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The Relationship of Force-Time Variables Between the Loaded Squat Jump and the Midthigh Block Clean Pull

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THE RELATIONSHIP OF FORCE-TIME VARIABLES BETWEEN THE LOADED SQUAT JUMP AND THE MIDTHIGH BLOCK CLEAN PULL

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Abstract

Loaded squat jumps and midthigh block clean pulls are exercises that can be used in a strength and conditioning program to increase lower-body power. Lower-body power is critical in jumping, sprinting, and other sport specific movements. Intensities of 45-pound barbell, 20%, 40%, and 60% of a high-force, low-velocity movement were used to assess the force-time variables of the loaded squat jump and midthigh block clean pull. The current study compared peak power output as well as peak barbell velocity to find which exercise and intensity combination would be most beneficial for an athlete to increase lower-body power. A linear position transducer was used to measure barbell velocity and calculate peak power and peak barbell velocity. Results from the current study showed that peak power took place with the barbell for the loaded squat jump, and at 60% one-repetition maximum (1RM) for the midthigh block clean pull. Interpretation of these results led to the conclusion that loaded squat jumps should be completed with the barbell to achieve maximal power. When comparing force-time variables between the loaded squat jump and midthigh block clean pull, the results showed peak power to be much less in the midthigh block clean pull. Athletes who do not have at least one year of weightlifting experience would benefit more from the loaded squat jump than the midthigh block clean pull. If the athlete does have weightlifting experience, they may benefit from the midthigh block clean pull and increase lower-body power.

Keywords: force-time variables, loaded squat jumps, midthigh block clean pulls, peak power, peak barbell velocity, intensity

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I. Introduction

Strength and conditioning coaches are constantly trying to program training sessions that optimally benefit their athletes. Lower-body power is an important physical quality that directly relates to athletic performance in most sports and needs to be developed to execute sport skills (Suchomel, Comfort, & Stone, 2015). For example, sport skills such as throwing, kicking, swinging a bat, or high jumping all require lower-body power to be successful. Athletes with high lower-body power output should have more success over other athletes who have less power when executing the same skill. Weightlifting movements can increase muscle-tendon stiffness and concentric power production, which results in an increase in the efficiency of the stretch shortening cycle, thus increasing vertical jump (Arabatzi & Kellis, 2012). According to Shalfawi, Enoksen, and Tonnessen (2014), vertical countermovement jumps (CMJ) are strongly correlated ($r > 0.5$) with maximal sprint speed, which suggests that lower-body power is a critical kinetic variable to the success of sprint performance. Durovic et al. (2015) observed that the greater amount of force swimmers were able to produce in a jump squat, the better their 10 meter start time. Comfort, Allen, and Graham-Smith (2011) compared peak vertical ground reaction forces as well as instantaneous rate of force development in power cleans, hang power clean, midthigh power clean, and midthigh clean pulls. Comfort et al. (2011) observed midthigh clean pulls significantly increased rate of force development and peak vertical ground reaction forces, which, in turn, will improve any lower-body power exercise from a static start due to the increased amount of force produced in a given amount of time.

The current study analyzed the relationship of force-time variables (peak power and peak velocity) between the loaded squat jump (LSJ) and midthigh block clean pull (MBCP). Analyzing these two variables is important because it shows strength and conditioning coaches which exercise at which intensity will be most beneficial for their athletes. Loaded squat jumps and MBCPs should be used in strength and conditioning training programs because they increase concentric lower-body power. Both exercises consist of the concentric phase only which decreases the chance of technique error taking place making them better exercises for large teams to complete with a larger coach to athlete ratio.

Significance

Many different exercises at different intensities can be used to increase lower-body power, but there is no one definitive answer as to which exercise and intensity combination would most likely increase lower-body power. The LSJ and MBCP are two exercises that are used at different intensities to increase lower-body power. Other exercises that could be used to improve lower-body power could include kettlebell swings, loaded countermovement jumps, cleans, and snatches, among other high-force, high-velocity exercises.

Midthigh block clean pull. Midthigh block clean pulls may be used in an athlete's strength program to develop lower-body power. Clean pulls are used over cleans because they are simpler and get the same result of an increase in lower-body power. The highest power output comes during the second pull phase when triple extension occurs (Garhammer, 1980; Garhammer, 1993; Gourgoulis, Aggeloussis, Kalivas, Antoniou, & Mavromatis, 2004; Kipp, Redden, Sabick, & Harris, 2012; Waller,

Piper, & Miller, 2009), which takes place in both the MBCPs as well as a full clean. Beginning at the midthigh position on blocks forces athletes to only focus on the second pull from a static start and eliminates the first pull reducing the chance for technique errors. For strength and conditioning coaches to reduce technique errors, they have athletes perform midthigh pulls from blocks or hang starting positions.

Correct technique is imperative when performing weightlifting movements, so athletes are able to produce optimal power output (Gourgoulis et al., 2004). The start position for the MBCP includes the athlete's feet about hip width apart with their shoulders over the barbell (see Figure 1). The athlete's back is flat with their chest out while using either an overhand or hook grip which is wide enough so the elbows remain extended and outside of the legs. Head position is straight forward being in neutral cervical position. The athlete's center of mass should be back so the feet are flat on the ground and weight is toward the middle of the foot. The pull is then completed when the athlete extends their ankles, knees, and hips, and elevates their scapulae to complete the second pull and shrug portion of the pull to maximize barbell velocity (DeWeese et al., 2016). The barbell remains close to the athlete and brushes against their thighs during the second pull to keep the barbell path vertical and decrease the amount of horizontal displacement (DeWeese, Serrano, Scruggs, & Burton, 2013; Drechsler, 1998; Waller et al., 2009).

An athlete who is able to minimize horizontal displacement during the pulling phase can increase vertical barbell velocity and maximal force production (Hoover, Carlson, Christensen, & Zebas, 2006; Winchester, Erickson, Blaak, & McBride, 2005). Power is calculated by multiplying force and velocity, so the movement should be

completed with the highest velocity possible at a selected intensity to maximize power output (Cosic, Duric, Zivkovic, & Nedeljkovic, 2017). Furthermore, there is an inverse relationship between barbell intensity and barbell velocity. According to McMahon, Jones, Suchomel, Lake, and Comfort (2018), as the velocity of a lift increased at a set intensity, the power also increased. When an intensity increases, the velocity will decrease, but the power may be maintained because the force is increased (Garhammer, 1993). Previous studies have shown peak power occurring between 30% and 60% one-repetition maximum (1RM) of high-force, low-velocity strength exercises, which reveals a gap in the research that needs to be filled (Kawamori et al., 2006; Suchomel, Beckham, & Wright, 2015; Suchomel & Sole, 2017; Suchomel, Wright, Kernozek, & Kline, 2014). The current study evaluated the exercise over a variety of intensities from the 45-pound barbell, 20%, 40%, and 60% 1RM of conventional deadlift to find which intensity will have the highest force-time variables of the block midthigh clean pull.

Loaded squat jump. Loaded squat jumps are used in program phases typically following a strength phase. Once the groundwork is completed and athletes have the strength to complete loaded power movements, LSJs are incorporated into the programs to develop lower-body power (Darmiento, Galpin, & Brown, 2012). According to Loturco, Pereira, et al. (2015), LSJs were used in a 4-week training period and from pre- and post-testing, and it was shown that LSJs increased lower-body power as well as acceleration in soccer athletes. The intensity used during training was the optimal intensity for training power. To determine optimal intensity, a linear position transducer was used, and the intensity was increased each set until power no longer increased. Following the 4-week training period, the percent increase of the squat jump was 1.18%,

and acceleration of 5 meters had a percent increase of 4.75% (Loturco, Pereira, et al., 2015). The percent increase is important because it supports the use of LSJs to improve lower-body power. In order to maximize lower-body power development through an LSJ, proper technique and appropriate intensity need to be applied.

Loaded squat jumps also begin at a static start position similar to MBCPs only consisting of the concentric phase of the movement. The start position of the LSJ begins with the barbell across the athlete's posterior deltoids and upper trapezius, with a self-selected hand position on the barbell (see Figure 2). The feet position is hip width with slight hip and knee flexion to keep the weight on the middle of the foot. The LSJ has hip and knee angles that are typically similar to the start position of the MBCP. After the athlete is set, they will vertically displace their body as well as the external load at a high velocity. Lower-body power is developed from the triple extension that takes place during the LSJ exercise (Moir, Gollie, Davis, Guers, & Witmer, 2012).

Loturco, Pereira, Kobal, and Nakamura (2018) explained the importance of mixed-methods training programs to develop power. When unloaded squat jumps are used in training, jump velocity increases, which also increases sprint performance and other high velocity movements. Furthermore, LSJs are widely used in training programs because they can be completed as high-force, low-velocity movements or low-force, high-velocity movements based upon the loading (Loturco et al., 2018). Loturco et al. (2018) also provided suggestions on training frequency, volume, and intensity for moderately and highly strength and power trained soccer athletes. For example, moderately trained athletes should use jump squats in training one or two sessions per week with four to six sets of four to six jumps with 60% of body mass while highly

trained athletes only need one training session per week with six sets of six jumps at 65% of body mass (Loturco et al., 2018). The loaded squat jump is an exercise that has been shown to increase lower-body power as well as sports performance (Loturco et al., 2018).

Durovic et al. (2015) studied force-time variables of squat jumps with swimmers and found that the time at 10 meters was moderately correlated with squat jump peak power ($r = 0.391$) and squat jump maximal force ($r = 0.420$). Jandacka, Uchytil, Farana, Zahradnik, and Hamill (2014) used intensities between 0% and 90% 1RM back squat for LSJs and observed that lighter intensities (< 30% 1RM) were optimal for total power output. Jandacka et al. (2014) observed angular power output of the hips, knees, and ankles for each intensity and found that power is not maximized at the same intensity for all joints, so a variety of intensities should be used in LSJ training. In the current study, the similarity between the MBCP and the LSJ was useful in comparing their barbell kinetics using the same intensity scheme.

Purpose and Hypothesis

The purpose of the current study was to analyze the relationship of force-time variables between the LSJ and the MBCP at different intensities. The null hypothesis is no significant difference exists between LSJ and MBCP as well as the corresponding intensities. The research hypothesis is that the highest power output will take place in the LSJ with 20% 1RM and 40% 1RM for the block midthigh clean pull. Overall, the relationship between the LSJ and MBCP will demonstrate a significant difference ($p < .05$) between the force-time variables.

The independent variables of the current study were the LSJ and MBCP as well as the four different intensities, which included the 45-pound barbell, 20%, 40%, and 60%

1RM of the two exercises. The dependent variables were peak power (W) and peak velocity (m/s). The moderator variables could not be manipulated and could have an effect on the dependent variable.

Control variables of the study include the shoes and clothing that were consistent through all of the testing sessions. The inclusion criteria of being able to squat one and a half times their bodyweight and possess one year of current strength and power training was another control variable. The exclusion criteria of possessing a musculoskeletal injury within the past year or surgeries that limit range of motion would also have been considered control variables. Participants were excluded if they had a musculoskeletal injury in the past year or if they had a musculoskeletal surgery that limited range of motion. Testing times were controlled within one hour. Start positions were also controlled as well as foot placement. Mediator variable included the type of training of the participants prior to testing. Moderator variables included age, sex, height, and limb length.

Verbal encouragement was given to each participant during maximal testing, but no other forms of motivation were used during testing. The rest time between sets of 1RM testing as well as during the testing sessions was consistent between all subjects. During maximal testing, two to five minutes passive rest was given to participants. When testing, 10 minutes took place between different intensities to diminish the probability of a potentiating effect taking place (Robbins, 2005). The time of day that participants were tested was within one hour of previous testing sessions on different testing days.

An extraneous variable of the current study was that time frame of testing was different between the participants. Some participants tested earlier in the day while others tested in the afternoon based upon scheduling and times available for participants and researchers. Subjective reporting of fatigue or tiredness by the participant is another extraneous variable that could not be controlled and could have affected the results. The participants could have also just had an "off" day and not performed to the best of their abilities.

Operational Definitions

Back Squat – Participant puts barbell on back and descends until the tops of the thighs are parallel to the floor and ascends back to start position (McGuigan, 2016).

Conventional Deadlift – Self-selected hand grip. Start position to extension of hips and knees and descend slowly back to start position (Caulfield & Berninger, 2016).

Loaded squat jump – Barbell placed on back, static start in quarter-squat position, athlete performs vertical jump (Bobbert, Gerritsen, Litjens, & Van Soest, 1996).

Midthigh block clean pull – Start barbell at power position and explode vertically to achieve triple extension of the lower body and a shrug of the shoulders (Drechsler, 1998).

Musculoskeletal injury – An injury needing medical attention (e.g. breaks, tears, severe sprains; Houglum, 2005).

One-repetition maximum (1RM) – "The greatest amount of weight that can be lifted with proper technique for only one repetition" (McGuigan, 2016, p. 451).

Power – "Time rate of doing work" (McBride, 2016, p. 28).

Strength – "The ability to exert force" (McBride, 2016, p. 25).

Weight trained athlete – one year of experience with strength and power exercises (Sheppard & Triplett, 2016).

Weightlifting familiarization – Having at least one year of weightlifting experience as well as competition experience.

Work – Product of the force exerted on an object and the distance the object moves in the direction in which the force is exerted (Triplett, 2016).

Assumptions

Participants self-reported being weight-trained, which was assumed to be accurately reported. Additionally, participants reported musculoskeletal injuries or surgeries that limit range of motion within the past year. When participants claimed to be injury free, it was assumed they did not have any pain that would hinder performance of the exercises associated with the study.

Maximal effort should be given in the 1RM back squat, 1RM conventional deadlift, and in both testing sessions at all intensities, and it was assumed that maximal effort was given. Maximal effort is necessary during 1RM testing because if it is inaccurate, then the percent 1RM used during testing would be inaccurate which could skew the data. If maximal effort was not given during testing sessions, power output would be inaccurate and would affect the results of the study.

Participants were instructed to maintain their current diet and not make any drastic changes during the testing period, and it was assumed that diet changes did not take place. Maintaining diet is important because changes in diet could cause changes in results. Investigators did not have any diet requirements for the current study.

Participants were told pre-workout supplementation could not be taken prior to testing sessions; it was assumed participants followed instructions and did not violate protocol of the study. Ingesting a pre-workout could cause the participant to perform differently than if they did not take the pre-workout. If participants did not follow protocols, it could cause the results to be unreliable.

An assumption can be made that participants completed 1RM back squat and conventional deadlift with maximal effort to obtain a valid load. Furthermore, investigators assumed that a maximal effort was also given during testing sessions with the LSJ and MBCP. The participants' efforts during all sessions were assumed to be maximal but familiarity with the exercises, rest, training experience and personal motivation may have influenced the participants' results.

Limitations

A limitation that occurred in the study was the amount of experience with weightlifting movements of the participants. The experience with MBCPs can alter the results due to inefficiency, poor motor pattern, improper technique, or discomfort of the participant. Even though familiarization sessions took place, not all participants had the same level of experience with the sport of weightlifting when it came to the MBCP technique.

Possibility of human error in recording measurements or data incorrectly is also a limitation. Other human errors that could have taken place could include incorrect data input. Human error could have affected the results of the study and skewed data.

When collecting data, there was no way to verify that full effort was given by participants. If participants did not give full effort when finding their maximum squat or

deadlift, it would skew the percentages used during testing sessions. Participants who did not give full effort would have provided false and inaccurate data recorded by the primary investigator.

