4-3-2019

# The Double Knee Bend Alters Rate of Force Development in The Clean Exercise

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THE DOUBLE KNEE BEND ALTERS RATE OF FORCE DEVELOPMENT IN THE CLEAN EXERCISE

by

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A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

Major: Health Studies

The University of Memphis

May 2019

# ABSTRACT

Weightlifting technique used by many team sport athletes differs from that of competitive weightlifters. Specifically, between the first and second pull, the double knee bend (DKB) involves an unweighting phase wherein the knees are flexed before extension in the second pull. Proficiency in this technique may be the primary mechanism by which weightlifters produce large vertical ground reaction force (GRF) peaks and rates of force development (RFD). The purpose of this study was therefore to evaluate differences in GRF during cleans with and without the DKB. GRF were measured during performance of 80%1RM cleans by 10 experienced weightlifters with or without the DKB. Paired samples *t*-tests revealed greater force reduction during unweighting ($d$=2.85), and greater RFD ($d$=2.30) in the second pull with the DKB compared with no DKB. Our findings suggest that the use of the DKB during training of the clean exercise may provide a greater power-specific training stimulus.

## PREFACE

The findings from this thesis will be submitted for publication to *The Journal of Strength and Conditioning Research* and the formatted manuscript for this journal is presented in Chapter II. The formatting of this portion of the document is therefore reflective of the submission requirements in this journal, however references will need to be in numerical format prior to submission.

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## ABBREVIATIONS

| | |
|---|---|
| 1RM | One-Repetition Maximum |
| CMJ | Countermovement Jump |
| DKB | Double Knee Bend |
| PL | Powerlifting |
| RFD | Rate of Force Development |
| MU | Motor Unit |
| vGRF | Vertical Ground Reaction Force |
| WL | Weightlifting |

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# CHAPTER I

## Introduction

In both team and individual sports, successful athletes are those who can accelerate faster, sprint at greater top speeds, jump higher, and change direction more quickly than their opponents. Superior expression of these sporting abilities is heavily reliant on the muscular strength and power development of the athlete, and can be improved with the use of resistance training. Muscular strength refers to the maximal voluntary force that can be produced by the muscles (Henricks, 2014; Stone, Moir, Glaister, & Sanders, 2002; Stone, Pierce, Sands, & Stone, 2006; Tillin & Folland, 2014), and power refers to the product of force and velocity, or the rate of doing work (Kawamori & Haff, 2004). Since critical phases of these sporting movements occurs over periods of 250 milliseconds or less, the magnitude of muscular force expressed outside of this timeframe may have little relevance to athletic performance (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002; Kawamori & Haff, 2004; Stone et al., 2006). For this reason, it has been consistently reported in the scientific literature that muscular power stands alone as the most critical factor in determining sporting success (G. R. Harris, Stone, O'bryant, Proulx, & Johnson, 2000; Kawamori & Haff, 2004; Kawamori et al., 2005).

As evidenced by the force-velocity relationship, maximal muscular force and velocity are mutually exclusive qualities in the context of muscular power expression. While maximal force production capacity can be a limiting factor in power production (Hori et al., 2008; Tillin & Folland, 2014), maximal power is achieved at a compromised level of submaximal force at submaximal velocity. For athletes of a low training age or limited resistance training experience, improving maximal force alone may be an effective means of improving muscular power (Channell & Barfield, 2008; Chiu & Schilling, 2005). However, as an athlete approaches their genetic maximum for muscular force production through resistance training, further improvements in maximal power must be derived from training with relatively lighter intensities at greater velocities (Chiu & Schilling, 2005; Hoffman, Cooper, Wendell, & Kang, 2004; Kawamori & Haff, 2004).

To accomplish this, exercises that are traditionally contested in competitive weightlifting (WL) have been adopted by strength and conditioning coaches. In fact, survey data indicates that WL exercises are used by no less than 85% of strength and conditioning coaches at the high school, collegiate and professional (including National Football and Hockey Leagues, as well as National Basketball Association) levels (Duehring, Feldmann, & Ebben, 2009; Durell, Pujol, & Barnes, 2003; W. P. Ebben, Carroll, & Simenz, 2004; Simenz, Dugan, & Ebben, 2005). The ubiquity of WL exercises in the training of athletes is likely owed to published data regarding the uniquely high force and power production characteristics of competitive weightlifters (Kawamori et al., 2005), and training studies which indicate that WL is superior to powerlifting or traditional (i.e. squat, bench, deadlift) training methods in terms of enhancing athletic performance-related outcomes (Arabatzi & Kellis, 2012; Ayers, DeBeliso, Sevene, & Adams, 2016; Hoffman et al., 2004; Tricoli, Lamas, Carnevale, & Ugrinowitsch, 2005).

One feature of WL exercises that has been explored in great detail is the double knee bend (DKB) technique. Briefly, as the barbell approaches mid-thigh, competitive weightlifters are observed to flex the knees and extend the torso (Enoka, 1979) during a period of non-propulsive force production. This is done prior to the second pull phase of the lift and is believed to create a stretch-shortening cycle effect, as well optimize the length-tension relationship of the knee extensors (Chiu & Schilling, 2005; Stone et al., 2006). Proficiency in this technique has been shown to discriminate between weightlifters of differing abilities (Enoka, 1988; Kipp, Redden, Sabick, & Harris, 2012a), and its absence as well as ostensible utility in the training of team-sport athletes has been debated (Duba, Kraemer, & Martin, 2009; Hydock, 2001; Takano, 1992). The authors of these opinion pieces acknowledge that many strength and conditioning practitioners may not be aware of the DKB technique or how to coach athletes to use it. Additionally, the question of whether or not it merits inclusion in the pedagogical process appears to be an issue of contention.

At the collegiate level, almost 40% of division I strength and conditioning coaches cite WL technique as the poorest area of preparation in all freshmen athletes (Wade, Pope, & Simonson, 2014), despite nearly 95% of high school strength and conditioning coaches using WL exercises in training (Duehring et al., 2009). While it is possible that high school strength and conditioning coaches are not as well versed in knowledge of exercise technique, the previously noted scrutiny is not relegated exclusively toward the coaching practices employed at that level. Data regarding competitive experience of division I collegiate strength and conditioning coaches indicates that less than 33% have club or open competition WL experience (Martinez, 2004). While competitive experience does not necessarily imply expertise in coaching, this suggests that these coaches may not necessarily be aware of the technical nuances of competitive weightlifters. The purpose of this study was therefore to evaluate whether or not the DKB technique has any potential to enhance the training stimulus of the clean exercise based on vertical ground reaction force (vGRF) variables.

## CHAPTER II

### Literature Review

*Phases of the Pull in the Clean Exercise*

So that a consistent understanding of the DKB technique may be established, a brief overview of the phases of the clean exercise is presented (**Figure 1**). Of the competitive events in WL (snatch, clean and jerk), the clean is believed to be least technically intensive and is therefore the preferred choice of strength and conditioning practitioners who opt to use these methods (Haug, Drinkwater, & Chapman, 2015). The clean pull is defined as the portion of the lift in which the barbell is displaced vertically from the floor to approximately waist height (Enoka, 1979), and has two propulsive phases, the **first pull**, and the **second pull**. In advanced weightlifters, these propulsive phases are separated by a brief period of non-propulsive force. From a kinetic perspective, the entirety of the clean pull can be divided into three distinct phases.

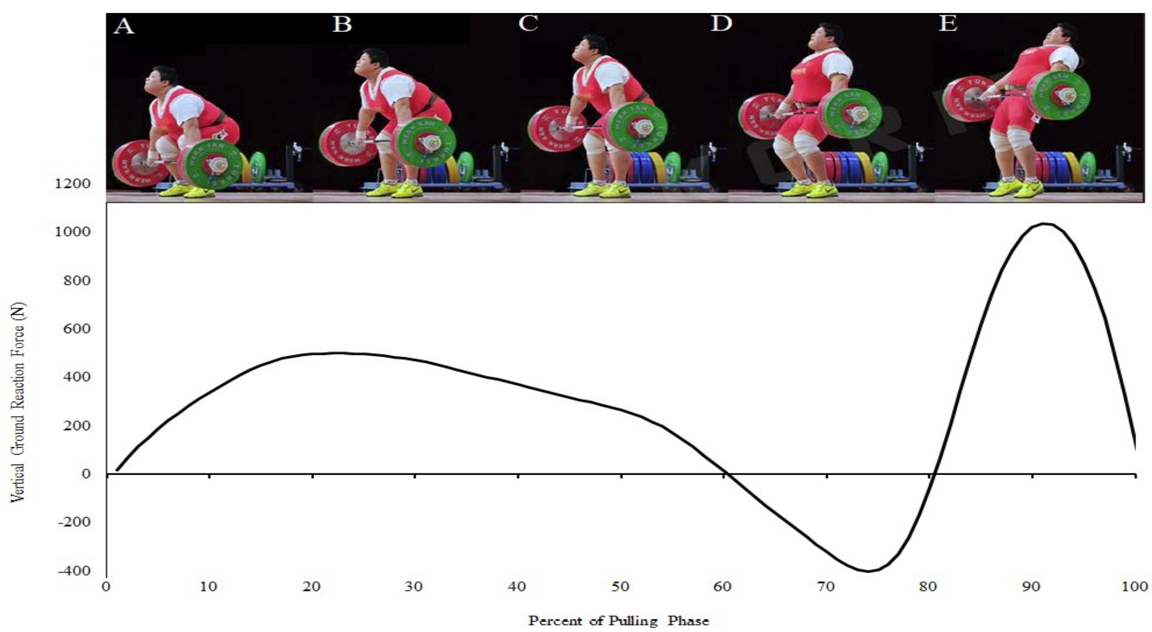


**Figure 1**: Body position of clean pull approximately relative to force-time history of clean pull. Images A-B approximate **Weighting I**. C-D approximate the start and end respectively of **Unweighting** phase. D-E approximate the start and end respectively of **Weighting II**.

