies should seek to understand the differences between those with, and without, experience performing maximal isometric tests from different positions; as well as how these disadvantageous positions may relate to other lifts, such as the back squat.

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