Different types of shoes were worn between participants, which could provide different results. Weightlifting shoes provide a heel lift that is not provided in tennis shoes. The heel lift could have caused greater relative joint angles during the 1RM back squat as well as 1RM conventional deadlift. The heel lift changes the joint angle of the ankle and will increase mobility during performance of the exercises.

Delimitations

Shoes worn during the study were kept consistent for each participant for all five sessions. Weightlifting, tennis, and thin, flat-bottomed shoes as well as others were types of shoes were worn for the study. Participants self-selected which type of shoe they wore for the testing period.

Participants also did not ingest pre-workout prior to sessions and maintained their normal diet and eating habits through the entirety of the study. Participants were not asked specifics about their diet or eating habits. Changes in diet could skew the results of the study, so the researcher decided to request maintenance of diet regardless of nutritional habits.

The stimulus provided for each of the participants remained the same; verbal motivation was given during testing, but no other types of motivation were promoted. Music was not allowed during testing sessions as it could increase adrenaline in some participants and have no effect on others. The primary investigator was present at all testing sessions and provided the same motivation to all participants.

The environment was consistent for all participants as well as testing sessions. All sessions took place in the exercise physiology lab at Arkansas Tech University where the temperature was controlled and maintained at 73 degrees Fahrenheit. The lab was set up the same way for each session and the same equipment was used for all participants.

The protocol for each of the five sessions was the same for all participants. The warm-up, testing, as well as rest periods were kept consistent to maintain control of extra variables and keep things as similar as possible between participants. The rest periods for session two were between two and five minutes while the rest periods for sessions four and five were 10 minutes. All rest periods were passive rest, and the participants were not allowed to stand up or walk around between sets.

Time of testing for data collection sessions were within one hour of each other for each participant. The reason for keeping the time close was to decrease the chance of the body performing differently at different times of day. Testing sessions took place any time between 7 a.m. and 7 p.m.

Figure 1. Start position of the midthigh block clean pull.

Figure 2. Start position for the loaded squat jump.

II. Literature Review

Force-Time Variables

Power is defined as force multiplied by velocity and has a positive relationship between power output, body mass, and jump height (Samozino, Morin, Hintzy, & Belli, 2008). According to Darmiento et al. (2012), power output and jumping ability have a direct correlation to sport performance, which helps strength and conditioning coaches to design programs that improve lower-body to improve jumping ability and sport performance. Athletes can use MBCPs and LSJs in a strength program along with manipulating the loading schemes to improve lower-body power. As stated by Cronin, McNair, and Marshall (2001), there are three things necessary to achieve high power output. First is the recruitment of type II motor units to provide greater contraction force output, followed by motor unit rate coding for greater contraction velocity, and finally motor unit synchronization so all fire at the same time. An athlete's motor unit recruitment, synchronization, and rate coding should improve with a strength and conditioning program that emphasizes power development (Zatsiorsky & Kraemer, 2006). For example, programs that utilize MBCPs and LSJs at different intensities may improve lower-body power through improvement of the neural adaptations (Comfort, Udall, & Jones, 2012; Moir et al., 2012).

In order for athletes to increase vertical jump, they must improve takeoff velocity (Bobbert, 2014). "Improving maximal force or velocity increases power production, and therefore theoretically enhances game play" (Darmiento et al., 2012, p. 34). A variety of training exercises and methods are used to increase lower-body power, but all should

consist of low volume per set (e.g. 1-5 repetitions), long rest periods (2-5 minutes), and be completed with a high contraction velocity (Darmiento et al., 2012).

According to Bobbert (2014), mean power is also a factor in jumping ability because it relates to the amount of work being completed at a given velocity through entirety of a movement. Bobbert (2014) has also observed that loaded and unloaded squat jumps had the highest relative power output and vertical velocity at -60% bodyweight, which may be explained by the force-velocity and power-velocity relationship. Bobbert (2014) also mentions that a theory for the intensity at which people exert highest effective energy of the center of mass depends on the loading conditions to which the individual is most accustomed with their training.

Velocity of the barbell is an important aspect of the MBCP and LSJs because it is one of the determining factors of power output. Barbell velocity can be measured by using a linear position transducer (GymAware™) which uses exercise intensity and participant body weight to calculate kinetic and kinematic variables. In a study by Comfort et al. (2012), a linear position transducer was used to measure barbell velocity during midthigh clean pulls. Comfort et al. (2012) tested with intensities of 40%, 60%, 80%, 100%, 120%, and 140% of 1RM power clean and observed that barbell velocity was significantly greater ($p < 0.001$) at 40% 1RM compared to all other intensities. Lighter intensities (< 40% 1RM) can be used for velocity-based training to increase velocity of movements.

Mann, Ivey, and Sayers (2015) explained the reasons for velocity-based training. Velocity has a direct relationship with power as power is the product of force and velocity (Ramirez, Nunez, Lancho, Poblador, & Lancho, 2015). Velocity-based training

can determine athletes' optimal intensity to maximize power as opposed to using percentages of 1RM. Training with percent of 1RM does not allow for the coach or athlete to have knowledge of barbell speed; therefore, there is no certainty that power is being maximized (Mann et al., 2015). Ramirez et al. (2015) stated, "Coaches or practitioners should keep in mind that it is not necessary to increase external load to improve relative and absolute power outputs" (p. 3087). Velocity-based training and percentage of 1RM training are methods used to develop power. The current study uses percentages of 1RM to find which intensity is most optimal for achieving peak power.

The conventional deadlift was used in the current study because it is a high-force, low-velocity movement with similar kinematics to MBCPs due to the pulling action (Gourgoulis et al., 2004). Percentages of the conventional deadlift 1RM were used for the MBCPs while percentages of the 1RM back squat were used for the LSJ. The current study is different from other studies because percentages of the conventional deadlift were used for the MBCP as opposed to using percentages of 1RM power clean. The percentages of the 1RM conventional deadlift are very different from a power clean because a power clean is a moderate-force, moderate-velocity while the conventional deadlift is a high-force, low-velocity movement, as mentioned earlier.

Midthigh Block Clean Pull

Midthigh block clean pulls are an exercise used in strength and conditioning programs to increase lower-body power. The hang power clean is an important exercise to understand because it is similar to the MBCP, which is used in the current study. The start positions of the hang power clean and the MBCP are the same and the movements only differ following the second pull, where peak power output takes place (Garhammer,

1980). Kawamori et al. (2005) demonstrated that when hang power cleans were performed, the highest relative average power, relative peak power, and peak power output occurred at the intensity of 70% 1RM of the hang power clean. The average relative power at 70% 1RM was statistically significant and greater than 30% 1RM ($p < .01$). Peak power and relative peak power at 70% 1RM were statistically significant and greater than 30% and 40% 1RM ($p < .001$; Kawamori et al., 2005). If the goal of the exercise is to maximize peak power, an intensity of 70% 1RM hang power clean should be used over intensities between 30% and 40% 1RM for the athlete to achieve maximum power.

Hang power cleans, hang high pulls, and MBCPs all have the same, critical commonality, the second pull. The second pull is the portion of the clean that results in the highest power output and has been commonly studied (Garhammer, 1980). Lower-body power is maximized in the biomechanical position of hip, knee, and ankle extension, which takes place during the second pull of the clean regardless of start and finish positions (Suchomel, Beckham, & Wright, 2015). Research studies include hang power clean, hang high pulls, and hang pulls, but they can all be compared to each other when looking at power output because they all contain the second pull.

Kawamori et al. (2006) also evaluated isometric as well as dynamic midthigh clean pulls with intensities between 30% and 120% 1RM of the power clean. Peak power took place at the intensity of 60% 1RM, but the value was not statistically significant or different from 30%, 90%, or 120% 1RM ($p > .01$; Kawamori et al., 2006). Suchomel et al. (2014), Suchomel et al. (2015[a]), and Suchomel et al. (2017), however, observed the power output of the hang power clean to have an optimal intensity for maximizing peak

power at 30% to 45% 1RM of the hang power clean, which is much lower than 60% and 70% of the hang power clean from Kawamori et al. (2005) and Kawamori et al. (2006).

The hang high pull was evaluated in three studies by Suchomel et al. (2014), Suchomel, Comfort, et al. (2015), and Suchomel and Sole (2017) to determine relative peak power, peak power, peak force, and peak velocity at different intensities. Suchomel et al. (2014) observed that hang cleans had the highest power output at 45% 1RM of a hang clean while intensities of 65% 1RM and 80% 1RM were of lesser values. When the high pull, hang clean, and jump shrug were analyzed at intensities of 30%, 45%, 65%, and 80% 1RM of the hang clean, the highest value was used for comparison between intensities. The high pull generated greater peak power ($p < .01$) and higher peak velocity ($p < .001$) than the hang clean (Suchomel et al., 2014). The jump shrug was analyzed and had the highest power output of the three exercises and was statistically significant and greater ($p < .001$) than the hang clean and high pull (Suchomel et al., 2014).

Suchomel, Comfort, et al., (2015) studied only the hang high pull with 30%, 40%, 65%, and 80% of hang power clean. Peak velocity took place at 30% 1RM of the hang power clean, while peak power took place at 45% 1RM. The peak velocity at 30% 1RM was not statistically significant or different from peak velocity at 45% 1RM ($p > .0001$). Peak power between intensities of the hang high pulls was not statistically different between 30% 1RM ($p > .05$) or 65% 1RM ($p <.04$), but 80% 1RM was statistically significant and different ($p < .04$; Suchomel, Comfort, et al., 2015). The results of the study would suggest that intensities between 30% and 45% 1RM could be most optimal for power development because there was not a statistical difference between the two

intensities, whereas there was a significant difference at 80% 1RM. As stated by Suchomel, Comfort, et al. (2015), “Training emphasis of practitioners during the hang high pull should be placed on lifting velocity to enhance explosiveness and by triple extension, their power development” (p. 1300).

Suchomel and Sole (2017) studied hang high pulls, jump shrugs, and hang power cleans at 30%, 45%, 65%, and 80% of 1RM hang power clean. Suchomel and Sole (2017) demonstrated that the relative peak power for the hang high pull took place at 45% 1RM hang power clean while the relative peak power for the hang power clean took place at 65% 1RM and at 30% 1RM for the jump shrug. The relative peak power produced by the jump shrug was statistically significant and greater ($p < .001$) than the hang clean pull and hang high pull. The hang high pull had a statistically significant and greater ($p = .008$) relative peak power than the hang power clean (Suchomel & Sole, 2017). In short, the greatest relative peak power was produced by the jump shrug followed by the hang high pull, and lastly, the hang power clean. According to Suchomel and Sole (2017), “Practitioners should prescribe moderate to heavy loads, 65-80% 1RM, to maximize power output of the hang clean pull” (p. 412).

Comfort, Jones, and Udall (2015) compared intensities of midthigh clean pulls between 40% and 140% 1RM of the power clean. The results showed the optimal range was between 40 and 60% 1RM to achieve peak power, similar to Suchomel et al. (2014), Suchomel, Beckham, et al. (2015), and Suchomel and Sole (2017). Comfort et al. (2012) also interpreted relative peak power and found that 40% 1RM was statistically significant and greater ($p < .01$) than 80%, 100%, 120%, and 140% 1RM. Comfort et al. (2012) emphasized the importance of knowing what the primary goal is before training, and that

the results of a training program focused on power are influenced directly by the intensity and velocity of the barbell. Kawamori et al. (2005), Kawamori et al. (2006), Suchomel et al. (2014), Suchomel, Comfort, et al. (2015), Suchomel and Sole (2017), and Comfort et al. (2012) explain that there are many different variations of weightlifting exercises as well as intensities that can be manipulated by strength and conditioning coaches to create training programs that will most benefit their athletes.

Clean pulls can be used as an exercise in strength and conditioning programs to increase lower-body power. As stated by Waller et al. (2009), "Training at a high rate of speed with the pull could increase the athlete's overall lower-body power" (p. 47). Furthermore, MBCPs can also be used to increase rate of force development that is important for sport performance by increasing intramuscular coordination (DeWeese et al., 2013; Tricoli, Lamas, Carnevale, & Ugrinowitsch, 2005). To achieve increases in intramuscular coordination, training must be conducted at different intensities to provide an adequate stimulus.

The current study used intensities of a 45-pound barbell and 20%, 40%, and 60% 1RM of the conventional deadlift for MBCP testing. The conventional deadlift was chosen because it is a high-force, low-velocity exercise with similar biomechanical kinematics as an MBCP in relation to the pulling action and extending the hips and knees (Gourgoulis et al., 2004). The midthigh block start position was chosen because the researcher wanted to isolate the second pull to eliminate the chance of technique error with a more complex exercise. The midthigh start position, also known as the power position, begins with the barbell above the knees sitting on blocks with the participants hips back in preparation for triple extension. The participants then extend their hips,

knees, and ankles and shrug their shoulders to complete the MBCP. The second pull is very short in duration, approximately 0.1 to 0.2 seconds (Garhammer, 1993). The intensities for the current study were chosen because, according to Potach and Chu (2016), external loading of power exercises have shown increases in power development with less than 60% 1RM.

Loaded Squat Jump

An LSJ is an exercise used in strength and conditioning programs to develop lower-body power and jumping performance. The exercise begins with a static start in a "quarter-squat" position followed by vertical displacement of the athlete's center of mass and the barbell load. Mackenzie, Lavers, and Wallace (2014) compared the kinetics and kinematics of the squat jump, power clean, and countermovement vertical jump through the use of force plates and electronic goniometers and found that greatest maximum power was observed with the countermovement vertical jump condition and was significantly greater ($p < .001$) than the jump squat and power clean. Although power cleans had the lowest peak power, they had the highest rate of force development and significantly higher ($p < .001$) than the countermovement vertical jump and squat jump (Mackenzie et al., 2014). Rate of force development is important to develop in athletes who begin movements with a static start. When analyzing the kinematics of the power clean and the jumps, Mackenzie et al. (2014) found that the power clean was not as similar to the vertical jump and jump squat as the vertical jump and squat jump were to each other. The order in which the hips, knees, and ankles extended created a difference between power clean and squat jump kinematics. Although the power clean is not as closely related to jumps as jumps are to each other, the relationship between the power

clean and jumping performance is important because power cleans can be used with appropriate intensities to increase lower-body power, which will, in turn, improve vertical jump performance (Mackenzie et al., 2014).

While Mackenzie et al. (2014) analyzed and compared kinematics of different exercises, Jandacka et al. (2014) analyzed kinematics of the LSJ at different intensities. Jandacka et al. (2014) used percentages of 1RM back squat as a high-force, low-velocity exercise to complete a LSJ. The intensities used by Jandacka et al. (2014) included 0%, 10%, 30%, 50%, 70%, and 90% of the 1RM back squat, and power of the hip, knee, and ankle joints were analyzed. The results demonstrated that at 0% 1RM, the power output from the knee was significantly different ($p < .05$) than the power output of the knee at an intensity of 90% 1RM. The knees could be performing differently with lighter intensities and relying on the hips and ankles to achieve vertical displacement as opposed to performing each intensity with the same kinematics. A reason for the difference in power output across joints could be the range of motion they go through when performing an LSJ. The intensity of 30% 1RM back squat produced the highest overall LSJ power output with 0%, 10%, and 50% 1RM within 200 watts of 30% 1RM (Jandacka et al., 2014). Moir et al. (2012) compared the lower-body kinetics of jump squats at different intensities including 0%, 12%, 27%, 42%, 56%, 71%, and 85% 1RM back squat. Relative power output was calculated for the hip, knee, and ankle as well as total relative power. As the intensity increased, the relative power for the hips continued to increase through 42% 1RM. The knee and ankle both experienced decrements in relative power as the intensities increased. It is important for strength and conditioning coaches to know that power can be maximized at different joints because it can affect their programming.