In **Figure 1**, the force-time curve is displayed relative to system weight (athlete + barbell mass x gravity). In this way, all positive values represent propulsive force production, and all negative values represent non-propulsive force production. **Weighting I** occurs from the onset of propulsive force production until vGRF drops below system weight (approximately 0-60% of the pull). The **Unweighting phase** is characterized by the total duration for which vGRF is below system weight (approximately 60-80% of pull phase). **Weighting II** includes the second period of propulsive force production (approximately 80-100% of pull phase). Note that although Weighting II considers the second period of propulsive force production, the generation of positively directed vGRF actually begins during the latter half of unweighting. These operative phase definitions have been established in reference to ground reaction force characteristics previously (Enoka, 1979).

*Relationships Between WL and Athletic Performance*

WL movements have long been thought to replicate the demands of sport-related activities. The concentric, vertically-oriented nature of WL movements are thought to be biomechanically similar to vertical jumping, and the acceleration phase of sprinting (Canavan, Garrett, & Armstrong, 1996; Garhammer & Gregor, 1992; Haug et al., 2015). Proponents of WL training for team-sport athletes also cite that the exercises are multi-joint in nature with the added advantage of overload (added weight) during this explosive event (Hori et al., 2008; Kawamori et al., 2005; Tricoli et al., 2005). In addition, WL exercises are inherently ballistic movements, meaning they involve the projection of the athlete or object (i.e. barbell) into free space at high velocities (Cormie, Mcguigan, & Newton, 2010). More traditional resistance exercises like those included in powerlifting (PL) methodology include extensive periods of deceleration during the concentric phase and occur at much slower velocities. Mean velocities of 0.30 meters per second in a back squat, and 0.15 meters per second in a bench press have been previously identified in the literature (Mann, Ivey, & Sayers, 2015).

With respect to the force-velocity relationship, WL exercises occupy a unique region of the curve wherein submaximal velocity and submaximal force are combined to result in near-maximal power production. In this way, WL- and PL-trained individuals have been compared to sprinters with respect to differences in countermovement jump (CMJ) performance qualities between groups who are habitually trained in each of these disciplines (McBride, Triplett-McBride, Davie, & Newton, 1999). The results of McBride et al. 1999 indicated that WL- and PL-trained athletes demonstrated comparable absolute strength (1RM Squat), but the WL-trained group expressed significantly superior power and peak force in the CMJ. It was also noted that while the sprint-trained group generated the highest peak velocities in the CMJ, some PL subjects actually produced peak velocities that were inferior to those of a control group. On this basis, while WL exercises employ moderate to heavy relative loads, they are still velocity-dependent exercises (Kawamori et al., 2005; Stone et al., 2006). This means that unless sufficient velocity is achieved, the athlete will suffer irreconcilable negative acceleration to the barbell resulting in a missed lift. In this light, it is of paramount importance that the athlete not only produce sufficient maximal force, but that force must be produced extremely quickly given that the entire lift lasts less than one second (Stone et al., 2006).

A number of other studies compare WL to PL and plyometric or jump training in terms of their effect on CMJ performance. A representation of their results has been combined to produce **Figure 2** and includes training studies ranging from 24-40 total sessions over durations of 8-12 weeks in healthy athletes. Pre- to post-test data were assessed for percent change from Tricoli et al. 2004, Hoffman et al. 2004, Arabatzi et al. 2012, Channell et al. 2008, and Moore et al. 2005.

Figure 2: Percent Change in CMJ Height by Training Mode

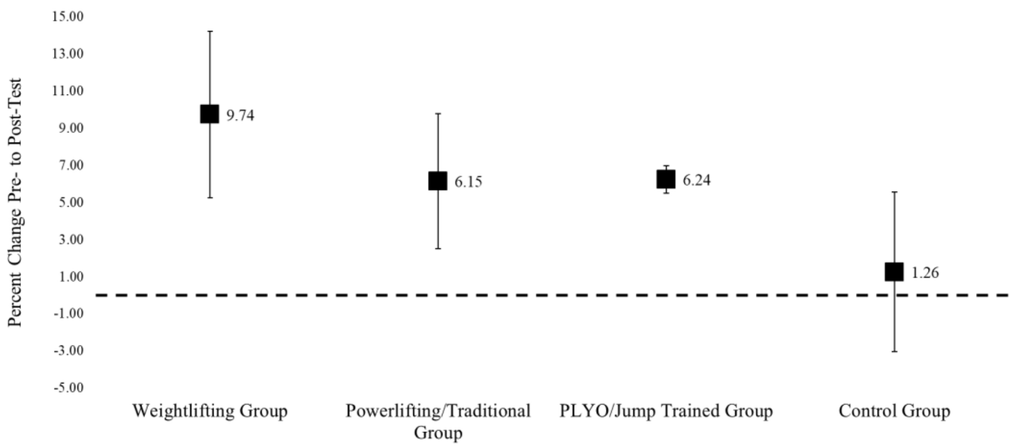


Figure 2: Aggregate percent change in CMJ performance after 8-12 weeks of training for five studies in healthy athletic subjects (n = 95), mean ± SD age of 19.43 ± 2.04 years

Studies were only included if they had a WL group, and if they compared pre- and post-intervention CMJ height scores to a plyometric/jump training group, PL/traditional group, or a control group. Aggregate percent change scores were as follows; WL group: 9.74 ± 4.48%, PL/Traditional group: 6.15 ± 3.63%, Plyometric/jump training group: 6.24 ± 0.74%, Control group: 1.26 ± 4.30%. Moderate to strong significant correlations ($r$ = 0.51 – 0.75) have also been reported between power clean and CMJ as well as short (20m) sprint performance, especially when power clean performance is expressed relative to body mass (Channell & Barfield, 2008; Hori et al., 2008). These results support the notion that mass-specific force and power production are important in the execution of sporting movements that may occur during pivotal moments of competition.

*Unique Aspects of the Unweighting Phase and DKB*

In 1979, Enoka conducted an analysis of 5 WL athletes performing 100% cleans and noted that forces during the Unweighting phase were reduced to 122-212% of body weight despite the fact the average system weight in the experiment was 2.26x greater than lifter body mass. Since propulsive force represents a combined extensor effort in excess of system weight against the surface being lifted on, extension must temporarily desist if an unweighting effect is to be achieved. This feature is not seen in the propulsive phases of other athletically related activities, and calls into question the kinetic similarities between those other activities and WL. However, the Unweighting phase immediately precedes Weighting II, where the largest magnitude propulsive forces are consistently reported to occur forces (Ayers et al., 2016; Comfort, Allen, & Graham-Smith, 2011a; Enoka, 1979; Haug et al., 2015; Souza, Shimada, & Koontz, 2002; Stone et al., 2006). This implies that individuals who are more skilled in WL exercise execution may have developed greater RFD capacities through use of the DKB technique by overcoming force decreases during Unweighting and still generating propulsive force during Weighting II.

In 2014, MacKenzie et al. produced a kinematic and kinetic comparison between the CMJ, a 70% power clean, and a 70% loaded jump squat. The authors noted that observable kinematic similarities between these movements had traditionally been cited as the mechanism by which positive transfer is possible, but presented results to the contrary. In their results, the power clean had a characteristic DKB (knee extension-flexion-extension) pattern compared to the continuous and concurrent extension of the hip, knee, and ankle during the CMJ and 70% jump squats. Their results revealed that the DKB occurred over approximately 50-75% of the upward phase of the movement, and that the 70% power clean resulted in significantly greater peak force and peak rate of force development (RFD) compared to the CMJ and the load-matched jump squat (MacKenzie, Lavers, & Wallace, 2014a). In their interpretation, the DKB may target trainable features of the neuromuscular system by (a) inducing a stretch-shortening cycle during execution of the movement, and (b) more dynamically organizing the relative position of lower extremity joints to enhance RFD.