If a soccer athlete is working to maximize power at the knee, then lighter intensities (< 42% 1RM) should be used (Moir et al., 2012). Total power peaked with 12% 1RM but remained about 4 watts per kilogram of body mass through 56% 1RM. Moir et al. (2012) recommends strength and conditioning coaches vary intensities with their athletes to develop more velocity with lighter intensities (< 30% 1RM) and force with heavier intensities (> 75% 1RM). Loturco, Nakamura, et al. (2015) took a different approach when selecting intensities for LSJs and decided to use percentage of body mass as opposed to a percentage of 1RM. The lightest intensity was 40% of body mass and increased by 10% until the mean peak power began to decline. The results of the study showed that peak power took place, for the majority of intensities, when their velocity was close to 1 $m \cdot s^{-1}$ (Loturco, Nakamura, et al., 2015). As stated by Loturco, Nakamura, et al. (2015), "Jump squat optimum power load can be determined simply by means of mean propulsive velocity or jump height determination in training" (p. 1). Due to the lack of extensive knowledge on LSJs and power development, further research needs to be performed to narrow the gap.

De Villiers and Venter (2015) conducted a study with rugby athletes and tested their peak power of the squat jump at different intensities both pre-season and in-season. Results concluded that peak power took place with intensities between 60% and 90% 1RM during pre-season, and in-season peak power was lower and fell between 50% and 90% 1RM. The reason the intensity would be lower in-season is because the main focus of an in-season training program is to maintain the attributes that the athletes already possess. The stress of games and practices could also be factors in the declination of performance and require training to take place at a lower intensity than pre-season so

athletes do not reach overtraining. There was a significant increase ($p < 0.01$) in peak-power production from pre- to in-season (De Villiers & Venter, 2015). The reason for the increase in peak-power production in-season was due to the increased barbell velocity at the same intensity compared to barbell velocity during pre-season. De Villiers and Venter (2015) also tested peak power output of hang cleans and found that optimal intensity for hang cleans during pre-season was 90% of 1RM. As the team transitioned to in-season, they still had a significant ($p < .01$) increase in power production (De Villiers & Venter, 2015). During the season, power increased with the intensities until the intensity reached 80% 1RM; then power began to decrease. The additional stress on the athletes' bodies could be reason for the declination in power output in both exercises.

Loturco et al. (2016) suggests that loading for the squat jump should be individualized as opposed to using a set percentage of 1RM. If athletes have individualized intensities, they will benefit more from the training program than if they completed sessions according to "norms" that do not apply to them. De Villiers and Venter (2015) expressed that more experienced strength trained athletes showed greater peak power at lower intensities than less experienced athletes. Inexperienced athletes are those who have less than one year of strength training, and it is recommended to develop lower-body power using sub-maximal intensities between 50% and 60% 1RM (De Villiers & Venter, 2015).

Research has demonstrated that squat jumps correlate with sport and functional performance, such as improved jumping and acceleration performance in soccer athletes. (Kitamura et al., 2017; Loturco, Nakamura, et al., 2015; Williams, Chapman, Phillips, & Ball, 2018). Loturco, Pereira, et al. (2015) suggested soccer athletes may improve

jumping performance through the use of half squats in training while squat jumps can be used to improve sprinting acceleration performance. In addition to improving sprinting acceleration performance, squat jumps can also be used to improve neuromuscular performance as well as maximize lower-body power output (Kitamura et al., 2017). When using the squat jump to assess lower-body power output, Jimenez-Reyes, Pareja-Blanco, Rodriguez-Rosell, Marques, and Gonzalez-Badillo (2016) suggest that maximum velocity should be used as opposed to flight time for determining this force-time variable because it is more valid and precise compared to performance. According to Cuk et al. (2014), LSJs have a high reliability, and moderate to high validity and can be used for testing force, velocity, and power of the lower-body.

In addition to LSJs being used for testing protocols, they can also be used in strength and conditioning programs to increase lower-body power (Loturco, Pereira, et al., 2015) The current study analyzed the LSJ with the intensities of the 45-pound barbell as well as 20%, 40%, and 60% 1RM of the back squat and collected data such as peak power, relative peak power, mean power, relative mean power, peak velocity, and mean velocity. The start position hip and knee joint angles were the same as when the participant performed an MBCP. The two exercises started with the same joint angles to keep as many variables consistent as possible. It is important for the participant to not start too low; otherwise, they will have an increased time to develop force and could skew the data.

Linear Position Transducer

The current study analyzed force-time variables through the use of a linear position transducer. Another study that only used a linear position transducer to collect

data would include a study by Hoffman et al. (2005), which compared loaded and unloaded jump squat training on strength and power performance. The linear position transducer was used to collect data on peak power and relative peak power. Studies that used both a linear transducer as well as a force plate include Comfort, Jones, and Udall (2015), Cormie, Deane, and McBride (2007), and Loturco et al. (2016). Comfort et al. (2015) studied the effect of intensity on kinetic variables of the midthigh pull and measured barbell displacement, barbell velocity, and absolute and relative power. Cormie et al. (2007) observed methodological concerns in determining power output in the jump squat and used the linear position transducer to measure peak force, peak velocity, and peak power. A methodological concern between a linear position transducer and a force plate is the linear position transducer measures the external barbell kinetics and kinematics, while the force plate measures the ground reaction forces of the barbell and participant. Loturco et al. (2016) observed mechanical differences between barbell and body optimum intensities in jump squat exercises and collected data on peak force, peak power, and mean propulsive power. While some research uses force plates to measure and calculate force-time variables (Kawamori et al., 2005; Kawamori et al., 2006; Moir et al., 2012; Suchomel et al., 2014; Suchomel, Comfort, et al., 2015; Suchomel & Sole, 2017; Williams et al., 2018), others choose to use a linear position transducer (De Villiers & Venter, 2015) to gather the same information. A linear position transducer uses the load inputted as well as the body mass of the participant and barbell velocity measured to calculate peak power. A force plate measures forces applied into the force plate to give data related to peak force and peak power. Two very different

tools can be used to receive similar information in regard to peak, mean, and relative power output.

Hansen, Cronin, and Newton (2011) compared the reliability of the force plate and linear position transducer and found the inter-class correlation to fall between .88 and .96. The relationship between the force plate and linear position transducer when measuring peak power of LSJs was very high (r = 0.67 to 0.88), according to Hansen et al. (2011). Garcia-Ramos et al. (2016) also compared the force plate and linear transducer in relation to force-, velocity-, and power-time curves. A strong correlation took place between both tools with values between 0.86 and 0.98 for the inter-class correlation. The relationship between the linear position transducer and the force plate is high (r = 0.83 to 0.99) when collecting data on the variables of peak force, peak velocity, peak power, mean force, mean velocity, and mean power (Garcia-Ramos et al., 2016). A big difference found between the force plate and linear position transducer was the point of the movement when the most data was collected. The linear transducer showed the greatest increase in power-related measurements at the beginning of the movement; whereas, the force plate showed larger values towards the end of the movement (Garcia-Ramos et al., 2016). The linear position transducer was used in the current study because of availability as well as the reliability and high correlation to the force plate.

Midthigh block clean pulls as well as LSJs are used in strength and conditioning programs to increase lower-body power. A linear position transducer is a tool that can be used to monitor the force-time variables (i.e. peak power, relative peak power, mean power, relative mean power, peak velocity, and mean velocity) of an athlete’s training performance. Intensities between 0% and 140% 1RM have previously been studied to

determine which exercise at which intensity will result in the highest peak power, relative peak power, mean power, relative mean power, peak velocity, or mean velocity. The current study uses the 45-pound barbell as well as 20%, 40%, and 60% 1RM of two high-force, low-velocity exercises (back squat and conventional deadlift) to collect force-time variables of two moderate-force, high-velocity movements (LSJ and MBCP).

III. Methods

Participants

Collaborative Institutional Training Initiative (CITI) training was completed by all researchers to protect participants. An application was sent to the Institutional Review Board and was accepted on September 4, 2018 (see Appendix A). Fourteen people were participants in the current study. Participants were all undergraduate students at Arkansas Tech University. Participants' mean (± standard deviation) age, height, weight, and body fat percent were 21.43 ± 2.57 years, 67.02 ± 12.27 inches, 172.67 ± 55.47 pounds, and 19.69 ± 11.21 percent, respectively. All participants had one year of current strength and power training and were absent of any musculoskeletal injuries in the past year or musculoskeletal conditions that limited their range of motion. Although weightlifting experience was preferred, it was not required. Participants were injury free at the time of testing, and participation was voluntary with written consent given.

Instrumentation

A Tanita® Body Composition Analyzer DC-430U (Tanita®, Tanita® Corporation, Tokyo, Japan, 2014) bioelectrical impedance scale was used to collect participants' body fat percent, lean body weight, and body weight. The Tanita Health Ware™ V2.10.908.0 (Tanita®, Tanita® Corporation of America, Arlington Heights, IL, 2017) software was used in conjunction with the bioelectrical impedance scale to gather information. The computer in which the Tanita Heath Ware™ software was installed was a Dell™ OptiPlex™ 9010 Desktop (Dell™, Round Rock, TX, 2013) computer with Windows® 10.

A Prestige Medical® Model 64 twelve-inch protractor goniometer (Prestige Medical®, Northridge, CA) was used to find hip and knee joint angles at the MBCP start position. A Lafayette large bone caliper™ (Lafayette Instrument Co., Lafayette, IN) was also used to measure foot placement in the MBCP start position. A Monark™ Ergomedic 828 E (Vansbro, Sweden, 2010) testing ergometer bike was used for all general warm-ups. A GymAware (GymAware™, Kinetic Performance Technology Pty Ltd., ACT, Australia) linear position transducer was used to collect peak power and peak velocity. According to Cronin, Hing, and McNair (2004) a linear position transducer had high correlation ($r = .861$ to $.995$) to a force plate when measuring mean force, peak force, and time-to-peak force. An iPad (Apple, CA, 2017) was used for the GymAware™ (GymAware Lite, 2.1.2) software.

A Pendlay 33-pound and a 45-pound HD Olympic Weightlifting Barbell were used for all testing. Bumpers were used and ranged from 10 pounds to 55 pounds. Standard five and two and half-pound plates (Power Systems, Knoxville, TN) were also used to get more precise loads.

Procedure

Five different sessions took place to collect data for the current study. Each session lasted between 20 and 60 minutes and took place in the Hull building on the Arkansas Tech University campus in Russellville, Arkansas. When data was being collected, there were at least 48 hours between testing sessions. Participants were instructed lower-body power training 24 hours prior to testing and no pre-workout supplementation was taken before sessions.

Session 1. During the first session (see Appendix B), the primary investigator explained the research protocol to the participant, which included an outline of what was going to take place in each of the five sessions as well as any benefits or risks that would come from participation. The primary investigator also provided the written health history and informed consent forms for the participant to read, review, ask questions, and sign (see Appendices C and D). Following the necessary paperwork, the participant was instructed to remove their shoes to accurately measure their height. The primary researcher recorded the participant's height on the data collection sheet (see Appendix E) and instructed them to remove their socks to prepare for body composition testing using the Tanita® bioelectrical impedance scale. Information such as the participant's name, identification number, birthdate, height, and activity level were inputted into the Tanita Health Ware™ system. When instructed by the primary investigator, the participant stepped onto the scale and stood still until the Tanita® bioelectrical impedance scale printed out a small sheet and a window opened on the Dell™ computer providing additional information concerning the participant's body composition. Body fat percentage, weight, age, and lean body weight of the participant were recorded, and the participant was instructed to put their shoes and socks back on their feet to prepare for further measurements.

The participant was then taken over to the testing area, and they selected the preferred rack height to use for the duration of the study. The participant was then instructed to remove the barbell from the rack and to get into the start position for their MBCP. Hip and knee joint angles were recorded and measured using the goniometer. The primary investigator then instructed the participant to put the barbell on their back in

the position they would begin the LSJs. The primary investigator adjusted the participant's hip and knee angles to achieve the exact same start position for the LSJ as the MBCP start position, and the height of the barbell was measured for during the start position of LSJ testing. Foot position was measured using a long bone caliper, and the measurement was recorded to ensure the foot start position was the same for both movements and consistent for each testing session.

After all measurements were recorded, a familiarization session took place. The participant was instructed to put the barbell on their back and to get into the start position to complete an LSJ. The height of the barbell was measured, and the primary investigator ensured the start position was correct. On the command of "GO!" the participant completed a repetition. The participant completed a total of four repetitions in the same manner before racking the barbell and sitting for a passive rest period. One to three sets were completed based upon proficiency of the movement judged by the primary investigator. Following the LSJs, the primary investigator set up blocks to place the barbell at the midthigh position. Once the height of blocks was set, the participant completed a set of four repetitions of an MBCP. The primary investigator provided coaching cues to increase the efficiency of the movement, especially if the participant did not have weightlifting experience. The participant completed a total of one to three sets based upon proficiency of the movement. The primary investigator concluded the first session by asking the participant if they had any questions about the research study.

Session 2. The second testing session (see Appendix B) consisted of the participant finding their 1RM back squat as well as their 1RM conventional deadlift. The participant performed a general, five-minute warm-up on a cycle ergometer with no

resistance at a cadence of 65 revolutions per minute. While the participant was competing their general warm-up, the primary investigator asked the participant what their estimated 1RM back squat was, so they could calculate percentages for the warm-up. The 1RM back squat as well as spotting was completed following the protocol set by Caulfield and Berninger (2016). The participant finished the general warm-up and then completed the exercise specific warm-up of 10 repetitions with the 45-pound barbell. The participant was instructed to complete a passive rest of two to five minutes in between each set completed. The primary investigator and two other researchers loaded the barbell with the participant's 30% estimated 1RM. Following the passive rest period, the participant completed five repetitions with 30% 1RM. The following sets consisted of one repetition at 50%, 70%, 80%, and 90% 1RM estimated back squat. After 90% 1RM was completed, the intensity was increased by percentages between two and five until the maximum was found with proper technique for safety. Once 1RM of the back squat was found, the timer was set to five minutes for passive rest to occur before the exercise specific warm-up was completed for the conventional deadlift. The same warm-up was completed for the conventional deadlift that was completed for the back squat. The rest periods remained the same through the duration of testing until 1RM was found. Following 1RM testing, another familiarization session took place. The protocol was the same as the first familiarization session.

Session 3. The third testing session (see Appendix B) consisted of a familiarization session, but unlike sessions one and two, utilizing the randomization sheet (see Appendix F), the intensity on the barbell was the same as what it would be for the testing sessions (45-pound barbell, 20%, 40%, and 60% 1RM LSJ or MBCP). Using

testing intensities allowed the participant to get a feel for what testing sessions and intensities would feel like and helped them mentally prepare for when testing occurred. The participant completed this session as if it were a testing session in which data was collected except rest periods were self-selected by the participant for this session.

Sessions 4 and 5 – Experimental testing. In the fourth and fifth testing sessions (see Appendix B), the participant completed the same five-minute general warm-up on the cycle ergometer as completed in session two. Following the five-minute general warm-up, the participant completed five repetitions of an LSJ and MBCP with a 63.5-inch PVC pipe. The participant was instructed to take a 10 minute passive rest period to decrease the chances of a potentiating effect taking place (Robbins, 2005). While the participant was seated and resting, the primary investigator and other researchers utilized the randomization sheet to load the appropriate intensity on the barbell for the correct, randomized exercise. The linear position transducer was then turned on, zeroed out, and strapped to the barbell. The body weight of the participant, load, and exercise were all entered into the software for the first set. Following the 10 minute passive rest period, the participant was instructed to complete the first set of the testing session.

When LSJs were being tested, the participant was instructed to approach the barbell and get into the start position. The primary investigator instructed the participant to move up or down to get in the correct start position. On the command, “GO!” from the primary investigator, the participant completed one repetition. The participant assumed the start position adjusted by the primary investigator, waited for the “GO!” command, and completed another repetition. The participant followed this protocol for the remainder of the four repetitions.

When the MBCP was tested, the same protocol was used, but the start position was not manipulated by the researcher. Four repetitions were completed from the blocks at the midthigh position from a static start. Following the sets, a timer was set for 10 minutes and the participant was instructed to complete passive rest for the duration of the 10 minutes. During the rest period, the researchers recorded peak power, relative peak power, mean power, relative mean power, peak velocity, and relative peak velocity and prepared the barbell for the next set. The same protocol took place for the second, third, and fourth set of the particular exercise, with the intensity being based on the randomization chart. At least 48 hours took place between testing sessions, and participants refrained from lower-body power training during the testing period.

Statistical Analysis and Design

A statistical analysis was performed using IBM® SPSS® Statistics 23 (Chicago, IL, 2015), and an 8 x 1 two-way repeated measures analysis of covariance (ANCOVA) was conducted to determine if there were any statistical differences in peak power (see Appendix G) between intensities (45-pound barbell, 20%, 40%, 60% 1RM) and exercises (LSJs and MBCP). A secondary repeated measures ANCOVA was run to evaluate peak barbell velocity (see Appendix H) of the exercises at different intensities as well as to see if the covariates of familiarity and training type had an effect on the results. A descriptive analysis was used to represent peak power and peak barbell velocity for four repetitions and 14 participants. If the assumption of sphericity was violated, Greenhouse-Geisser adjusted values were reported. The Bonferroni post hoc was chosen to control the Type I error because pairwise comparisons were made. The alpha significance level was set at $p < 0.05$ for all statistical measures. A Pearson's correlation was run to

determine the relationship between exercises and intensities for peak power (see Appendix I) and peak barbell velocity (see Appendix J). A sample size of 14 participants provided a statistical power of 0.85 at an alpha level of 0.05 (2-tailed).

IV. Results

Peak Power

Loaded squat jump. Table 1 displays the means and standard deviations for peak power of the LSJ and MBCP. Figure 3 shows the comparison between exercises at each of the four intensities. The highest peak power of the LSJ took place with the 45-pound barbell (LSJ BB) and did not show a significant ($p > 0.05$) difference between peak power of 20% (LSJ 20%) and 40% 1RM of back squat intensities (LSJ 40%). There was a significant ($p = 0.050$) difference between the LSJ BB and 60% 1RM of back squat (LSJ 60%). The lowest peak power took place at LSJ 60% and was statistically significant ($p = .000$ to $.05$) and different from the three lighter intensities. All three lighter LSJ intensities (BB, 20%, and 40%) were not significantly ($p = .634$ to 1.000) different and strongly correlated ($r = .832$ to $.865$) to each other.

Midthigh block clean pull. Peak power of the MBCP was highest at an intensity of 60% 1RM of conventional deadlift (MBCP 60%). The lowest peak power was observed at the 45-pound barbell load (MBCP BB) and was not statistically significant ($p = 0.631$) or different from 20% 1RM of conventional deadlift (MBCP 20%). Peak power between MBCP 20% and 40% 1RM of conventional deadlift (MBCP 40%) was statistically significant ($p = 0.004$) and different with MBCP 40% having a higher peak power. Peak power between 40% and 60% 1RM of conventional deadlift showed no significant difference ($p = 1.000$). The peak power of the MBCP BB and MBCP 60% were statistically significant ($p = 0.049$) and moderately correlated ($r = .535$), while all other peak power correlations among intensities were statistically significant ($p = 0.000$ to 0.003) and correlated. The MBCP BB peak power was strongly ($r = .889$), moderately

strongly (r = .727), and moderately (r = .535) correlated to the peak power of MBCP 20%, MBCP 40%, and MBCP 60%, respectively. Peak power of the MBCP 20% was strongly (r = .910) and moderately strongly (r = .740) correlated to MBCP 40% and MBCP 60%, respectively. The peak power at MBCP 40% was strongly (r = .890) correlated to MBCP 60%.

Correlation Between Peak Power of the Loaded Squat Jump and Midthigh Block Clean Pull

The value, as seen in Table 1, for peak power of the MBCP is drastically lower (2400 W) than the LSJ with the same intensity of 60% 1RM of high-force, low-velocity movement. All peak power values of the LSJ were statistically significant ($p < .001$) and different from peak power of the MBCP when comparing all intensities. Peak power of the LSJ BB was statistically significant ($p = 0.000$ to 0.003) and correlated to the peak power of MBCP 20%, MBCP 40%, and MBCP 60% 1RM. The LSJ BB peak power was moderately (r = .486), moderately strongly (r = .725), strongly (r = .823), and moderately strongly (r = .734) correlated to peak power of the MBCP BB, MBCP 20%, MBCP 40%, and MBCP 60%, respectively. Peak power of the LSJ 20% was statistically significant (p = 0.001 to 0.009) and correlated to peak power of the MBCP 20%, MBCP 40%, and MBCP 60%. Peak power of the LSJ 20% was moderately (r = .445), moderately strongly (.671 to .758) and strongly (r = .803) correlated to MBCP BB, MBCP 20%, MBCP 60%, and MBCP 40%, respectively. Peak power at LSJ 40% was statistically significant (p = 0.000 to 0.004) and correlated to peak power of the MBCP 20%, MBCP 60%, and MBCP 40%. Peak power of the LSJ 40% was moderately (r = .472), moderately strongly (.716 to .768), and strongly (r = .829) correlated to MBCP BB, MBCP 20%, MBCP 60%, and

MBCP 40%, respectively. Lastly, when the peak power of LSJ 60% was compared to intensities of the MBCP, it was observed that there was a statistically significant ($p < 0.05$ and $p < 0.01$) correlation to MBCP 20%, MBCP 40%, and MBCP 60%, respectively. There was a weak ($r = .346$) and moderately strong ($r = .616$ to $.761$) correlation among LSJ 60% and MBCP BB, MBCP 20%, MBCP 40%, and MBCP 60%. Familiarity and training were reported as not statistically significant ($p > 0.05$), but the effect that familiarity had on results was just 3.3% while training type had a 6.4% effect on the results.

Peak Barbell Velocity

Loaded squat jump. Table 2 displays the means and standard deviations for peak barbell velocity of the LSJ and MBCP at each of the four different intensities. Figure 2 shows visual representation of the comparison between the two exercises. The highest peak barbell velocity of the LSJ was observed with the LSJ BB which was statistically significant ($p < 0.001$) and different than peak barbell velocity of the LSJ 60%. Peak barbell velocity of LSJ BB was statistically significant ($p < 0.05$) and correlated and moderately strongly ($r = .649$ to $.716$) correlated to LSJ 20%, LSJ 40%, and LSJ 60%. Peak barbell velocity LSJ 20% was strongly ($r = .828$) and moderately strongly ($r = .707$) correlated to LSJ 40% and LSJ 60%, respectively. A strong ($r = .920$) correlation took place between peak barbell velocities of LSJ 40% and LSJ 60%.

Midthigh block clean pull. The MBCP showed a peak barbell velocity pattern similar to the LSJ in relation to intensity, but peak barbell velocities occurred at lower values. The highest peak barbell velocity was observed with the MBCP BB, and the lowest peak barbell velocity was observed with MBCP 60%. Peak barbell velocity

between the MBCP BB and MBCP 20% were not statistically different ($p = 1.000$), but the difference in peak barbell velocity between the MBCP BB and MBCP 40% were statistically significant ($p = 0.032$). Furthermore, the difference between MBCP 20% and MBCP 40% peak barbell velocity trended towards significance ($p = .068$) while the peak barbell velocity between MBCP 40% and MBCP 60% significantly different ($p < 0.001$). Peak barbell velocity of the MBCP BB was statistically significant ($p < 0.05$) and correlated and had a strong ($r = .846$), moderately strong ($r = .715$) correlation to MBCP 20% and MBCP 40%. Peak velocity at MBCP 20% was statistically significant ($p < 0.05$) and correlated with a strong ($r = .811$) and moderate ($r = .565$) correlation to MBCP 40% and MBCP 60%, respectively. Peak barbell velocity at MBCP 40% was statistically significant ($p = 0.002$) and correlated moderately ($r = .744$) to peak barbell velocity of the MBCP 60%.

Correlation Between Peak Barbell Velocity of the Loaded Squat Jump and Midthigh Block Clean Pull

The LSJ BB peak velocity was not statistically significant ($p > 0.05$) or different from the MBCP BB and MBCP 20% intensities, but the LSJ BB peak velocity was statistically significant ($p < 0.05$) and different from MBCP 40% and MBCP 60%. Peak barbell velocity of LSJ 20% and LSJ 40% are not statistically different ($p > 0.05$) from the MBCP 45-pound barbell and 20% 1RM of conventional deadlift, but they are statistically significant ($p < 0.05$) and different from 40% and 60% 1RM of conventional deadlift of MBCP. Peak barbell velocity of LSJ 60% is statistically significant ($p = 0.021$) and different from the MBCP 60%. There were no statistically significant ($p >$

0.05) correlations between LSJs and MBCPs, and no correlations (r = .011 to .191) between exercises at all intensities observed.

Familiarity and training type were the covariates in the current study and were thought to potentially have an effect on peak power or peak velocity. Familiarity had a statistically significant ($p < 0.05$) effect on barbell velocity and had a 40.2% effect on the results. In contrast, training type was not statistically significant ($p > 0.05$) and had just an 8.1% effect on peak barbell velocity.

Table 1

Peak Power (mean ± SD) *of LSJ and MBCP at Various Intensities*

Exercise	45-lb Barbell (W)	20% 1RM (W)	40% 1RM (W)	60% 1RM (W)
LSJ	4682.14 ± 1557.94	4253.07 ± 1172.58	4139.64 ± 1141.19	3706.57 ± 1029.14†‡*
MBCP	759.93 ± 354.30*	941.07 ± 519.69*	1288.29 ± 480.07†‡	1361.50 ± 457.71†‡

Note. † = significantly different from 45-lb; ‡ = significantly different from 20% 1RM; * = significantly different from 40% 1RM

Table 2

Peak Barbell Velocity (mean ± SD) *of LSJ and MBCP at Various Intensities*

Exercise	45-lb Barbell (m/s)	20% 1RM (m/s)	40% 1RM (m/s)	60% 1RM (m/s)
LSJ	$2.27 \pm 0.24^{*}$	$2.14 \pm 0.17^{*}$	$1.88 \pm 0.15^{\dagger\ddagger}$	$1.56 \pm 0.16^{\dagger\ddagger*}$
MBCP	$1.91 \pm 0.39^{*}$	$1.80 \pm 0.35^{*}$	$1.56 \pm 0.22^{\dagger}$	$1.23 \pm 0.21^{\dagger\ddagger*}$

Note. † = significantly different from 45-lb; ‡ = significantly different from 20% 1RM; * = significantly different from 40% 1RM

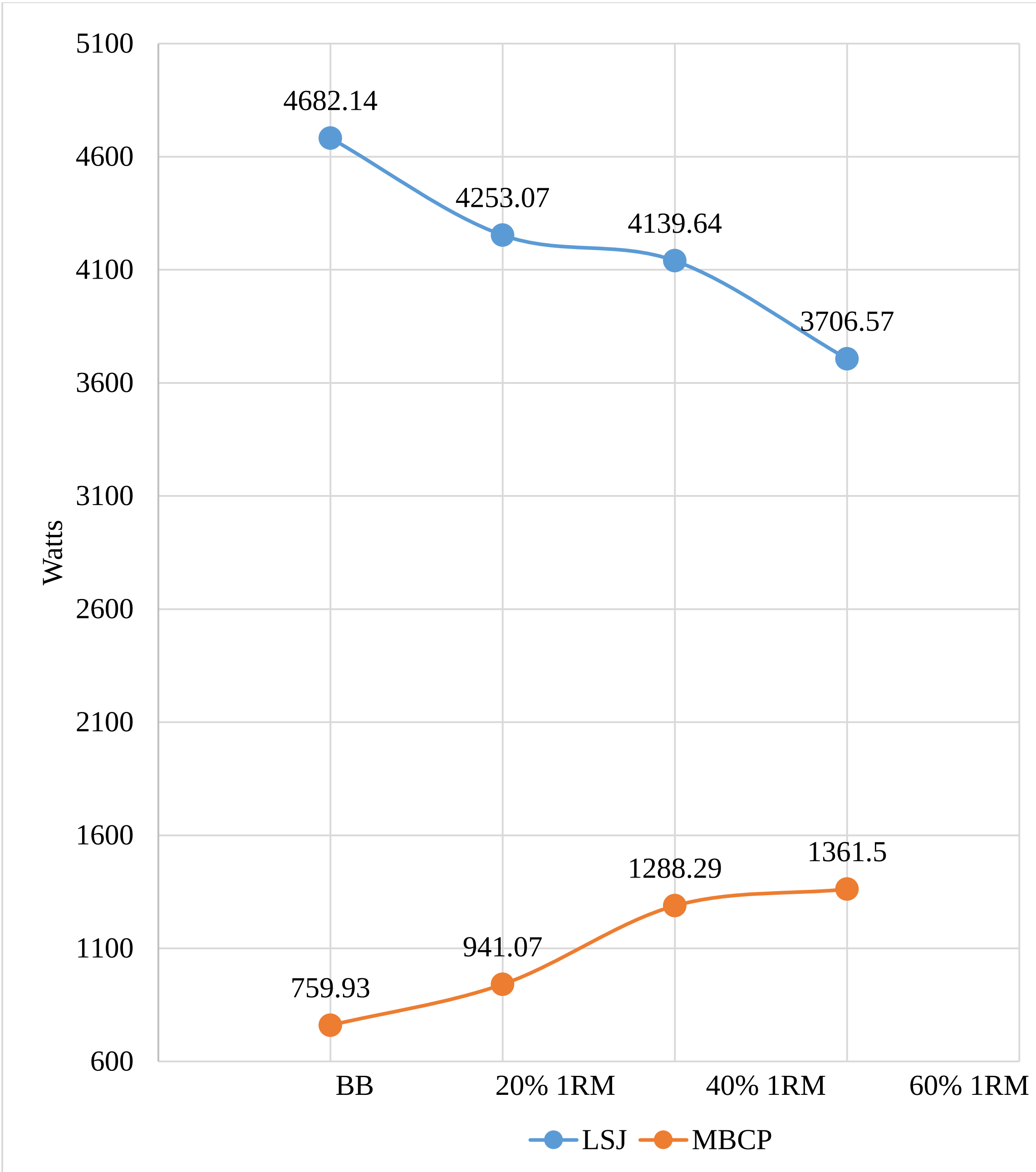

Figure 3. Peak power of the LSJ and MBCP at four intensities.