*Neural Aspects of WL Training*

By virtue of the fact that extremely high relative intensities can be used in PL and traditional weight training exercises, a great deal of force production is required during the performance of these exercises. As mentioned however this comes at the expense of velocity, which can be readily observed in a one-repetition maximum (1RM) attempt in a back squat or deadlift. Generating these high muscular forces requires recruitment of high threshold motor units (MU) (Kawamori & Haff, 2004), a known adaptation to resistance training. These larger, high-threshold MU can innervate close to 2000 individual muscle fibers (Haff, Whitley, & Potteiger, 2001) and are capable of generating high degrees of muscular tension, thereby enabling maximal force production. The way in which higher velocities are achieved during WL and plyometric or sprint activities on the other hand is via improvement of the RFD, accomplished via enhanced rate coding (increased frequency of MU firing), a key contributor to explosive strength (Chiu & Schilling, 2005; Kawamori & Haff, 2004). According to the size principle, smaller MU (fewer muscle fibers per motor neuron) are recruited first in the accumulation of muscular force, followed by larger MU if the force demands of the movement are sufficient to require an increase in muscular force production (Haff et al., 2001). Based again on the overload principle, if an athlete is infrequently exposed to exercise or resistance-training stimuli that require recruitment of large MU, no central (neural) adaptation occurs.

Briefly, the RFD is believed to be analogous to the velocity of contraction (Tricoli et al., 2005), and is defined as the rate of rise in contractile force at the onset of muscular contraction (W. Ebben, Flanagan, & Jensen, 2007). The RFD is the expression of enhanced neural function in response to resistance training at higher velocities once sufficient force production capacity has been developed. It is therefore considered to be of great importance in enhancing muscular power by increasing the velocity of contraction (Aagaard et al., 2002; Comfort et al., 2011a; Garhammer & Gregor, 1992; Haff et al., 2001; Haff, Carlock, Hartman, & Kilgore, 2005; G. R. Harris et al., 2000; Kawamori & Haff, 2004; MacKenzie, Lavers, & Wallace, 2014; McBride et al., 1999; Tillin & Folland, 2014; Tricoli et al., 2005; Wurm, Garceau, Zanden, Fauth, & Ebben, 2010). This is a critical perspective since it involves tapping into trainable features of the neuromuscular system as opposed to strictly attempting to mimic the kinematics of any specific sporting movement with resistance training exercise (MacKenzie et al., 2014). These are important features of any training exercise given the temporal constraints of force production in sporting movements, and the diversely applicable nature of neural adaptations.

In this context, MU that are not recruited are not trained to an extent that may promote a positive adaptation (N. Harris, Cronin, & Keogh, 2007). Of course, these high threshold MU can be trained merely by exposure to higher loads, but this does not address a deficiency with respect to rate coding or synchronization (concurrent firing) of these MU. Where rate coding refers to the frequency of MU activation, it is unique in that it can result in greater force generation without the addition of other MU. This addition or concurrent firing of additional MU is termed synchronization (Haff et al., 2001). It has been suggested that increased training loads that require high threshold MU activation effectively teaches the nervous system to improve power production capacity via these mechanisms (Kawamori & Haff, 2004). In addition, when MU recruitment is sufficient to achieve maximal force, an increase in firing frequency is required to generate additional force (Kawamori & Haff, 2004). Together, activation of high threshold MU as well as synchronization requires a sufficiently high force demand, while rate coding requires that these force demands are met quickly. Effectively, this is the crux of power training.

A 2012 study by Arabatzi & Kellis examined the effects of WL versus PL/Traditional resistance training on CMJ and drop jump performance. During pre- and post-testing, besides ground reaction force variables, study participants were assessed for co-activation index (antagonist biceps femoris divided by agonist rectus femoris). Of particular interest in their findings was an increase in concentric phase co-activation index during CMJ and 20cm drop jumps for the traditionally-trained group. This group also did not significantly increase displacement in the squat jump or CMJ following eight weeks of training. The WL group on the other hand outperformed the TW group in terms of jump displacement while concentric phase co-activation index significantly decreased. Given the formula used in this study for calculating co-activation index, the only mechanism whereby this index may become greater is via increased activity recorded for the knee flexors, or decreased activity recorded for the knee extensors. A decrease in co-activation index therefore reflects a more extensor-dominant ratio. The authors of this paper suggest that since some of the TW exercises involved single joint movements, joint stability in more complex movement patterns such as those tested may be increased via co-activation of flexors and extensors. On the other hand, the WL group was exposed to eight weeks of training specifically aimed at total-body, complex movements that inherently necessitate higher movement velocities. The mechanism for transfer here is most likely related to antagonist inhibition whereby the WL group developed muscular activation strategies and patterns that maximize contribution of the extensors. This provides another potential insight into the many ways in which WL training may result in improved performance beneath the surface of observable similarities between movements.

**Literature Gaps and Limitations**

Based on the previous narrative regarding muscular power production, training the muscular system not only to produce maximal force, but also to contract at maximal velocities cannot happen concurrently. Training with maximal loads at very low velocities appears effective at improving the maximal force production capacity, whereas training with maximal velocities at very low loads appears effective at improving the maximal speed capacities (McBride et al., 1999). In this respect, the absence of a DKB when attempting to train for greater power using WL exercises should result in an explosive movement being performed at submaximal velocity with submaximal load.

Anecdotally, the DKB is not taught among the majority of collegiate athletes specifically. In addition, it was noted earlier that a great deal of scrutiny toward the technical knowledge and coaching practice of strength and conditioning professionals (as opposed to WL coaches) has been expressed with respect to the implementation of the WL movements. In addition, some commentary has been publicly offered with respect to whether or not the DKB should even be taught to athletes who are not competitive weightlifters. As a result, increased interest is evident with regard to modifying the movements to a start position above the knee or from the mid-thigh (Comfort, Allen, & Graham-Smith, 2011b; Comfort, Fletcher, & McMahon, 2012; Suchomel, Comfort, & Stone, 2015). Interestingly, it appears that there is indeed reason for a great deal of unfamiliarity with the WL movements as performed by competitive weightlifters among collegiate coaches despite their high rate of use. Survey data indicates that while 85% of collegiate strength and conditioning coaches use WL movements in the training of their athletes (Durell et al., 2003), and approximately one-third of division I strength and conditioning coaches having club or open competition WL experience (Martinez, 2004). Despite experience being quite an auxiliary factor in determining the true effectiveness of a coach, WL movements are technically complex, and a lack of awareness in these areas would not be surprising. As one final point of merit, the only two organizations that a collegiate strength and conditioning coach may be certified by (National Strength and Conditioning Association, NSCA, and the collegiate Strength and Conditioning Coaches Association, cSCCA) (Hornsby et al., 2017) both make reference to the DKB in their exam and preparatory materials.

What remains to be seen is how the absence of a DKB in the execution of WL movements (specifically the clean) affects the force-time profile of the movement. It was noted that discrimination between WL performance (as determined by load lifted) can be explained by differences in vGRF characteristics of the movement, but no recommendation has been provided advocating the use or teaching of a DKB technique specifically to improve WL exercise execution.

**Research Questions and Hypotheses**

The purpose of the current project is to determine exactly how the absence of the DKB technique might influence ground reaction force characteristics of the clean exercise. Dependent variables specifically include: timing of peak forces and, peak vertical ground reaction force, vertical impulse, and rate of force development.

Research Question 1

Question 1: Does use of the DKB increase vGRF peaks in the second pull of the clean exercise?

Hypothesis 1

Use of the DKB technique would increase peak vGRF during the second pull of the clean exercise compared to when it is not used.

Research Question 2

Question 2: Does use of the DKB increase RFD in the second pull of the clean exercise?

Hypothesis 2

Use of the DKB would increase RFD during the second pull of the clean exercise compared to when it is not used.

## CHAPTER III

## The Double Knee Bend Technique Alters Rate of Force Development in The Clean Exercise

**Alex M. Carnall, J. Bryan Mann, Lawrence W. Weiss, Max R. Paquette, Douglas W. Powell**

*Manuscript in preparation for Journal of Strength and Conditioning Research*

### INTRODUCTION

Success in sport is dominated by participants with superior physical qualities. With the monetary value of athletic contracts ever rising, and the reputation of sporting organizations hanging in the balance of wins and losses, athletes and teams alike seek the best modes of physical preparation and performance enhancement available. In many sports, the most successful athletes are those who possess the ability to accelerate faster, sprint at greater top speeds, jump higher, and change direction more quickly than their opponents. These movements occur over very short periods of time, often less than 250 milliseconds (Aagaard 2002, Kawamori 2004, Stone 2006), and therefore require the expression of great muscular strength within these short time periods.