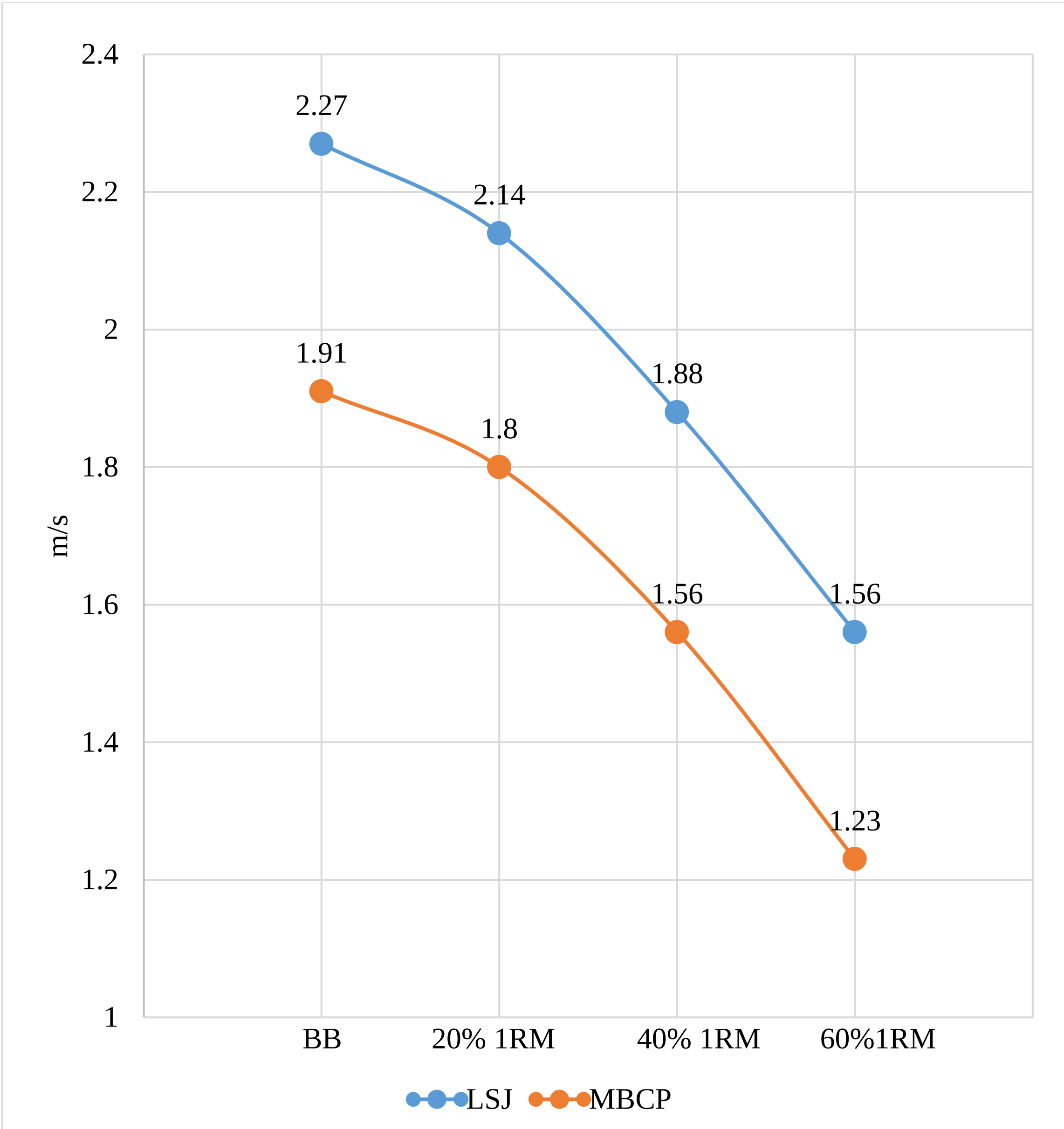

Figure 4. Peak barbell velocity of the LSJ and MBCP at four intensities.

V. Discussion

Loaded squat jumps and MBCPs were completed at different intensities based upon a high-force, low-velocity 1RM to assess the kinetic and kinematic differences between conditions. The null hypothesis was rejected and alternative accepted because there were significant differences in the force-time variables between the LSJ and MBCP conditions. Some exceptions existed such as peak barbell velocity between the LSJ BB and MBCP BB and 20% where no difference was found. Another exception would be that peak barbell velocity was not significantly different among LSJ 20% and LSJ BB and MBCP 20%, LSJ 40% and MBCP BB and MBCP 40%, and finally among LSJ 60% and MBCP BB, MBCP 20%, and MBCP 40%. Suchomel, Comfort, et al. (2015) found similar results as there was no significant difference in peak power between 30% and 45% 1RM when testing hang high pulls. The research hypothesis was rejected as well because the highest peak power did not occur at LSJ 20% or at MBCP 40% as hypothesized.

No statistical difference was observed between the LSJ BB and LSJ 20% mean peak power as the mean peak power for the barbell intensity was large enough to overlap 20% intensity (see Table 1). A possible reason for this overlap would be because a couple of the participants completed their LSJ 20% with a load less than 45 pounds. The 45-pound barbell load was used for every participant, which was typically lighter than the 20% load. The use of a load below the 45-pound barbell for the 20% intensity could have resulted in a higher barbell velocity increasing peak power for the LSJ. Lack of significant difference in peak power between LSJ 20% and 40% intensities suggests a 45-pound barbell may be sufficient to develop lower-body power when using the LSJ in a

strength and conditioning program. The LSJ 60% had the lowest peak power that was significantly different ($p < 0.05$) from the LSJ BB, 20%, and 40% intensities, which supports the inverse relationship between force and velocity.

Peak barbell velocity was highest for LSJ BB and was significantly different ($p < 0.001$) from LSJ 60% as the lower intensity could be moved faster with the same force output of the LSJ 60%. The lack of statistical difference ($p = 0.697$) between peak barbell velocity of the LSJ BB and LSJ 20% could be explained by some of the lower loads at the 20% intensity. Another reason is that the 45-pound barbell was a different percentage of 1RM for each individual person and, thus, might allow for higher barbell velocities or change the participant's effort. The remainder of interactions (LSJ 20%, LSJ 40%, and LSJ 60%) for the LSJ intensities and peak barbell velocity are significantly different ($p < 0.05$) from one another. The significant differences in peak barbell velocity among intensities of the LSJ demonstrates that as force increased, velocity decreased resulting in a decrease in power with increasing intensities.

Table 1 displays the power output of the MBCP different intensities, which demonstrates the MBCP 60% experienced the highest power output. A lack of statistical difference between the MBCP BB and 20% may not have occurred because the intensities were not adequate to create a differentiation in muscle spindle activation and intramuscular coordination (Gabriel, Kamen, & Frost, 2006). However, the values between the MBCP BB and 40% were significantly different ($p = 0.004$), which makes sense because of the inverse force and velocity relationship. There was also a significant difference ($p = .002$) between MBCP 20% and 40%, which suggests the intensity at which MBCPs should be performed should be at least 40% 1RM of a high-force, low-

velocity exercise for greater peak power outputs. Peak power values of the MBCP were much lower than the LSJ suggesting the participants were not experienced with weightlifting movements despite the familiarization sessions and self-reported weight training experiences. The physical increases from extensive weightlifting training (> 1 year) would improve the participant's ability to produce power from a midthigh block start position. If a strength and conditioning coach is programming for athletes who lack weightlifting experience, the application of LSJs would be more beneficial to improve lower-body power adaptation.

Peak barbell velocity showed a similar pattern to the LSJ that can be seen in Figures 1 and 2. The highest peak barbell velocity took place with the 45-pound barbell and continually decreased, which was expected due to the low amounts of force necessary to complete the movement. Lower peak barbell velocities could have also resulted from the lack of weightlifting training of the participants, which suggests their strength training includes mainly high-force, low-velocity movements, as opposed to moderate-force, high-velocity movements such as LSJs and MBCPs. Peak barbell velocity of the MBCP BB was not statistically ($p = 1.000$) significant or different from MBCP 20%. Results demonstrated that if MBCPs were to be used in a strength and conditioning program with athletes without weightlifting experience, the intensity used should be 20% 1RM. Based on the results from the current study, there was no significant difference in peak power among 20% and 40% or 60% 1RM. Athletes who are experienced in weightlifting should train using higher intensities (60 to 80% 1RM) to achieve peak power output (Haff & Nimphius, 2012). Significant differences took place between peak barbell velocity of the MBCP BB and MBCP 40%, which was expected.

The peak barbell velocity was expected to be statistically significant and different between the MBCP BB and 40% because of the increased amount of force the participant must generate to complete the repetitions with an increased load. Peak barbell velocity of the MBCP at 40% and 60% 1RM were statistically significant ($p = 0.000$) and different, which means that peak barbell velocity was much lower with the MBCP 60%. Even though the velocity gradually decreased with increased intensities, the relationship between the velocity and intensity showed highest values at MBCP 60%. The difference in peak velocity values between the LSJ and MBCP demonstrate that the participants of the research study did not have experience with weightlifting movements. The primary investigator expected peak barbell velocities to be similar between the two movements because they were each based upon their own high-force, low-velocity movement.

Weightlifting experience is critical for optimal technique execution of MBCPs that would maximize improvements to the lower-body power adaptations (Gourgoulis et al., 2004). If appropriate MBCP technique is not used, the participant will not be able to achieve optimal peak power due to the poor neuromuscular coordination and muscular morphology (Gabriel et al., 2006). Neuromuscular coordination refers to intramuscular coordination (motor unit rate coding, synchronization and recruitment) as well as intermuscular coordination, which would have enhanced neural contribution in an experienced weightlifter compared to a less-trained person (Gabriel et al., 2006; Folland & Williams, 2007). The low power outputs achieved by participants in the current study indicate a lack of experience with weightlifting, or more specifically, MBCPs.

The MBCP starts in the “power position” and is limited to the second pull phase of a weightlifting movement, minimizing the chance of technique error while allowing

for optimal power production. During the second pull, the participant should keep a vertical barbell path that is as close to the body as possible to decrease the amount of horizontal displacement and reduce anterior torque in the hip joints (DeWeese et al., 2013; Drechsler, 1998; Waller et al., 2009). An athlete who is able to minimize horizontal displacement during the pulling phase can increase vertical barbell velocity and maximal force production (Hoover et al., 2006; Winchester et al., 2005). The proper kinematics of the MBCP are critical to achieve maximal power during the second pull.

The lower-body joint actions of vertical jumps and weightlifting movements are similar (Canavan, Garrett, & Armstrong, 1996), while also having the similarity of being high-velocity, moderate-force exercises. The LSJ and MBCP exercises begin with slight hip and knee flexion; and then when completing the movement, extension of the hips, knees, and ankles takes place to achieve peak power (Mackala, Stodolka, Siemienski, & Coh, 2013; Mackenzie et al., 2014). Figure 3 shows the LSJ peak power approximately 3000 W higher than the MBCP, and peak power of the LSJ decreases with increased intensity, while peak power of the MBCP increased as the intensities increased. The difference in wattage between the two exercises could have been due to experience with or technique of the LSJ and MBCP.

Figure 4 displays the peak barbell velocity of the LSJ and the MBCP at all four intensities where a similarity in the velocity curves between the two exercises exists. The similarity of peak barbell velocity between the two exercises shows that as the intensities increased, barbell velocity decreased, which was expected because the participants must produce more force to complete the movements for the higher intensities. Figure 4 also demonstrates that the peak barbell velocity values are lower for the MBCP than they are

for the LSJ. The primary investigator observed that participants were unable to perform the MBCPs in one fluid motion, along with inconsistent technique among each of repetitions. For example, the participants did not always achieve a triple extension during the MBCP thus hindering vertical barbell displacement and velocity. One year of weightlifting training and competition would not be enough for an athlete to get close to perfecting the snatch and the clean and jerk, but it would have been sufficient for the athlete to have developed the motor pattern and neuromuscular coordination necessary to properly perform a MBCP. Some participants verbalized to the primary investigator that the MBCP felt awkward and that the LSJ was the preferred test in regard to participant comfort level and feeling successful. All of the previous factors mentioned could have had an effect on the results of peak power and peak barbell velocity. If a triple extension was absent during some repetitions, the peak power would not be optimized as the peak power comes from triple extension in the second pull (Garhammer, 1980; Garhammer, 1993; Gourgoulis et al., 2004; Kipp et al., 2012; Waller et al., 2009). Coaching cues were provided by the primary investigator during familiarization sessions to help the participant perform both exercises to the best of their abilities.

Loaded squat jumps and MBCPs are exercises used to develop lower-body power and the results of the current study can be used by strength and conditioning coaches to program the correct exercise and intensity for their athletes. Interestingly, when comparing the LSJ and MBCP results, peak power took place at very different intensities. Peak power of the LSJ was optimized at the 45-pound barbell while peak power of the MBCP was optimized at 60% 1RM. The peak values between LSJ and MBCP are very different from each other (see Table 1). A reason for the peak power being much higher

in the LSJ is that there was a larger displacement in the LSJ than the MBCP. Even though the start positions were the same for both exercises (DeWeese et al., 2013; Mackenzie et al., 2014), the participants left the ground with LSJs but only went up on their toes with the MBCPs. The LSJ had a greater vertical displacement, thus may have produced higher kinetic and kinematic values than the MBCP. Although this is partial reason for LSJ having higher peak power values, it does not account for a difference as large as was observed (see Table 1). All peak power values at all four intensities of LSJ were significantly ($p < 0.05$) different from peak power outputs of MBCP. Loaded squat jumps and MBCPs had very different power outputs, which means that the participants did not have weightlifting experience necessary to maximize peak power. A pilot study was completed with three participants who had experience in weightlifting, and peak power outputs of the MBCP showed similar results to that of the LSJ.

According to Kawamori et al. (2006), peak power of a midthigh clean pull showed values above 2000 W with intensities between 30% and 120% 1RM of power clean. Although these intensities use 1RM power clean as opposed to a conventional deadlift, they are still an accurate representation of how many watts of power should be generated during an MBCP. Mackenzie et al. (2014) compared a countermovement jump, power clean, and a jump squat and found that power output between the power clean and the jump squat were not significantly different ($p > .05$) from one another, which disagrees with the results of the current study. An explanation as to why the results were not significantly different could be that the participants were collegiate volleyball and football players that had at least two years of familiarity and exposure to

the exercises as opposed to the current study where participants did not have weightlifting experience or this same level of exposure to the exercises prior to testing.

The current study demonstrated peak power outputs ranging between 3706 and 4682 W for the LSJ, which is similar to other studies (Jandacka et al., 2014). Jandacka et al. (2014) compared peak power output between loads of 0% to 90% 1RM of squat jump and found peak power ranged between 3100 and 4700 W, which is very similar to the results of the current study. De Villiers and Venter (2015) completed power testing with LSJs and found that peak power took place between 60% and 90% 1RM jump squat, which varies a great deal from the current study where peak power took place with the 45-pound barbell, which was less than 20% 1RM. The difference in intensities could be due to the fact that De Villiers and Venter (2015) used rugby athletes who had experience with the lifts as opposed to the current study that used participants who only reported at least one year of strength training.

Weightlifting experience and training type were recorded for each participant and showed that neither of the two variables statistically affected the results. The LSJ has a preloaded period of time, so participants have time to create tension in order to prepare for the lift as opposed to the MBCP which starts from an unloaded position as the barbell rested on blocks. Participants all knew how to complete the LSJ, but coaching cues were necessary for the MBCP for many participants to complete the exercise with appropriate technique.

Type of training participants used in their programming also affected the results because many reported that they consistently do strength training. Strength training includes high-force, low-velocity movements, which will cause the body to adapt to this

type of training and will perform high-velocity movements with a lower velocity than a person who frequently does sprint and plyometric training (Pareja-Blanco et al., 2017). Peak power for the MBCP took place at 60% 1RM, which was not unexpected because of the participants' high-force, low-velocity strength training experience. The results of the study conclude that peak power took place with the LSJ at 45-pound barbell intensity, and the LSJ and MBCP exercises did not have statistically similar results when analyzing peak power between the two exercises at four different intensities.

VI. Summary, Conclusions, and Recommendations

When comparing these results to other research studies, there was agreement with the results of the LSJ while discrepancies were evident with the MBCP. The peak power measured during the LSJ was comparable to other studies, while other force-time variables were inconclusive due to method variations. The MBCP, interestingly, displayed lower peak power and other force-time variable values than previous studies. The lower performance in the MBCP for the current study may have been attributed to the participants' lack of weightlifting experience. Although the participants were strength trained and had adequate lower-body strength (i.e. back squat 1.5 x bodyweight), this did not translate into proficient execution of a weightlifting movement (e.g. MBCP). The primary investigator hypothesized that the lack of experience in weightlifting technique diminished inter- and intramuscular coordination that hampered the participants' ability to achieve optimal force-time variable output. The results suggest that strength and conditioning coaches can use the LSJ in a program for athletes to improve lower-body power if they have achieved a lower-body strength level by back squatting greater than 1.5 times bodyweight. Furthermore, the results of the current study suggest that the ideal load for the LSJ would be 45-pounds to achieve peak power output. However, if athletes are experienced with weightlifting movements (i.e. consistent training greater than one year), then the MBCP might be a viable option in a strength program. The similarity of the lower-body segmental kinematics between the LSJ and MBCP suggest these exercises would produce similar neuromuscular adaptations when used in a strength program. However, the effectiveness of a strength program that incorporates the LSJ and MBCP is beyond the scope of the current study.

Future Research

Future research should include participants with weightlifting experience to increase the accuracy when comparing the LSJ and MBCP. Although the strength and conditioning coach may not be necessarily working with weightlifters, the use of weightlifting movements in a strength program may lead to the development of optimal technique and desired neuromuscular adaptations. The effectiveness of athletes learning weightlifting movements (e.g. power clean) over the course of training phase would be an area of future study to determine if the force-time variables can be increased in an LSJ and MBCP. Another suggestion for future research would be to have the participants all wear weightlifting shoes to standardize footwear and to decrease the variability in results due to that inter-subject factor. The heel lift of a weightlifting shoe increases ankle mobility and provides a more stable shoe bottom, which could improve participants' 1RM testing or power output during the LSJ and MBCP testing exercises. The differentiation between athletes with weightlifting experience and those without should be considered when comparing a movement such as the MBCP and a comparable power movement like the LSJ. The use of weightlifting shoes by experienced athletes may help minimize variation in the force-time variables, but further examination is warranted.

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Appendix A

Institutional Review Board Approval

From: Sara Bailey
Sent: Tuesday, September 4, 2018 2:10 PM
To: Hannah Macke
Subject: FW: IRB Proposal

Hannah:

Your IRB proposal, Macke_090418, has been approved. Please see the attached for your records.

Thanks!

Sara Bailey, Grant Coordinator
Arkansas Tech University
Office of Sponsored Programs and University Initiatives
1509 N. Boulder Ave.
Administration 207
Russellville, AR 72801
Telephone: (479) 880-4327

Appendix B

Session Protocol

Session 1 – Initial Measurements and Familiarization

Informed Consent

Health History

Height (in)

Body Weight (lbs)

BF %

LBW (lbs)

Goniometer Hip

Goniometer Knee

Barbell height LSJ (in)

Familiarization with barbell – MBCP and LSJ

Session 2 – 1RM and Familiarization

Warm-up – 5-minute cycle ergometer

1RM back squat

*5 minutes rest

1RM conventional deadlift

MBCP and LSJ Familiarization

Session 3 - Familiarization

Familiarization of MBCP and LSJ with testing intensities

Randomized – 45-pound barbell, 20%, 40%, 60%

Session 4 – 1st Testing

MBCP or LSJ based on randomization sheet

Randomized intensities - 45-pound barbell, 20%, 40%, 60%

4 repetitions at each intensity

10 minutes between sets

Linear position transducer used for barbell velocity

Session 5 – 2nd Testing

MBCP or LSJ based on randomization sheet

Randomized intensities - 45-pound barbell, 20%, 40%, 60%

4 repetitions at each intensity

10 minutes between sets

Linear position transducer used for barbell velocity

Conventional Deadlift

1. The conventional deadlift 1RM followed the technique as outlined by Caufield and Berninger (2016)
2. Standard 7 ft Olympic barbell and plates.
3. At least one investigator will be used for safety and assistance with equipment preparation.
4. Hand-grip is placed so the elbows are outside of the knees in the start position
5. Progression for 1RM:
    a. 5 minutes on cycle ergometer (adjust seat height, use same ergometer)
    b. Empty barbell x 10 repetitions
    c. 30% of estimated 1RM x 5 repetitions;
    d. 50% of estimated 1RM x 1 repetition
    e. 70% of estimated 1RM x 1 repetition
    f. 80% of estimated 1RM x 1 repetition
    g. 90% of estimated 1RM x 1 repetition
    h. Maximal Attempt 1 (Repeat until maximum is achieved)

Back Squat

1. The back squat 1RM followed the technique as outlined by Caufield and Berninger (2016)
2. Standard 7 ft Olympic barbell and plates.
3. At least two investigators will be used for safety and assistance with equipment preparation.
4. Hand-grip self-selected by the participant
5. Barbell will rest across upper trapezius and posterior deltoid
6. Progression for 1RM:
    a. 5 minutes on cycle ergometer (adjust seat height, use same ergometer)
    b. Empty barbell x 10 repetitions
    c. 30% of estimated 1RM x 5 repetitions;
    d. 50% of estimated 1RM x 1 repetition

e. 70% of estimated 1RM x 1 repetition
f. 80% of estimated 1RM x 1 repetition
g. 90% of estimated 1RM x 1 repetition
h. Maximal Attempt 1 (Repeat until maximum is achieved)

Loaded Squat Jump (LSJ)

1. The LSJ will follow the technique as outline by Caufield and Berninger (2016)
2. Standard 7 ft Olympic barbell and plates will be used
3. A linear transducer (Gymaware) will be attached to the barbell
4. At least one investigator will be present to ensure safety and correct technique
5. Hand grip will be self-selected by the participant
6. Barbell will rest across the upper trapezius and posterior deltoid
7. Participant will walk underneath barbell in correct position and step out of the rack to prepare for exercise
8. Participant assumes start position (self-selected & measured) and stays for 3 seconds to ensure static start takes place
9. Participant will complete a repetition and replace the barbell on the rack to prepare for the next repetition
10. 4 repetitions will be completed for each of the 4 intensities (Barbell, 20, 40, 60% 1RM back squat)

Midthigh Block Clean Pull (MBCP)

1. The BCP will follow the technique as outline by Caufield and Berninger (2016)
2. Standard 7 ft Olympic barbell and plates will be used
3. A linear transducer (Gymaware) will be attached to the barbell
4. At least one investigator will be present to ensure safety and correct technique
5. Hand grip will be the same as conventional deadlift (elbows outside of knees at start)
6. Barbell begins on blocks so participant does not start holding the load of the barbell
7. Participant assumes start position (same as squat jump-self-selected then measured) and stays for 3 seconds to ensure static start takes place
8. Participant will complete a repetition and replace the barbell on the blocks to prepare for the next repetition
9. 4 repetitions will be completed for each of the 4 intensities (Barbell, 20, 40, 60% 1RM back squat)

Appendix C

Health History Form

1. Do you have at least one year of current strength and power training?
   Yes__________ No__________
2. Are you able to back squat 1.5 times your bodyweight?
   Yes__________ No__________
3. Have you had any musculoskeletal injuries in the past year?
   Yes__________ No__________
4. Have you had any orthopedic injuries or surgeries that limit your range of motion?
   Yes__________ No__________
5. Do you have a cardiovascular disease (High BP, chest pains, stroke, heart murmur)?
   Yes__________ No__________
6. Are you on any medications that would affect your abilities to participate in the study?
   Yes__________ No__________
7. Do you have asthma or other breathing issues?
   Yes__________ No__________
8. Do you have a physician's advice not to participate in certain activities or exercises?
   Yes__________ No__________
9. Do you have any other health problems that would affect your training or that I need to be aware of?
   Yes__________ No__________

Participant Printed Name:____

Participant Signature:____

Date:______________

Signature of Witness:____

Date:______________

Appendix D

Informed Consent Form

Arkansas Tech University

Title of Project: The Relationship of Force-time Variables Between the Loaded Squat Jump and the Block Clean Pull.

Principal Investigator: Hannah Macke, Arkansas Tech University

Other Investigators: Mike Waller (ATU), Gina Kraft (ATU), Shelia Jackson (ATU)

Participant's Printed Name:

____

We invite you to take part in a research study (The relationship of force-time variables between the loaded squat jump and the block clean pull) at Arkansas Tech University, which seeks to examine the relationship between two lower-body power movements. Taking part in this study is entirely voluntary. We urge you discuss any questions about this study with our staff members. Talk to your family and friends about it and take your time to make your decision. If you decide to participate you must sign this form to show that you want to take part.

Section 1. Purpose of the Research

You have been selected to participate in the current study because you have at least one year of current strength and power resistance training experience. The purpose of this study is to examine the relationship of force-time variables between the loaded squat jump and the block clean pull. Additional information from the study will assist strength and conditioning coaches determine which lower-body power exercise and load intensity would be most applicable for to use with their athletes to develop lower-body power.

Section 2. Procedures

The data will be collected during the 2018-2019 academic year. Once you commit to volunteering for the study, you should complete the study within 3 weeks depending on scheduling of initial meeting, familiarization and testing sessions. Each test session should be completed in 60 minutes. You will have your hip and knee range of motion tested using a goniometer and will have your height and body mass obtained prior to the start of the study. Height, body mass and body composition will be measured using a weight scale and a bioelectrical impedance scale respectively.

The back squat and conventional deadlift with a barbell will be used to test your single repetition maximums (1RM). The 1RM back squat and conventional deadlift will follow the protocol as outlined by McGuigan (2016) and will be performed using squat stands and a standard 7 ft "Olympic" bar and plates. At least 2 spotters will be used for safety, spotting and assistance with equipment preparation.

The block clean pull will be measured by a linear transducer (Gymaware™, Kinetic Performance Technology Pty Ltd. 8/26 Winchcombe court, Mitchell 2911, ACT, Australia) and will follow company guidelines for measurement. The start position for the block clean pull will have the barbell just above the knees. The hips and knees will be slightly flexed with the shoulders over the bar. Technique of the clean pull is based on the authors Caulfield & Berninger (2016), and the feet will be hip width apart and the weight will be in the middle of the foot. The elbows will be completely extended as they are not used in this movement. Hand placement is so the arms are on the outside of the knees. A hook grip or overhand grip may be used with testing depending on your comfort. The block clean pull will be completed by moving the barbell from the blocks and performing a rapid extension of the hip, knee, and ankle joints as well as elevation of the scapulae. Following the pull, you will then decelerate the barbell and guide it back to the blocks to prepare for the next repetition. Three sets and four repetitions will be completed for this exercise.

The loaded squat jump and block clean pull will be measured by a linear transducer (Gymaware™, Kinetic Performance Technology Pty Ltd. 8/26 Winchcombe court, Mitchell 2911, ACT, Australia) and will follow company guidelines for measurement. The loaded squat jump is completed in a rack so prior to the movement, the participant is unloaded. The start position for the loaded squat jump will consist of the same hip and knee flexion that takes place in the block clean pull. The barbell is placed on your back and the grip width is what is comfortable for you. The loaded squat jump is completed by you lowering yourself to the start position underneath the barbell on racks. You will then, with proper technique, quickly perform a rapid extension of the hip, knee, and ankle joints and jump into the air as quickly as possible. You will then land on the ground absorbing the forces to decelerate your body as well as the external load. Three sets and four repetitions will be completed for this exercise.

The testing timeline should be completed within two to three weeks from the time you attend the initial baseline testing session until your last experimental testing day. The first week will consist of your screening session where consent forms, health history questionnaire, inclusion of the participant determination, and your demographics will be obtained. Following the paperwork, you will perform a maximum back squat and conventional deadlift to calculate intensities necessary for testing. The intensities for the loaded squat jump will be based on your back squat 1RM while the intensities for the block clean pull will be based on your conventional deadlift 1RM. Two familiarization sessions will follow the baseline testing in which you will learn the movements and complete them at each of the testing intensities to become familiar with the loads. During the experimental testing sessions, you will perform 4 repetitions of the loaded squat jump or block clean pull at 45lb barbell, 20, 40, and 60% 1RM in a randomized order with 10 minutes between each test. The 10 minutes will be enough time to minimize a post-activation potentiation and fatiguing effects on the following tests. Testing of the loaded squat jump at four different intensities will be completed in one session while the four intensities of the block clean pull will be tested in another session. The sessions will be 48 to 72 hours apart.

Section 3. Time Duration of the Procedures and Study
If you agree to take part in this study, your involvement will last approximately 2 to 3 weeks total with only 5 total testing sessions in that time which should only last 45 to 60 minutes. Testing sessions will be separated by 48 – 72 hours. You need to refrain from lower-body training sessions for the duration of the testing.

Section 4. Discomforts and Risks
The risks associated with this study are the same if they are participating in a resistance training (e.g. free weight training), strength & conditioning program, or fitness testing. Testing sessions will be supervised by the primary investigator to ensure correct technique is used with all lifts. On days in which you are finding one repetition maximum on the back squat, at least 2 spotters will be used to ensure safety.

Section 5. Potential Benefits
You will gain knowledge on your lower-body muscular power performance. You will also experience different lower-body power testing intensities and aid in your own strength and conditioning program development. The completion of this study will provide information to strength and conditioning coaches in regard to lower-body power training and the efficiency of exercises and intensities.

Section 6. Statement of Confidentiality
Confidentiality will be maintained at all times by using a numbering system to recognize the participants during the study. The data will be stored in an external hard drive and stored in a locked cabinet for compliance purposes.

6a. Privacy and confidentiality measures
All of your data collected will be stored in a locked office only accessible by the investigators. Any of the data collected and used in a published research study will never include your name or any personal identification. Additionally, the data collected will be coded in order to remove your name and any other identifying information. Only the paper version of the test results will link you to your results and as previously mentioned those results will be in a secure location. Raw data will be maintained for 5 years in a locked office and will be shredded within five years after publication. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

Section 7. Costs for
Participation a. Costs:
The total time commitment for participation in the study should be no more than 12 hours over the three weeks dependent on the need to travel to the test site.

b. Treatment and compensation for injury:
Every effort to prevent injury as a result of your participation will be taken. It is possible, however, that you could develop complications or injuries as a result of participating in this research study. In the event of injury resulting from this research, medical treatment is available but will be provided at the usual charge. It is the policy of this institution to provide

neither financial compensation nor free medical treatment for research-related injury. Costs for the treatment of research-related injuries will be charged to your insurance carrier or to you. Some insurance companies may not cover costs associated with research studies. If for any reason these costs are not covered by your insurance, they will be your responsibility. You will also be responsible for any deductible, co-insurance and/or co-pay.