To develop the ability to express muscular force in short timeframes, strength and conditioning coaches employ various modes of power (i.e., force and velocity) training in the physical preparation of athletes. It has been previously stated that muscular power stands alone as the most critical factor in determining sporting success (Kawamori 2005, Harris 2000, Hori 2008, Kawamori 2004). Within popular modes of enhancing muscular power, common methodologies with scientific support include powerlifting (i.e. squat, bench press, deadlift), plyometrics (i.e. stretch-shortening cycle activities and jump training), and weightlifting (WL) movements or their derivative exercises. WL exercises (i.e. snatch, clean and jerk, derivative movements) optimally combine near-maximal force production with near-maximal muscular shortening velocity (Channell 2008, Hoffman 2004, Hori 2008, McBride 1999, Tricoli 2005). Survey data indicates that within American high school, Division I collegiate, and professional sports, greater than 85% of strength and conditioning coaches use WL exercises in the physical preparation of athletes (Duehring 2009, Durrell 2003) (Ebben 2001, Ebben 2004, Simenz 2005). WL training is effective in enhancing athletic performance-related outcomes like the CMJ (Tricoli 2005, Hoffman 2004, Arabatzi 2012, Channell 2008, Moore 2005) short sprint (10-40m) performance (Tricoli 2005, Hoffman 2004, Ayers 2016, Moore 2005), and is particularly effective in discriminating superior athletic performance when expressed relative to body mass (Hori 2008). WL training is believed to enhance the frequency (i.e. rate coding) of firing of motor units (Kawamori 2004), and rate of force development (RFD) which is believed to be analogous to the velocity of contraction (Tricoli 2005). This is considered to be of great importance in enhancing muscular power (Aagaard 2002, Comfort 2011a, Garhammer 1992, Haff 2001, Haff 2005, Carlock 2005, Harris 2000, Kawamori 2004, Mackenzie 2014, McBride 1999, Tillin 2014, Tricoli 2005, Wurm 2010). Effectively, the RFD is enhanced via increased rate coding following the development of sufficient maximal strength, and thus, may be considered to be the crux of power training.

Competitive WL athletes produce some of the highest power outputs ever achieved in human performance (Haff 2001, Kawamori 2005), and a number of researchers have cited the characteristic double knee bend (DKB) technique of the clean exercise as a key feature enabling this expression of large magnitude forces with high contractile velocities (Enoka 1979, Enoka 1988, Stone 2006, Mackenzie 2014). The DKB involves a period of reduced vertical ground reaction force magnitude (vGRF) as the barbell passes mid-thigh, during which the lifter reorients lower extremity joint positions in preparation for the critical second pull of the exercise (Enoka 1979, Stone 2006). While evidence suggests that proficiency in this technique has the discriminatory power to differentiate between WL athletes of differing abilities (as measured by competitive performance) (Enoka 1988, Stone 2006), contention remains with respect to whether the DKB can or should be taught to athletes who do not compete in WL (Walsh 1989, Duba 2009). Leading competitive WL coaches have also suggested technical inferiority of the cleans performed by non-WL athletes (Takano 1992, Takano), partly relating to the absence of a DKB technique.

The purpose of this study was therefore to investigate the effect of technique on kinetic characteristics of the clean exercise when performed with and without a DKB. We hypothesized that compared to no DKB, the DKB technique would increase peak vGRF and RFD during the second pull of the clean.

## METHODS

### *Participants*

An *a priori* sample size analysis (G*Power 3.1.9.2) concluded that ten participants would be required for a paired samples *t*-test to detect significant differences using a Cohen's *d* effect size of 0.5, a power of 0.80 (1-β) and an α of 0.05. The power analysis was conducted using means and standard deviations of RFD data in the second pull of the clean exercise collected during pilot testing. Thus, 10 experienced weightlifters (**Table 1**) were recruited and volunteered for this study. Eligibility criteria stated that all participants must be (a) between the ages of 18-35, (b) free of lower extremity surgical history, or recent (<6 months) injury, (c) be actively engaged for three or more days per week in WL training, (d) be familiar with the DKB technique, and (e) have been training in WL for at least three years prior to enrollment.

Participants were recruited from local gyms and area WL clubs. All procedures were approved by the University of Memphis Institutional Review Board (IRB) – **Appendix F**.

*Procedures*

All participants attended one laboratory testing session. Participants were provided with a detailed overview of the experimental protocol and provided written informed consent [**Appendix D**] acknowledging all potential risks and benefits of the experiment. Participants then completed a questionnaire regarding WL experience and performances. Finally, participants completed and signed a physical activity readiness questionnaire to determine if any pre-existing medical conditions would merit disqualification. Participants wore their own personal WL shoes during data collection.

Participants first performed their preferred warm-up routine using a gender-appropriate barbell and weight discs. The warm-up was performed in the laboratory in order to gain familiarity with the orientation and positioning to be used for experimental trials. Following the warm-up, participants were provided a final overview of the experimental protocol and loaded the barbell to begin experimental procedures.

Before performing any of the clean trials, participants performed 6 clean pulls with the 80%1RM load. Following a mandatory minimum 2-minute rest (additional rest was left to individual discretion), all participants then performed six trials of the clean exercise at 80% of their self-reported 1RM. This load was chosen as it is believed to be necessary for the recruitment of high threshold motor units and WL power is maximized around this intensity (Comfort et al. 2011a, Kawamori 2005). It has also been shown not to differ from loads of 70% or 90% in this regard (Kawamori 2004, Kawamori 2005). During the first three trials, participants were specifically instructed not to use a DKB technique (NO DKB condition), while in the final three trials, they were instructed to use the DKB technique (DKB condition). Each condition was treated as a cluster-set, meaning that participants rested approximately 10-30 seconds between each repetition, with a mandated minimum of two minutes rest between conditions, consistent with recommendations for multiple-effort power events (Baechle & Earle, 2008). This cluster-set configuration has been used in previous investigations of power clean variations, albeit at a lower intensity of 60%1RM (Comfort et al., 2011b).

*Instrumentation*

All experimental trials were performed such that the left and right foot of the participant were on separate force platforms (1200Hz, AMTI Inc., Watertown, MA). Two sets of gymnastics mats were placed on the floor in front of participants in the event they would need to drop the barbell during any trials. The force platform signals were collected independently via USB analog acquisition interface (Qualisys, Goteborg, Sweden) and recorded in Qualisys Track Manager Software (QTM v17.1, Qualisys, Goteborg, Sweden). All male participants completed experimental trials using a 20kg weightlifting training bar (DHS, Dynamic Fitness Equipment, Lake Tapps, WA), and all female participants completed experimental trials using a 15kg weightlifting training bar (PB Extreme, Perform Better, Cranston, RI) as is customary in WL training and competition. To achieve the experimental barbell loads, all participants used the same weightlifting training bumper plates (Eleiko Weightlifting Training Disc, Eleiko, Halmstad, Sweden) secured using spring loaded collars.

*Data Processing and Analysis*

All data were processed and analyzed in Visual3D software (C-Motion, Germantown, MD). The left and right vGRF signals were summed and low-pass filtered using a fourth order Butterworth filter with a cutoff frequency of 25Hz (Kipp, Redden, Sabick, & Harris, 2012b). In addition to complying with previous filtering recommendations for the force platform signal, a Fast Fourier Transform was performed on the raw exported vGRF signals using MATLAB (MathWorks, Natick, MA) and the majority of the signal was found to consist of signal less than 10Hz. The vGRF was expressed with system weight (SW) (i.e., sum of athlete and bar weight) subtracted. Ascending and descending thresholds about SW were therefore used to determine propulsive and non-propulsive phases respectively within the filtered vGRF signal.

Time of threshold events as well as peak vGRF values and respective times of occurrence were extracted for comparison between conditions in each phase as well as for calculation of RFD in the first and second pull. RFD in the first pull was calculated as the quotient of peak force in the first pull divided by time from onset of propulsive force generation to time of peak force in this phase. RFD in the second pull was calculated by dividing the change in force between peak unweighting force and peak force in the second pull by the time between these events. Both measures of RFD are therefore representative of average RFD, as opposed to instantaneous or peak RFD. Impulse of each phase was determined by integrating the summed vGRF with respect to time, using the trapezoidal integration rule.

## RESULTS

### *Weighting I Phase*

During Weighting I (**Table 2**), absolute duration ($d = 0.36$, $p = 0.007$) and impulse ($d = 0.12$, $p = 0.006$) were found to be significantly greater during the DKB condition compared to the NO DKB condition.

*Unweighting Phase*

The Unweighting phase (**Table 3**) was found to be significantly longer during the DKB condition in both absolute ($d = 1.02$, $p = 0.022$) and relative ($d = 0.94$, $p = 0.041$) duration. In addition, Unweighting impulse ($d = 2.72$, $p = 0.001$) and peak minimum force ($d = 2.85$, $p = 0.001$) were found to be significantly lower in the DKB condition compared to the NO DKB condition.

*Weighting II Phase*

During Weighting II (**Table 4**), time to peak force ($d = 1.24$, $p = 0.002$) and relative phase duration ($d = 1.32$, $p = 0.008$) were found to be significantly shorter in the DKB condition compared to the NO DKB condition. RFD was also found to be significantly greater ($d = 2.30$, $p = 0.001$) in the DKB condition compared to the NO DKB condition.

## DISCUSSION

The purpose of this study was to investigate the effect of technique on kinetic characteristics of the clean exercise, specifically when performed with and without a DKB. Major findings of the study were that absolute and relative durations of the unweighting phase were significantly longer with a significant reduction in Unweighting peak force with the DKB technique. Ultimately, this led to an large decrease in time to peak force in the second pull and thereby, a significant increase in RFD. Force-time history of the two conditions is presented in **Figure 3**.

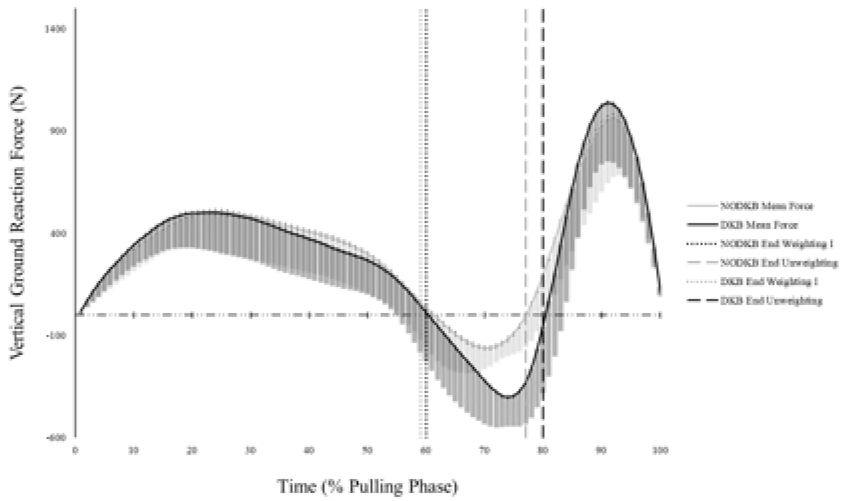


**Figure 3**: Group average force-time history between DKB (solid black line) and NO DKB conditions (solid grey line). Signal magnitude is expressed relative to system weight (zero) and includes mean -1 SD.

The Unweighting phase is characterized by a reduction in vGRF (**Figure 4**), associated with a temporary cessation of lower extremity extension, wherein the lifter actually performs concentric knee flexion (i.e. hamstring activity) before the second pull (Enoka, 1979; Stone et al., 2006). This hamstring involvement temporarily reduces vertical velocity of the system as indicated by the lower impulse values (**Figure 5**) during the unweighting phase with DKB. Understandably, achieving a position of greater knee flexion requires more time and is reflected by the greater absolute, and relative phase durations observed for Unweighting in the DKB condition. The reduction in relative phase duration of Weighting II is likely the result of a stretch-shortening cycle effect on the knee extensors in addition to achieving a more optimal muscle length during unweighting. If indeed there is a stretch-shortening cycle effect, and the position of the knee is more advantageous for the knee extensors (Enoka 1979, Smidt 1973), contractile force as well as velocity should thereby be enhanced during weighting II to improve vertical displacement of the whole system.

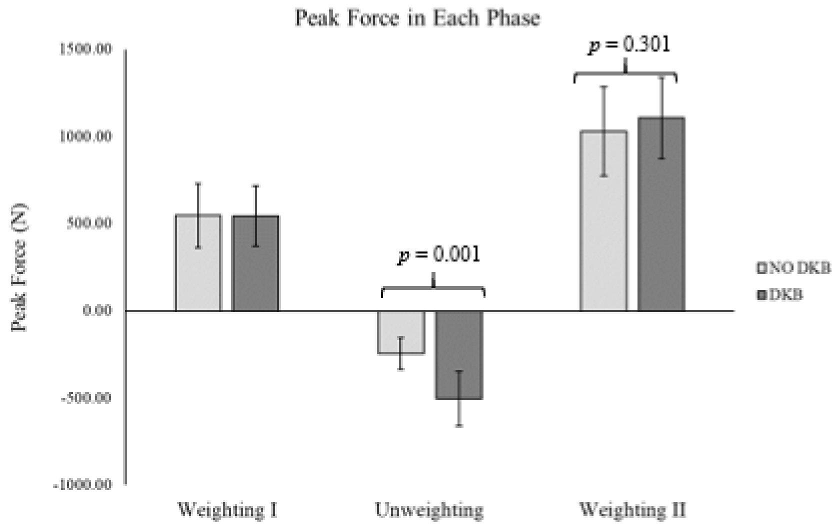


**Figure 4**: Graphical Representation of group average ± 1SD peak magnitude force values in each phase of the DKB and NO DKB conditions.

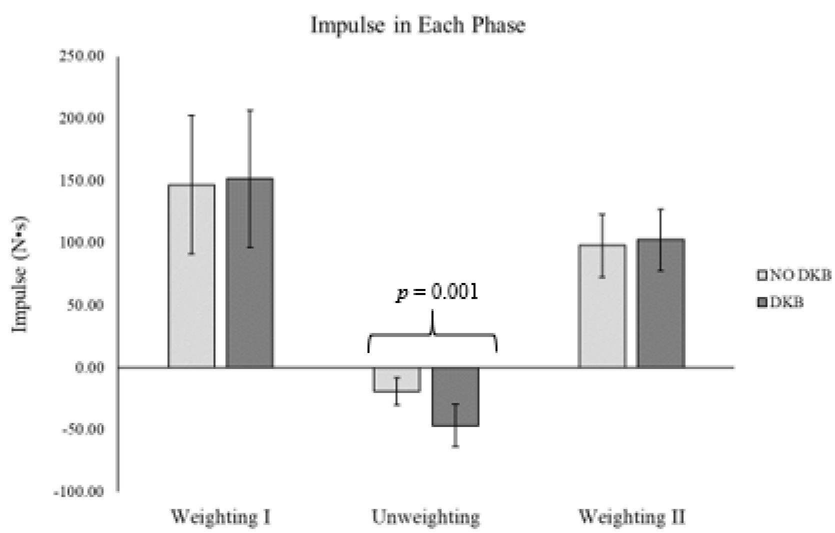


**Figure 5**: Graphical representation of group average ± 1SD impulse during each phase of the DKB and NO DKB conditions

Interestingly, the use of the DKB technique did not result in significantly greater peak force during the second pull. This finding was contrary to our first hypothesis which was based on the notion that a more optimal position for knee extensor torque production would be achieved during this phase of the movement. Although a 7.45% increase with moderate effect size ($d$ = 0.44) in peak force during Weighting II was observed with DKB, this result did not meet our *a priori* alpha level. However, the small differences in Weighting II peak force observed with DKB compared to NO DKB conditions may be due to the within-subject nature of our experimental design. With both clean techniques, the same subjects were performing the movement and thus, we must discount any long-term training effects of using each of these techniques independently. Therefore, observing no significant differences in peak force production may be the result of the experimental design rather than the movement pattern and should not be entirely unexpected.

Peak force production is of little importance without temporal context in athletic performance and transfer of power-based training strategies to functional outcomes. As such, we hypothesized that the DKB condition would be associated with greater RFD and ultimately, shorter time to peak force in the second pull. As expected, the DKB technique resulted in an 18.45% shorter time to peak force ($d$ = 1.24, $p$ = 0.002), with a 57.1% increase in RFD ($d$ = 2.30, $p$ = 0.001) during the second pull in the DKB condition (**Figure 6**). Thus, these findings make the small increase (7.45%) in second pull peak force much more relevant to clean performance with DKB. Functionally, the DKB technique enabled participants to achieve a greater force in a shorter period of time, resulting in greater RFD during the second pull phase of the clean movement. This is believed to be the portion of the movement of greatest practical significance (Ayers et al., 2016; Souza & Shimada, 2002), and therefore, any technical intervention that influences this phase of the movement is of substantial practical significance.