You will not lose any legal rights by signing this form.

Section 8. Compensation for Participation
You will not be compensated for providing your information for the relationship of force-time variables between the loaded squat jump and the block clean pull study.

Section 9. Research Funding
There is no external funding for this study.

Section 10. Voluntary Participation
Taking part in this research study is voluntary. If you choose to take part in this research, your major responsibilities will include reporting any conflicts with testing sessions or the occurrence of injury. You do not have to participate in this research. If you choose to take part, you have the right to stop at any time. If you decide not to participate or if you decide to stop taking part in the research at a later date, there will be no penalty or loss of benefits to which you are otherwise entitled. Your investigator may take you out of the research study without your permission. Some possible reasons for this are: safety, non-compliance or lack of physical effort. If your participation in the research ends early, you may be asked to visit the investigator for a final visit.

Section 11. Contact Information for Questions or Concerns
The primary investigator conducting this study is Hannah Macke. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Hannah Macke at hmacke@atu.edu. If you have questions regarding your rights as a research subject, you may contact Arkansas Tech University Office of Sponsored Programs and University Initiatives (OSPUI), 1509 N Boulder Ave. Administration 207, Russellville, AR 72801 (https://www.atu.edu/ospui/index.php). You may contact this office with problems, complaints, or concerns about the research. Please contact this office if you cannot reach research staff, or you wish to talk with someone who is an informed individual who is independent of the research
team. For more information about participation in a researchstudy and about the Institutio nal Review
Board (IRB), a group of people who review theresearch to protect your rights, please visit Arkansas Tech University's *IRB* web site at https://www.atu.edu/ospui/human_subjects.p hp. Included on this web site, under the
heading Subject Info", you can access federal regulations and information about the protection of human research subjects. If you do not have access to the internet, copies of these federal regulations are available by calling the Arkansas Tech University's at (844) 804-2628.

Before making the decision regarding enrollment in this research you should have:

- Discussed this study with an investigator,
- Reviewed the information in this form, and
- Had the opportunity to ask any questions you may have.

Your signature below means that you have received this information, have asked the questions you currently have about the research and those questions have been answered. You will receive a copy of the signed and dated form to keep for future reference.

Participant: By signing this consent form, you indicate that you are voluntarily choosing to take part in this research.

____________________________ __________ ______ ________________
Signature of Participant Date Time Printed Name

Person Explaining the Research: Your signature below means that you have explained the research to the participant/participant representative and have answered any questions he/she has about the research.

______________________________ _________ ______ __________
Signature of person who explained this research Date Time Printed Name

Only approved investigators for this research may explain the research and obtain informed consent.

A witness or witness/translator is required when the participant cannot read the consent document, and it was read or translated.

Appendix E

Data Collection Sheets

Participant Number ________

Height (in)________ Body weight (lbs)________

% Body Fat______ LBW (lbs) _________

Hip start angle_______ Knee start angle__________

Age_________LSJ BB Height___________

Foot placement (cm)_______ Rack #______

1RM Back Squat ________________

20%________ 40%________ 60%________

1RM Conventional Deadlift_____________

20%________ 40%________ 60%________

LOADED SQUAT JUMP

	Rep 1						Rep 2						Rep 3						Rep 4					
Load	PP	RPP	MP	RMP	PV	MV	PP	RPP	MP	RMP	PV	MV	PP	RPP	MP	RMP	PV	MV	PP	RPP	MP	RMP	PV	MV
45 lb bar																								
20% 1RM																								
40% 1RM																								
60% 1RM																								

BLOCK CLEAN PULL

	Rep 1						Rep 2						Rep 3						Rep 4					
Load	PP	RPP	MP	RMP	PV	MV	PP	RPP	MP	RMP	PV	MV	PP	RPP	MP	RMP	PV	MV	PP	RPP	MP	RMP	PV	MV
45 lb bar																								
20% 1RM																								
40% 1RM																								
60% 1RM																								

Appendix F

Randomization Sheet for Exercise and Intensity

Participant #	LSJ/MBCP	Intensity
1	1	2
2	1	1
3	1	2
4	1	1
5	1	1
6	1	0
7	0	1
8	0	2
9	0	1
10	0	1
11	0	2
12	1	3
13	0	1
14	1	2
15	1	3
16	0	3
17	1	2
18	0	1
19	0	3
20	1	1
21	0	1
22	0	1
23	1	1
24	0	1
25	1	2
26	0	2
27	1	1
28	0	2
29	0	0
30	0	2
31	1	2
32	0	1
33	1	2
34	0	3
35	1	1

Appendix G

Peak Power Repeated Measures ANCOVA SPSS Output File

Table G1

Peak Power ANCOVA Within-Subjects Factors

Intensity	Dependent Variable
1	PPbbLSQpk
2	PP20LSQpk
3	PP40LSQpk
4	PP60LSQpk
5	PPbbBCPpk
6	PP20BCPpk
7	PP40BCPpk
8	PP60BCPpk

Table G2

Peak Power ANCOVA Descriptives Statistics

	Mean	Std. Deviation	N
PPbbLSQpk	4682.1429	1557.94074	14
PP20LSQpk	4253.0714	1172.58094	14
PP40LSQpk	4139.6429	1141.18964	14
PP60LSQpk	3706.5714	1029.13516	14
PPbbBCPpk	759.9286	354.29963	14
PP20BCPpk	941.0714	519.69495	14
PP40BCPpk	1288.2857	480.06929	14
PP60BCPpk	1361.5000	457.71149	14

Table G3

Peak Power ANCOVA Mauchly's Test of Sphericity[a]

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Intensity	.000	111.559	27	.000	.252	.352	.143

Note. Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
[a]Design: Intercept + Familiarity + Training; Within Subjects Design: Intensity. [b]May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in Table G4.

Table G4

Peak Power ANCOVA Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intensity	Sphericity Assumed	192109730.059	7	27444247.151	78.421	.000	.877	548.944	1.000
	Greenhouse-Geisser	192109730.059	1.766	108776065.206	78.421	.000	.877	138.499	1.000
	Huynh-Feldt	192109730.059	2.461	78058834.652	78.421	.000	.877	193.000	1.000
	Lower-bound	192109730.059	1.000	192109730.059	78.421	.000	.877	78.421	1.000
Intensity * Familiarity	Sphericity Assumed	354968.538	7	50709.791	.145	.994	.013	1.014	.087
	Greenhouse-Geisser	354968.538	1.766	200989.720	.145	.841	.013	.256	.068
	Huynh-Feldt	354968.538	2.461	144232.311	.145	.903	.013	.357	.072
	Lower-bound	354968.538	1.000	354968.538	.145	.711	.013	.145	.064
Intensity * Training	Sphericity Assumed	2604432.933	7	372061.848	1.063	.395	.088	7.442	.429
	Greenhouse-Geisser	2604432.933	1.766	1474677.865	1.063	.357	.088	1.878	.200
	Huynh-Feldt	2604432.933	2.461	1058244.159	1.063	.371	.088	2.617	.235
	Lower-bound	2604432.933	1.000	2604432.933	1.063	.325	.088	1.063	.156
Error (Intensity)	Sphericity Assumed	26947115.289	77	349962.536					
	Greenhouse-Geisser	26947115.289	19.427	1387086.607					
	Huynh-Feldt	26947115.289	27.072	995387.762					
	Lower-bound	26947115.289	11.000	2449737.754					

[a]Computed using alpha = .05.

Table G5

Peak Power ANCOVA Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	549114970.789	1	549114970.789	116.061	.000	.913	116.061	1.000
Familiarity	1755337.590	1	1755337.590	.371	.555	.033	.371	.086
Training	3545300.739	1	3545300.739	.749	.405	.064	.749	.124
Error	52043925.306	11	4731265.937					

[a]Computed using alpha = .05.

Table G6

Peak Power ANCOVA Intensity Estimates

Intensity	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4682.143[a]	419.352	3759.155	5605.131
2	4253.071[a]	326.816	3533.754	4972.389
3	4139.643[a]	311.594	3453.829	4825.457
4	3706.571[a]	267.196	3118.478	4294.665
5	759.929[a]	99.235	541.513	978.344
6	941.071[a]	145.385	621.081	1261.062
7	1288.286[a]	127.794	1007.013	1569.559
8	1361.500[a]	120.265	1096.798	1626.202

[a]Covariates appearing in the model are evaluated at the following values: Familiarity = .3571, Training = .6429.

Table G7

Peak Power ANCOVA Pairwise Comparisons

(I) Intensity	(J) Intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	429.071	238.123	1.000	-545.151	1403.294
	3	542.500	247.111	1.000	-468.494	1553.494
	4	975.571	238.541	.050	-.359	1951.502
	5	3922.214*	380.232	.000	2366.587	5477.842
	6	3741.071*	334.020	.000	2374.510	5107.633
	7	3393.857*	326.725	.000	2057.140	4730.574
	8	3320.643*	343.209	.000	1916.487	4724.798
2	1	-429.071	238.123	1.000	-1403.294	545.151
	3	113.429	42.826	.634	-61.784	288.641
	4	546.500*	85.883	.001	195.130	897.870
	5	3493.143*	295.277	.000	2285.089	4701.197
	6	3312.000*	257.765	.000	2257.416	4366.584
	7	2964.786*	238.368	.000	1989.563	3940.008
	8	2891.571*	246.187	.000	1884.359	3898.784
3	1	-542.500	247.111	1.000	-1553.494	468.494
	2	-113.429	42.826	.634	-288.641	61.784
	4	433.071*	83.714	.009	90.575	775.568
	5	3379.714*	276.121	.000	2250.032	4509.397
	6	3198.571*	234.675	.000	2238.455	4158.688
	7	2851.357*	219.367	.000	1953.871	3748.843
	8	2778.143*	229.144	.000	1840.656	3715.630
4	1	-975.571	238.541	.050	-1951.502	.359
	2	-546.500*	85.883	.001	-897.870	-195.130
	3	-433.071*	83.714	.009	-775.568	-90.575
	5	2946.643*	247.361	.000	1934.626	3958.660
	6	2765.500*	216.009	.000	1881.751	3649.249
	7	2418.286*	192.795	.000	1629.512	3207.059
	8	2345.071*	196.236	.000	1542.220	3147.923

5	1	-3922.214*	380.232	.000	-5477.842	-2366.587
	2	-3493.143*	295.277	.000	-4701.197	-2285.089
	3	-3379.714*	276.121	.000	-4509.397	-2250.032
	4	-2946.643*	247.361	.000	-3958.660	-1934.626
	6	-181.143	68.318	.631	-460.649	98.363
	7	-528.357*	85.224	.002	-877.032	-179.683
	8	-601.571*	111.331	.006	-1057.057	-146.086
6	1	-3741.071*	334.020	.000	-5107.633	-2374.510
	2	-3312.000*	257.765	.000	-4366.584	-2257.416
	3	-3198.571*	234.675	.000	-4158.688	-2238.455
	4	-2765.500*	216.009	.000	-3649.249	-1881.751
	5	181.143	68.318	.631	-98.363	460.649
	7	-347.214*	60.673	.004	-595.443	-98.985
	8	-420.429*	100.298	.042	-830.773	-10.084
7	1	-3393.857*	326.725	.000	-4730.574	-2057.140
	2	-2964.786*	238.368	.000	-3940.008	-1989.563
	3	-2851.357*	219.367	.000	-3748.843	-1953.871
	4	-2418.286*	192.795	.000	-3207.059	-1629.512
	5	528.357*	85.224	.002	179.683	877.032
	6	347.214*	60.673	.004	98.985	595.443
	8	-73.214	60.677	1.000	-321.460	175.031
8	1	-3320.643*	343.209	.000	-4724.798	-1916.487
	2	-2891.571*	246.187	.000	-3898.784	-1884.359
	3	-2778.143*	229.144	.000	-3715.630	-1840.656
	4	-2345.071*	196.236	.000	-3147.923	-1542.220
	5	601.571*	111.331	.006	146.086	1057.057
	6	420.429*	100.298	.042	10.084	830.773
	7	73.214	60.677	1.000	-175.031	321.460

Note. Based on estimated marginal means.

*The mean difference is significant at the .05 level.

[b]Adjustment for multiple comparisons: Bonferroni.

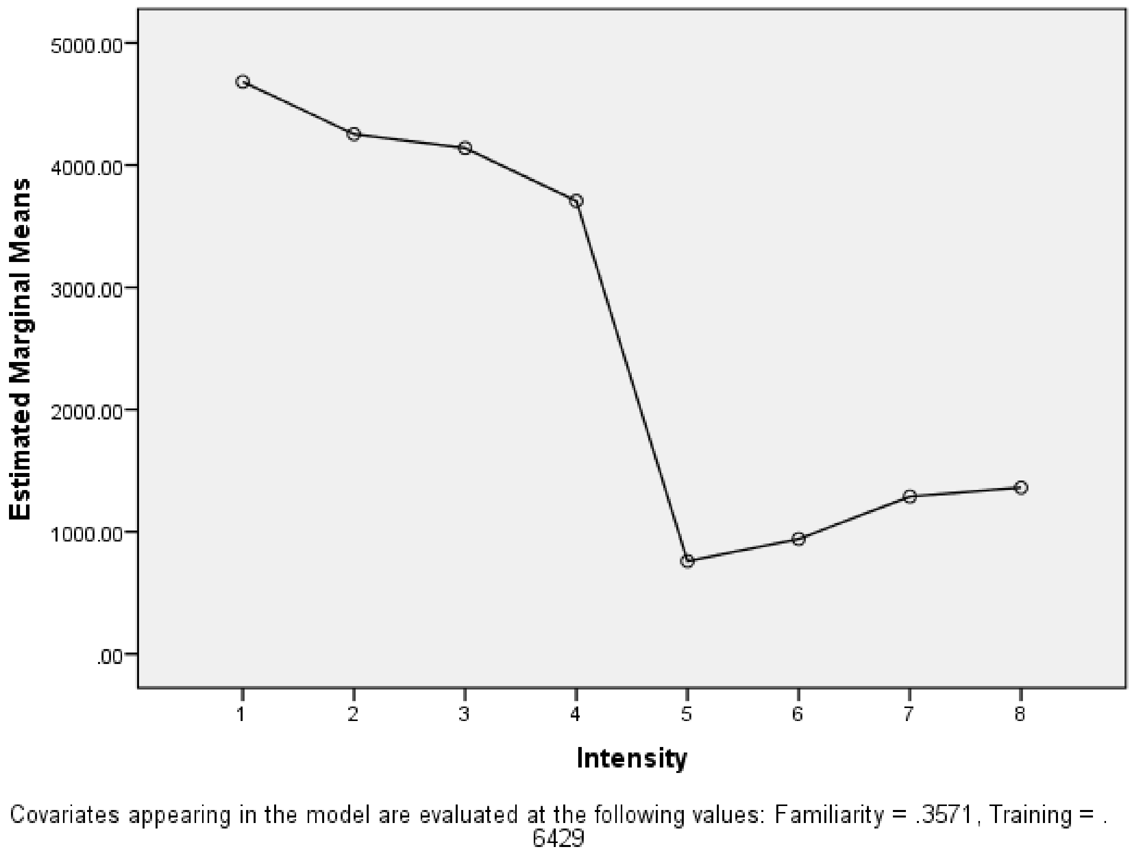

Figure G1. Peak power ANCOVA estimated marginal means.