Variability of performance may also be of interest in comparing these two technical variations of the clean technique when considering second pull RFD results. Standard deviations were much greater with DKB (3625.3 N/s) compared to NO DKB (2601.9 N/s). It could be postulated that the absence of the DKB technique effectively constrains force production of athletes during the latter half of the clean exercise. Therefore, athletes who are instructed to perform the clean exercise by extending the knee joint over all three phases of the movement may inadvertently reduce RFD of the vGRF. This may limit the transferability of adaptations realized through performance of the clean exercise by reducing peak force and RFD during the second pull.

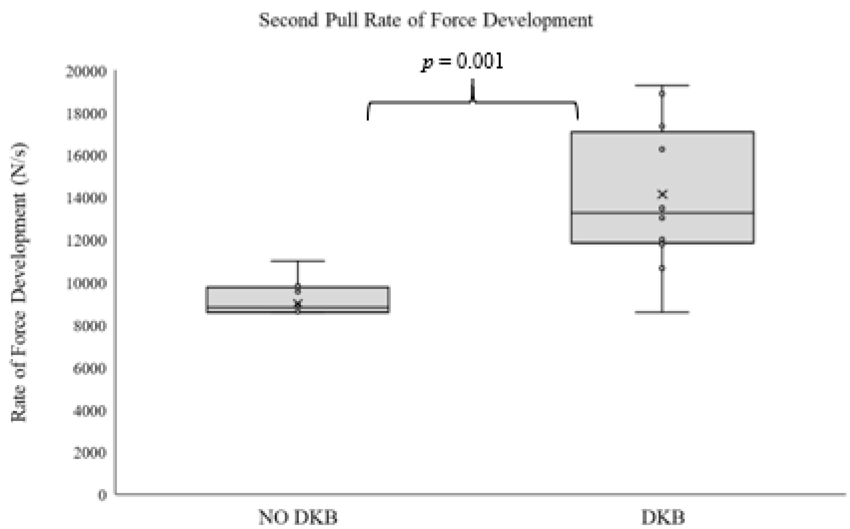


**Figure 6:** Graphical representation of rate of force development in the second pull with condition means expressed as "x" with inclusive median (solid line inside box). Quartiles are represented by the upper and lower borders of the box plots as well as error bars extending vertically from the box plot.

In 1979, Enoka noted that during the unweighting phase, the knee joint was flexed by approximately 10° while the trunk extended by 38° (Enoka 1979). Given that the vertical component of the GRF is reduced below a threshold that would be considered propulsive during this phase, this should effectively reduce the resistive torque acting on the extensors of the spine. This was suggested originally by Enoka, and implies that the DKB technique effectively shifts the positive joint work in a way that favors the lower extremity (Enoka, 1988) as opposed to the trunk. In this framework it may be sensible to suggest that athletes who are not instructed in correct execution of the DKB are actually increasing reliance on the trunk musculature as opposed to hip and knee musculature. This results in more of a ballistic deadlift as opposed to a true clean. This effectively negates, in large part, the RFD-training quality of the movement, as well as potentially negates some of the antagonist inhibiting qualities associated with power exercises (Arabatzi & Kellis, 2012; Baker & Newton, 2005). As a result, it is possible that these limitations have the capacity to reduce the total barbell load that can be lifted by athletes, reducing the stimulus of the exercise, and potentially compromising safety.

## PRACTICAL APPLICATIONS

The findings of the current study indicate that the DKB technique significantly increases rate of force development. Underpinning these increases in rate of force development are moderate increases in peak force generated and reductions in the time to peak force during the second pull of the clean exercise. When athletes do not use the DKB technique, rate of force development and peak force values achieved during the clean exercise are limited. These outcomes would result in reduced training adaptations to the clean exercise. Therefore practitioners should provide specific instruction to athletes regarding correct clean technique using the DKB and monitor athlete technique during training.

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## APPENDICES

### Appendix A: Tables

**Table 1**. Participant Characteristics (mean ± SD).

| | **Males (*n* = 7)** | **Females (*n* = 3)** |
|---|---|---|
| Age (years) | 27.86 ± 2.48 | 29.33 ± 6.35 |
| Height (m) | 1.77 ± 0.07 | 1.68 ± 0.03 |
| Mass (kg) | 85.44 ± 41.28 | 69.59 ± 3.69 |
| Weightlifting Experience (years) | 3.93 ± 0.61 | 6.00 ± 2.65 |
| Relative Clean 1RM (kg/Body Mass) | 1.36 ± 0.18 | 1.09 ± 0.15 |

**Table 2**. Weighting I Phase Force-Time Characteristics Between the NO DKB and DKB conditions (mean ± SD).

| | **NO DKB** | **DKB** | ***d*** | ***p*** |
|---|---|---|---|---|
| Absolute Duration (s) | 0.42 ± 0.07 | 0.44 ± 0.08 | 0.36 | 0.007 |
| Relative Duration (%) | 60 ± 7 | 59 ± 7 | -0.14 | 0.649 |
| Time to Peak Force (s) | 0.17 ± 0.04 | 0.16 ± 0.03 | -0.14 | 0.583 |
| Impulse (N-SW•s) | 146.69 ± 55.60 | 151.48 ± 54.92 | 0.12 | 0.006 |
| Peak Force above SW (N) | 544.75 ± 183.39 | 542.38 ± 172.64 | -0.02 | 0.901 |
| Rate of Force Development (N/s) | 3318.24 ± 971.33 | 3432.46 ± 1172.42 | 0.15 | 0.440 |

**Table 3**. Unweighting Phase Force-Time Characteristics Between the NO DKB and DKB conditions (mean ± SD).

| | **NO DKB** | **DKB** | ***d*** | ***p*** |
|---|---|---|---|---|
| Absolute Duration (s) | 0.12 ± 0.05 | 0.16 ± 0.05 | 1.02 | 0.022 |
| Relative Duration (%) | 17 ± 6 | 21 ± 7 | 0.94 | 0.041 |
| Impulse (N-SW•s) | -19.22 ± 10.96 | -46.66 ± 16.94 | -2.72 | 0.001 |
| Peak Force below SW (N) | -245.47 ± 92.20 | -505.02 ± 157.19 | -2.85 | 0.001 |

**Table 4**. Weighting II Phase Force-Time Characteristics Between the NO DKB and DKB conditions (mean ± SD).

| | **NO DKB** | **DKB** | ***d*** | ***p*** |
|---|---|---|---|---|
| Absolute Duration (s) | 0.16 ± 0.03 | 0.15 ± 0.03 | -0.78 | 0.109 |
| Relative Duration (%) | 23 ± 4 | 20 ± 3 | -1.32 | 0.008 |
| Time to Peak Force (s) | 0.15 ± 0.03 | 0.12 ± 0.03 | -1.24 | 0.002 |
| Impulse (N-SW•s) | 97.85 ± 25.12 | 102.53 ± 24.44 | 0.27 | 0.529 |
| Peak Force above SW (N) | 1028.99 ± 254.72 | 1105.62 ± 231.96 | 0.44 | 0.301 |
| Rate of Force Development (N/s) | 8990.23 ± 2601.94 | 14123.98 ± 3625.32 | 2.30 | 0.001 |

**Appendix B: Figures**

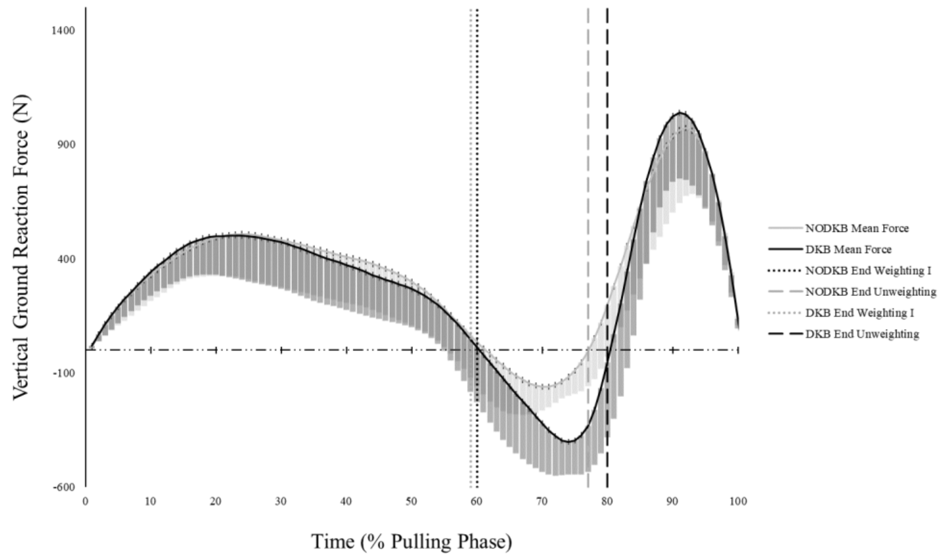


**Figure 3.** Group average force-time history between DKB (solid black line) and NO DKB conditions (solid grey line). Signal magnitude is expressed relative to system weight (zero) and includes mean -1 SD.