Appendix H

Peak Barbell Velocity Repeated Measures ANCOVA SPSS Output File

Table H1

Peak Barbell Velocity ANCOVA Within-Subjects Factors

Intensity	Dependent Variable
1	PVbbLSQpk
2	PV20LSQpk
3	PV40LSQpk
4	PV60LSQpk
5	PVbbBCPpk
6	PV20BCPpk
7	PV40BCPpk
8	PV60LBCPpk

Table H2

Peak Barbell Velocity ANCOVA Descriptives Statistics

	Mean	Std. Deviation	N
PVbbLSQpk	2.2671	.24424	14
PV20LSQpk	2.1443	.16842	14
PV40LSQpk	1.8757	.14857	14
PV60LSQpk	1.5586	.16019	14
PVbbBCPpk	1.9143	.39469	14
PV20BCPpk	1.8021	.34980	14
PV40BCPpk	1.5607	.21741	14
PV60LBCPpk	1.2321	.20648	14

Table H3

Peak Barbell Velocity ANCOVA Mauchly's Test of Sphericity[a]

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Intensity	.000	74.321	27	.000	.279	.400	.143

Note. Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

[a]Design: Intercept + Familiarity + Training; Within Subjects Design: Intensity. [b]May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in Table H4.

Table H4

Peak Barbell Velocity ANCOVA Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intensity	Sphericity Assumed	6.705	7	.958	18.688	.000	.629	130.819	1.000
	Greenhouse-Geisser	6.705	1.954	3.431	18.688	.000	.629	36.521	1.000
	Huynh-Feldt	6.705	2.803	2.392	18.688	.000	.629	52.391	1.000
	Lower-bound	6.705	1.000	6.705	18.688	.001	.629	18.688	.975
Intensity * Familiarity	Sphericity Assumed	.158	7	.023	.440	.874	.038	3.083	.182
	Greenhouse-Geisser	.158	1.954	.081	.440	.645	.038	.861	.112
	Huynh-Feldt	.158	2.803	.056	.440	.713	.038	1.235	.126
	Lower-bound	.158	1.000	.158	.440	.521	.038	.440	.093
Intensity * Training	Sphericity Assumed	.233	7	.033	.649	.714	.056	4.545	.262
	Greenhouse-Geisser	.233	1.954	.119	.649	.529	.056	1.269	.144
	Huynh-Feldt	.233	2.803	.083	.649	.579	.056	1.820	.166
	Lower-bound	.233	1.000	.233	.649	.437	.056	.649	.114
Error (Intensity)	Sphericity Assumed	3.946	77	.051					
	Greenhouse-Geisser	3.946	21.496	.184					
	Huynh-Feldt	3.946	30.838	.128					
	Lower-bound	3.946	11.000	.359					

[a]Computed using alpha = .05.

Table H5

Peak Barbell Velocity ANCOVA Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	229.952	1	229.952	1861.746	.000	.994	1861.746	1.000
Familiarity	.912	1	.912	7.383	.020	.402	7.383	.697
Training	.119	1	.119	.966	.347	.081	.966	.146
Error	1.359	11	.124					

[a]Computed using alpha = .05

Table H6

Peak Barbell Velocity ANCOVA Intensity Estimates

Intensity	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	2.267[a]	.069	2.116	2.418
2	2.144[a]	.046	2.043	2.245
3	1.876[a]	.038	1.793	1.958
4	1.559[a]	.039	1.473	1.644
5	1.914[a]	.104	1.685	2.144
6	1.802[a]	.096	1.591	2.013
7	1.561[a]	.052	1.447	1.674
8	1.232[a]	.044	1.135	1.329

[a]Covariates appearing in the model are evaluated at the following values: Familiarity = .3571, Training = .6429.

Table H7

Peak Barbell Velocity ANCOVA Pairwise Comparisons

(I) Intensity	(J) Intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	.123	.047	.697	-.071	.317
	3	.391*	.054	.000	.171	.612
	4	.709*	.053	.000	.491	.926
	5	.353	.124	.446	-.154	.860
	6	.465	.121	.077	-.030	.960
	7	.706*	.093	.000	.328	1.085
	8	1.035*	.091	.000	.661	1.409
2	1	-.123	.047	.697	-.317	.071
	3	.269*	.024	.000	.171	.366
	4	.586*	.029	.000	.466	.705
	5	.230	.129	1.000	-.299	.759
	6	.342	.118	.409	-.142	.826
	7	.584*	.081	.000	.253	.914
	8	.912*	.078	.000	.592	1.233
3	1	-.391*	.054	.000	-.612	-.171
	2	-.269*	.024	.000	-.366	-.171
	4	.317*	.016	.000	.251	.383
	5	-.039	.119	1.000	-.527	.450
	6	.074	.105	1.000	-.356	.503
	7	.315*	.070	.024	.030	.600
	8	.644*	.071	.000	.352	.936
4	1	-.709*	.053	.000	-.926	-.491
	2	-.586*	.029	.000	-.705	-.466
	3	-.317*	.016	.000	-.383	-.251
	5	-.356	.123	.413	-.860	.148
	6	-.244	.109	1.000	-.689	.202
	7	-.002	.072	1.000	-.296	.292
	8	.326*	.071	.021	.036	.616

5	1	-.353	.124	.446	-.860	.154
	2	-.230	.129	1.000	-.759	.299
	3	.039	.119	1.000	-.450	.527
	4	.356	.123	.413	-.148	.860
	6	.112	.057	1.000	-.120	.345
	7	.354*	.081	.032	.021	.686
	8	.682*	.101	.001	.268	1.097
6	1	-.465	.121	.077	-.960	.030
	2	-.342	.118	.409	-.826	.142
	3	-.074	.105	1.000	-.503	.356
	4	.244	.109	1.000	-.202	.689
	5	-.112	.057	1.000	-.345	.120
	7	.241	.062	.068	-.011	.494
	8	.570*	.084	.001	.228	.912
7	1	-.706*	.093	.000	-1.085	-.328
	2	-.584*	.081	.000	-.914	-.253
	3	-.315*	.070	.024	-.600	-.030
	4	.002	.072	1.000	-.292	.296
	5	-.354*	.081	.032	-.686	-.021
	6	-.241	.062	.068	-.494	.011
	8	.329*	.042	.000	.157	.500
8	1	-1.035*	.091	.000	-1.409	-.661
	2	-.912*	.078	.000	-1.233	-.592
	3	-.644*	.071	.000	-.936	-.352
	4	-.326*	.071	.021	-.616	-.036
	5	-.682*	.101	.001	-1.097	-.268
	6	-.570*	.084	.001	-.912	-.228
	7	-.329*	.042	.000	-.500	-.157

Note. Based on estimated marginal means

*The mean difference is significant at the .05 level.

[b]Adjustment for multiple comparisons: Bonferroni.

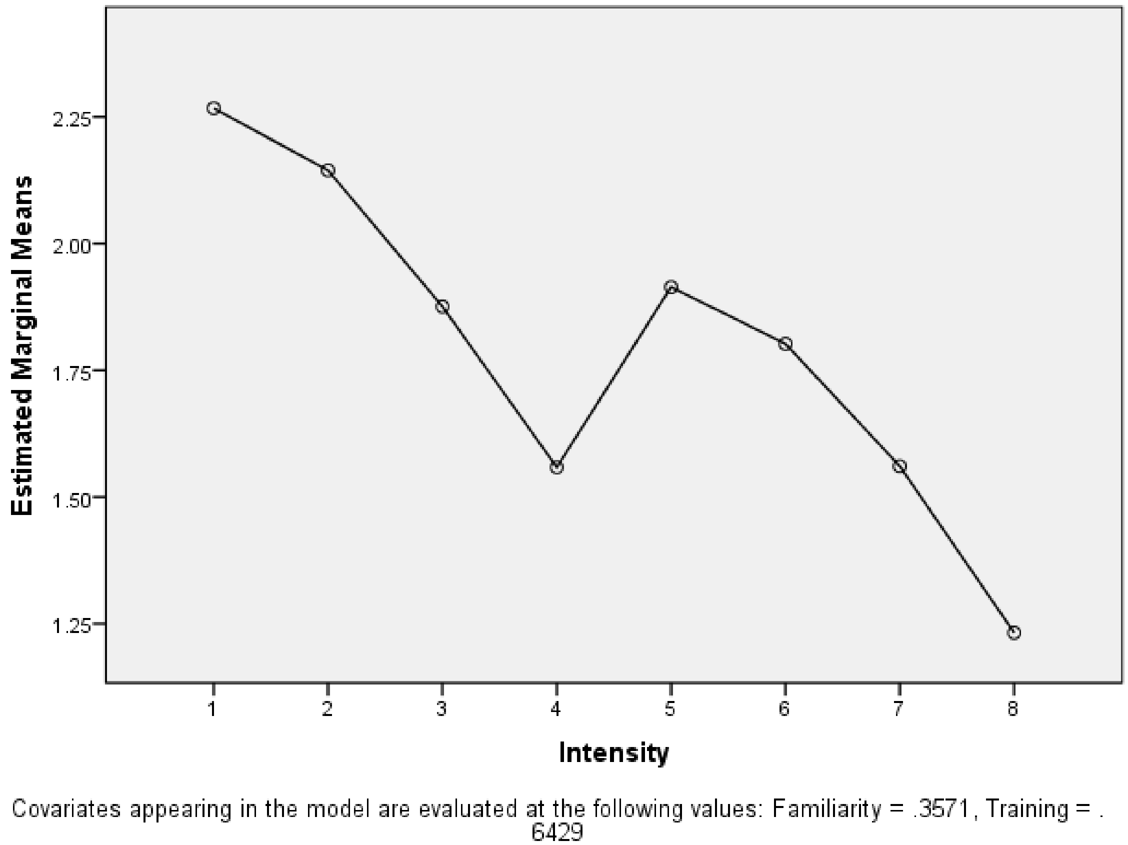

Figure H1. Peak barbell velocity ANCOVA estimated marginal means.

Appendix I

Peak Power Correlation SPSS Output File

Table I1

Peak Power Correlational Descriptives Statistics

	Mean	Std. Deviation	N
PPbbLSQpk	4682.1429	1557.9474	14
PP20LSQpk	4253.0714	1172.58094	14
PP40LSQpk	4139.6429	1141.18964	14
PP60LSQpk	3706.5714	1029.13516	14
PPbbBCPpk	759.9286	354.29963	14
PP20BCPpk	941.0714	519.69495	14
PP40BCPpk	1288.2857	480.06929	14
PP60BCPpk	1361.5000	457.71149	14

Table I2

Peak Power Correlational Matrix

		PPbbLSQpk	PP20LSQpk	PP40LSQpk	PP60LSQpk	PPbbBCPpk	PP20BCPpk	PP40BCPpk	PP60BCPpk
PPbbLSQpk	Pearson Correlation	1	.838**	.832**	.865**	.486	.725**	.823**	.734**
	Sig. (2-tailed)		.000	.000	.000	.078	.003	.000	.003
	N	14	14	14	14	14	14	14	14
PP20LSQpk	Pearson Correlation	.838**	1	.991**	.964**	.445	.671**	.803**	.758**
	Sig. (2-tailed)	.000		.000	.000	.111	.009	.001	.002
	N	14	14	14	14	14	14	14	14
PP40LSQpk	Pearson Correlation	.832**	.991**	1	.967**	.472	.716**	.829**	.768**
	Sig. (2-tailed)	.000	.000		.000	.088	.004	.000	.001
	N	14	14	14	14	14	14	14	14
PP60LSQpk	Pearson Correlation	.865**	.964**	.967**	1	.346	.616*	.761**	.714**
	Sig. (2-tailed)	.000	.000	.000		.226	.019	.002	.004
	N	14	14	14	14	14	14	14	14
PPbbBCPpk	Pearson Correlation	.486	.445	.472	.346	1	.889**	.727**	.535*
	Sig. (2-tailed)	.078	.111	.088	.226		.000	.003	.049
	N	14	14	14	14	14	14	14	14

PP20BCPpk	Pearson Correlation	.725**	.671**	.716**	.616*	.889**	1	.910**	.740**
	Sig. (2-tailed)	.003	.009	.004	.019	.000		.000	.002
	N	14	14	14	14	14	14	14	14
PP40BCPpk	Pearson Correlation	.823**	.803**	.829**	.761**	.727**	.910**	1	.890**
	Sig. (2-tailed)	.000	.001	.000	.002	.003	.000		.000
	N	14	14	14	14	14	14	14	14
PP60BCPpk	Pearson Correlation	.734**	.758**	.768**	.714**	.535*	.740**	.890**	1
	Sig. (2-tailed)	.003	.002	.001	.004	.049	.002	.000	
	N	14	14	14	14	14	14	14	14

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Appendix J

Peak Barbell Velocity Correlation SPSS Output File

Table J1

Peak Barbell Velocity Correlational Descriptives Statistics

	Mean	Std. Deviation	N
PVbbLSQpk	2.2671	.24424	14
PV20LSQpk	2.1443	.16842	14
PV40LSQpk	1.8757	.14857	14
PV60LSQpk	1.5586	.16019	14
PVbbBCPpk	1.9143	.39469	14
PV20BCPpk	1.8021	.34980	14
PV40BCPpk	1.5607	.21741	14
PV60LBCPpk	1.2321	.20648	14

Table J2

Peak Barbell Velocity Correlational Matrix

		PVbbLSQpk	PV20LSQpk	PV40LSQpk	PV60LSQpk	PVbbBCPpk	PV20BCPpk	PV40BCPpk	PV60LBCPpk
PVbbLSQpk	Pearson Correlation	1	.716**	.649*	.651*	.101	-.011	-.029	-.130
	Sig. (2-tailed)		.004	.012	.012	.732	.971	.921	.659
	N	14	14	14	14	14	14	14	14
PV20LSQpk	Pearson Correlation	.716**	1	.828**	.707**	-.191	-.157	-.084	-.130
	Sig. (2-tailed)	.004		.000	.005	.513	.591	.774	.657
	N	14	14	14	14	14	14	14	14
PV40LSQpk	Pearson Correlation	.649*	.828**	1	.920**	-.011	.055	.086	-.148
	Sig. (2-tailed)	.012	.000		.000	.971	.852	.769	.613
	N	14	14	14	14	14	14	14	14
PV60LSQpk	Pearson Correlation	.651*	.707**	.920**	1	-.091	-.058	.021	-.176
	Sig. (2-tailed)	.012	.005	.000		.758	.843	.942	.547
	N	14	14	14	14	14	14	14	14

PVbbBCPpk	Pearson Correlation	.101	-.191	-.011	-.091	1	.846**	.715**	.429
	Sig. (2-tailed)	.732	.513	.971	.758		.000	.004	.126
	N	14	14	14	14	14	14	14	14
PV20BCPpk	Pearson Correlation	-.011	-.157	.055	-.058	.846**	1	.811**	.565*
	Sig. (2-tailed)	.971	.591	.852	.843	.000		.000	.035
	N	14	14	14	14	14	14	14	14
PV40BCPpk	Pearson Correlation	-.029	-.084	.086	.021	.715**	.811**	1	.744**
	Sig. (2-tailed)	.921	.774	.769	.942	.004	.000		.002
	N	14	14	14	14	14	14	14	14
PV60LBCPpk	Pearson Correlation	-.130	-.130	-.148	-.176	.429	.565*	.744**	1
	Sig. (2-tailed)	.659	.657	.613	.547	.126	.035	.002	
	N	14	14	14	14	14	14	14	14

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).