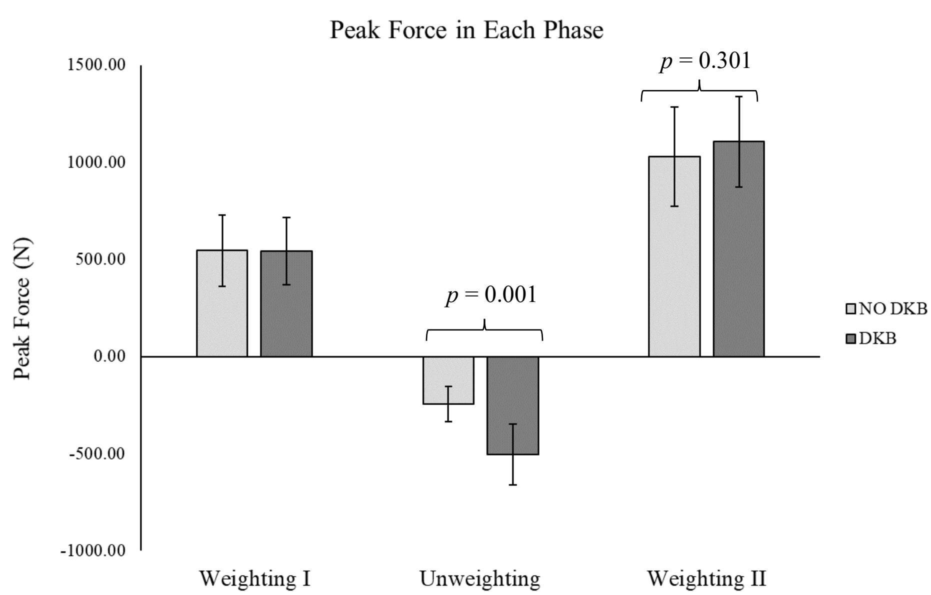


**Figure 4.** Graphical Representation of group average ± 1SD peak magnitude force values in each phase of the DKB and NO DKB conditions.

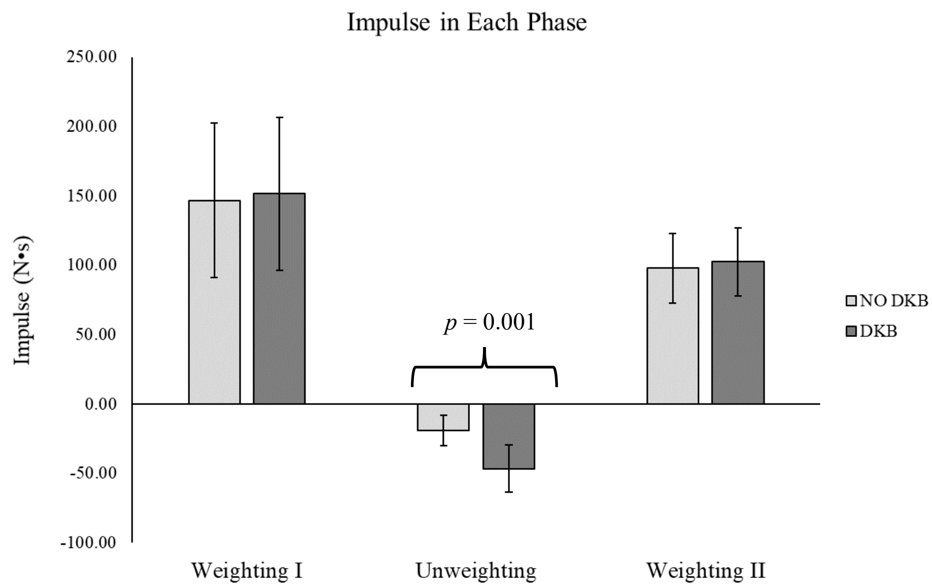


**Figure 5.** Graphical representation of group average ± 1SD impulse during each phase of the DKB and NO DKB conditions.

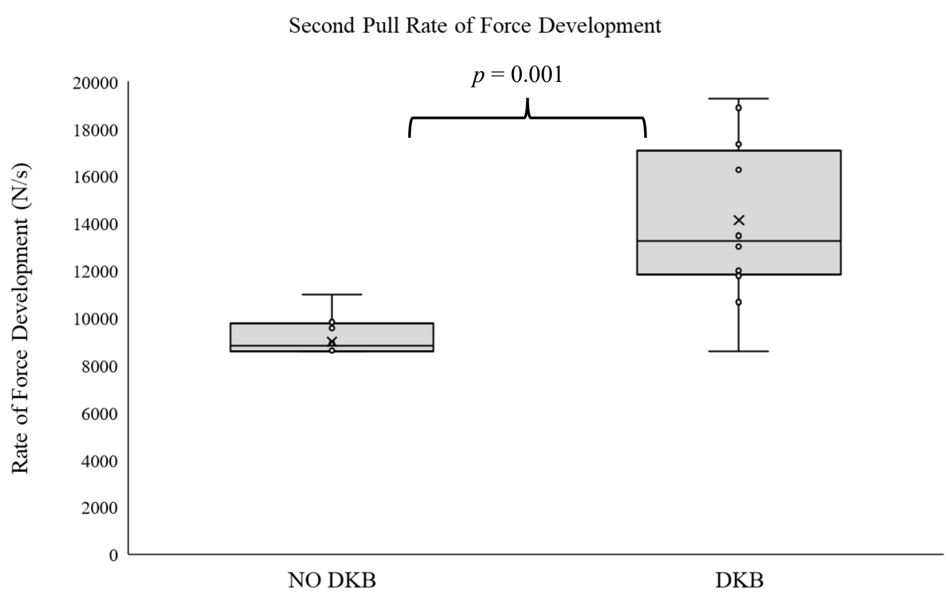


**Figure 6.** Graphical representation of rate of force development in the second pull with condition means expressed as "x" with inclusive median (solid line inside box). Quartiles are represented by the upper and lower borders of the box plots as well as error bars extending vertically from the box plot.

**Appendix C: Recruitment Flyer**

Institutional Review Board
315 Administration Building
Memphis, TN 38152-3370
Office: 901.678.2705
Fax: 901.678.2199

# Appendix D: Consent Form

**Consent to Participate in a Research Study**

**EFFECTS OF THE DOUBLE KNEE BEND TECHNIQUE ON GROUND REACTION FORCE AND EXTENSOR MOMENT VARIABLES IN THE CLEAN AND TWO OF ITS VARIANTS**

**WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?**

You are being invited to take part in a research study in which we are examining the effects of using the double knee bend technique on peak force and rate of force development in the clean, hang clean, clean pull, and hang clean pull. During the testing session you will be asked to complete two sets of three repetitions of each of the following: (a) Clean Pull from the floor at 80% 1RM, (b) Clean from the floor at 80% 1RM, (c) Below Knee Hang Clean Pull at 60% 1RM, and (d) Below Knee Hang Clean at 60% 1RM.

For each of the above listed variations (a-d), you will be asked to first perform three repetitions with the use of a double knee bend, followed by a second set of three repetitions in which you are asked not to use a double knee bend. During these trials, you will be allowed to wear your regular competitive singlet and shoes.

This invitation to participate is being extended to you because you have indicated to the investigator that you (are) (a) between 18 and 35 years of age, (b) have been specifically weightlifting training for a minimum of one year, (c) currently train weightlifting-specific movements two or more days per week, (d) use, and are familiar with the double knee bend technique, and (e) have no history of lower extremity surgeries or any participation limiting injuries in the past six months. If you volunteer to participate in this study, you will be one of about 10 people to do so at the University of Memphis.

**WHO IS DOING THE STUDY?**

The principal investigator for this study is Douglas Powell, PhD of the School of Health Studies at the University of Memphis. The graduate researcher who is supporting the experiment is Alex Carnall, currently enrolled in the School of Health Studies at the University of Memphis.

**WHAT IS THE PURPOSE OF THIS STUDY?**

Overall, the purpose of the study is (1) to determine whether or not the use of the double knee bend technique has any effect on peak vertical ground reaction force, rate of force development, and/or ground reaction force impulse during the second pull in variations of the clean and clean pull. The secondary purpose of this study is (2) to determine whether or not the use of the double knee bend technique has an effect on knee and low back torques in performance of variations of the clean and clean pull. The outcome of the study may indicate further study on technical differences in the execution of these movements when used for enhancing athletic performance.

**ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?**

Before you are included in the study, you will complete the Physical Activity Readiness Questionnaire (PAR-Q; Appendix B). If you report any condition that would predispose you to injury you will be excluded from participation in this study, unless medical clearance is obtained first. Additionally, if you are under 18 or over 30 years of age, you will be ineligible to participate.

Initials: ______________

Institutional Review Board
315 Administration Building
Memphis, TN 38152-3370
Office: 901.678.2705
Fax: 901.678.2199

**WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?**

All research procedures will be conducted in the Musculoskeletal Analysis Laboratory located in Room 171 of the Elma Neal Roane Fieldhouse on campus at the University of Memphis. Once preliminary screening and paperwork (i.e. PAR-Q, Weightlifting Experience Survey; Appendix C) have been completed, you will be asked to finish one testing session in the Musculoskeletal Analysis Laboratory lasting approximately 90-120 minutes.

**WHAT WILL YOU BE ASKED TO DO?**

A total of one testing session is required for complete participation. This testing session will last approximately 90 to 120 minutes and will involve the following in order: (1) coverage of informed consent and supplementary paperwork, (2) warmup exercises and confirmation of movement testing order, (3) placement of anatomical markers to be tracked during motion trials, and (4) execution of movements to be tested. Tested movements include three repetitions at 80% one-repetition maximum load for each of the following: (i) Clean from the floor, (ii) Clean pull from the floor, (iii) Hang Clean from below the knee, (iv) Hang Clean Pull from below the knee. Each movement will be repeated for three trials with a double knee bend used, and then each movement will be repeated for three trials without the use of a double knee bend. Only then will participants be asked to move on to the next movement variation (e.g. Clean from the floor, to Clean Pull from the floor).

Participants will be invited to wear their regular competition singlet (one-piece) or comparably fitted clothing to enable investigators to locate specific anatomical landmarks and reduce the likelihood of marker movement artifact due to excessively loose clothing. All participants will also be asked to refrain from strenuous physical exercise and to adhere to routine diet and hydration habits for at least 48 hours prior to their scheduled testing session.

**WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?**

To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life. Since inclusion criteria for participation requires that you have a certain level of proficiency with these movements (i.e. 1+ years weightlifting training), and indication that you train multiple (i.e. 2+) times per week with these movements, and have no recent (i.e. 6 months) musculoskeletal injury, we believe that this testing protocol presents no increased risk of injury to you compared to your normal training.

The testing protocol in this study may result in delayed onset muscle soreness (i.e. 24-48 hours post-exercise), and it is possible that you may experience muscular strain, tear, or joint injury during the course of these procedures. These risks exist and are similar to those that you assume when participating in regular weightlifting training. Efforts to minimize risks during testing will be in place via thorough instruction and supervised practice following appropriate guidelines as described by the National Strength and Conditioning Association (NSCA). If any abnormal signs or symptoms appear during participation, the exercise will be terminated and you will receive immediate attention, and lab personnel are trained to follow the Adverse Events Protocol (Appendix D) located in the Musculoskeletal Analysis Lab.

**WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?**

There is no guarantee that you will benefit from participating in this study. Your willingness to participate however may result in a greater understanding of the research topic.

Initials: _____________

Institutional Review Board
315 Administration Building
Memphis, TN 38152-3370
Office: 901.678.2705
Fax: 901.678.2199

**DO YOU HAVE TO TAKE PART IN THE STUDY?**

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. If you decide not to take part in this study, your decision will have no effect on the quality of care, services, etc., you receive). As a student, if you decide not to take part in this study, your choice will have no effect on your academic status or grade in any class.

**IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?**

If you do not want to be in the study, there are no other choices except not to take part in the study.

**WHAT WILL IT COST YOU TO PARTICIPATE?**

There are no costs associated with taking part in the study.

**WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?**

You will not receive any rewards or payment for taking part in the study.

**WHO WILL SEE THE INFORMATION THAT YOU GIVE?**

We will make every effort to keep private all research records that identify you to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. However, there are some circumstances in which we may have to share your information with other people. For example, in the event of an injury occurring during the study we may be required to provide the Physical Activity Readiness Questionnaire (PAR-Q) to medical professionals. In addition, we may be required to show information which identifies you to people who need to be sure we have conducted this research appropriately, including people with research oversight authority from the University of Memphis.

Your study-related information (including results) will be combined with information from other participants in the research investigation. When we share the study design and findings with others in written and/or oral form, we will only report the combined information we have gathered and you will not be personally identified. We will make concerted attempts to publish the results of this study; however we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. All paper records and portable storage devices will be secured in a locked file cabinet that is accessible only to the investigators of this study.

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**CAN YOUR TAKING PART IN THE STUDY END EARLY?**

If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study. Additionally, the individuals conducting the study may need to withdraw you from the study. This may occur if you are not able to follow the directions they give you, or if they find that your being in the study is of more risk than benefit to you.

**ARE YOU PARTICIPATING OR CAN YOU PARTICIPATE IN ANOTHER RESEARCH STUDY AT THE SAME TIME AS PARTICIPATING IN THIS ONE?**

You may take part in this study if you are currently involved in another research study that does not require strenuous physical activity. It is important to let the investigator/your doctor know if you are in another research study. You should also discuss with the investigator before you agree to participate in another research study while you are enrolled in this study.

**WHAT HAPPENS IF YOU GET HURT OR SICK DURING THE STUDY?**

If you believe you are hurt or if you get sick because of something that is due to the study, you should contact Douglas Powell, PhD at dwpowell@memphis.edu or graduate researcher Alex Carnall at mcarnall@memphis.edu or (901) 678-3339 immediately. In the case of a life-threatening emergency, you should call 911.

It is important for you to understand that the University of Memphis does not have funds set aside to pay for the cost of any care or treatment that might be necessary because you get hurt or sick while taking part in this study. Also, the University of Memphis will not pay for any wages you may lose if you are harmed by this study.

Medical costs that result from research-related harm cannot be included as regular medical costs. Therefore, the medical costs related to your care and treatment because of research related harm will be your responsibility. A co-payment/deductible from you may be required by your insurer or Medicare/Medicaid even if your insurer or Medicare/Medicaid has agreed to pay the costs. The amount of this co-payment/deductible may be substantial. You do not give up your legal rights by signing this form.

**WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?**

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Douglas Powell, PhD, at dwpowell@memphis.edu or graduate researcher Alex Carnall at mcarnall@memphis.edu. If you have any questions about your rights as a volunteer in this research, contact the Institutional Review Board staff at the University of Memphis at 901-678-2705. We will give you a signed copy of this consent form to take with you.

Initials: ______________

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**WHAT IF NEW INFORMATION IS LEARNED DURING THE STUDY THAT MIGHT AFFECT YOUR DECISION TO PARTICIPATE?**

If the researchers learn of any new information concerning this study that might change your willingness to continue as a participant, that information will be provided to you. You may be asked to sign a new informed consent form if the information is provided to you after you have joined the study.

If the researcher learns of new information in regards to this study, and it might change your willingness to stay in this study, the information will be provided to you. You may be asked to sign a new informed consent form if the information is provided to you after you have joined the study.

________________________________________ ____________
Signature of person agreeing to take part in the study Date

________________________________________
Printed name of person agreeing to take part in the study

________________________________________ ____________
Name of [authorized] person obtaining informed consent Date

Initials: ___________

## Appendix E: Participant Survey

### Participant Information and Weightlifting Experience Questionnaire

Participant Number: ____________

Height: ________________

Weight Class: _________________

Date of Birth (mm/dd/yyyy): _________________

Number of Years Weightlifting Training Experience: _____________________

Highest Level of Competitive Participation Experience:

Local ☐ State ☐ National ☐ International ☐

Personal Bests (From Most Recent Training):

Snatch: ________________

Clean & Jerk: ____________

Days Weightlifting (Clean & Jerk and/or Snatch) Training Per Week: _____________________

**Appendix F: IRB Approval**

Institutional Review Board
Office of Sponsored Programs
University of Memphis
315 Admin Bldg
Memphis, TN 38152-3370

August 24, 2018

**PI Name**: Douglas Powell
**Co-Investigators**: Maxime Paquette, Alexander Carnall
**Advisor and/or Co-PI**:
**Submission Type**: Initial
**Title**: Technique alters rate of force development in power clean exercise
**IRB ID :** #PRO-FY2019-99

**Expedited Approval**: August 24, 2018
**Expiration**: August 24, 2019

Approval of this project is given with the following obligations:

1. This IRB approval has an expiration date, an approved renewal must be in effect to continue the project prior to that date. If approval is not obtained, the human subjects consent form(s) and recruiting material(s) are no longer valid and any research activities involving human subjects must stop.

2. When the project is finished or terminated, a completion form must be submitted.

3. No change may be made in the approved protocol without prior board approval.

Thank you,
James P. Whelan, Ph.D.
Institutional Review Board Chair