EFFECT OF THE CATCH POSITION ON POWER CHARACTERISTICS IN SNATCH DERIVATIVES

A Thesis
by
GARRETT WEST FEIMSTER

Submitted to the Graduate School
at Appalachian State University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

May 2017
Department of Health and Exercise Science

EFFECT OF THE CATCH POSTION ON POWER CHARACTERISTICS IN SNATCH DERIVATIVES

A Thesis
by
GARRETT WEST FEIMSTER
MAY 2017

APPROVED BY:

N. Travis Triplett, Ph.D.
Chairperson, Thesis Committee

Jeffrey M. McBride, Ph.D.
Member, Thesis Committee

Timothy J. Suchomel, Ph.D.
Member, Thesis Committee

Kelly J. Cole, Ph.D.
Chairperson, Department of Health and Exercise Science

Max C. Poole, Ph.D.
Dean, Cratis D. Williams School of Graduate Studies

Abstract

EFFECT OF THE CATCH POSITION ON POWER CHARACTERISTICS IN SNATCH DERIVATIVES

Garrett West Feimster
CSCS, USAW-L1
B.S., University of Appalachian State University
M.S., Appalachian State University

Chairperson: N. Travis Triplett, Ph.D.

It has been determined that a strong relationship exists between an athlete's ability to develop high levels of muscular power and athletic performance (Baker, Nance, & Moore, 2001). Therefore, the ability to train lower body muscular power using weightlifting movements, primarily the power clean, has been heavily studied (Kawamori & Haff, 2004). Little or no research has focused on the kinetic or kinematic variables involved in the snatch and variations of the snatch movement. The purpose of this study was to compare the peak power output (PP), peak force (PF), and peak velocity (PV) of three different hang snatch variations: jump shrug (JS), high pull (HP), and hang snatch (HS), at four different relative loads to determine the effect of the overhead catch position on power output. Nine athletic males with at least 2 years of power snatch training experience and no previous competitive weightlifting experience were included in the study. Subjects completed 3 repetitions of the JS, HP, and HS at relative loads of 30, 45, 65, and 80% of their predetermined 1 repetition maximum (1RM) HS on a force plate. The order of movements performed and order of loads were randomized. PP, PF, and PV were measured using a force plate and potentiometers, and each repetition was recorded. Only the attempt with the highest peak power output (PP) for each individual at each load was used for comparison. The main results from this study showed significant interactions between exercises did occur for PF and PV. However, no significant differences in PP were found between the three exercises used in this study. When comparing the load interactions for PF and PV a significant difference was noted between all 4 loads used. However, no differences in PP occurred between the loads used. Differences in PP for load and exercise interactions were noted, JS produced the greatest amounts of PP at the loads of 30 and 45% 1RM HS while, HS produced the greatest amount of PP at higher loads of 65 and 80% 1RM HS. Results provided by this study may be useful to strength and conditioning professionals when programing the HS movement and its derivatives. Since only minor significant differences were present during the exercise and load interactions between the 3 exercises using HS variations such as the JS or HP for an athlete who is injured or has a hard time grasping the HS technique may still provide beneficial when training for PP.

Acknowledgments

I would like to thank the members of my thesis committee: Dr. N. Travis Triplett, Dr. Jeffery M. McBride, and Dr. Timothy J. Suchomel for their help and guidance during this thesis project. I would also like to thank my peers and classmates Paige Rice, Taylor Goodman, and Pavel Podolskiy for their time and assistance.

Table of Contents

Foreword

This thesis will be submitted to *The Journal of Strength and Conditioning Research.* This research journal addresses a wide variety of topics concerning conditioning and exercise demands that range from the effects of training programs on physical performance to the underlying biological basis for exercise performance.

INTRODUCTION

Training athletes for power production is an important goal for strength and conditioning professionals due to the strong relationship between an athlete's ability to produce high levels of muscular power and performance in sport (Baker et al., 2001; Comfort, Allen, & Graham-Smith, 2011; Comfort, Fletcher, & McMahon, 2012; Cormie, McBride, & McCaulley, 2007; Cronin, McNair, & Marshall, 2001; Garhammer, 1979). Sport-specific movements that produce maximal power, such as the weightlifting movements, are an ideal stimulus to increase power production (Kawamori & Haff, 2004; Suchomel, Comfort, & Stone, 2015). Many studies involving the weightlifting movements have been conducted using the clean and clean derivatives, while the snatch and snatch derivatives have received far less attention in the research.

Implementing weightlifting movements into strength and conditioning programs can increase muscular power through training triple extension. Triple extension involves the explosive extension of the hips, knees, and ankles (plantar flexion) in unison (Kawamori et al., 2005). The portion of the lift known as the second pull is where triple extension is achieved. The second pull is similar to many sport movements, which is the reason many strength and conditioning specialists and researchers refer to the weightlifting movements as sport-specific (Hori, Newton, Nosaka, & Stone, 2005). The second pull is also the period at which the greatest ground reaction force is produced during the clean and snatch movements (Garhammer, 1979). The snatch or clean can be implemented into training programs to maximize power development during the second pull phase to increase lower body muscular power (Ayers, J. L., DeBeliso, M., Sevene, T.

G., & Adams, K. J., 2016). The many benefits of these movements may be overshadowed by the difficulty of learning the movements, so using derivatives of the hang snatch (HS), which focus on the second pull phase, may allow athletes to train lower body muscular power and possibly produce a higher peak power output at certain loads (Suchomel et al., 2014a; Comfort et al., 2011a; Comfort et al., 2011b). The hang snatch (HS) and hang clean (HC) are taught in a very similar fashion when taught by USA Weightlifting protocol. However, differences between the two movements do exist including the grip width, the total displacement of the bar from the starting position to the overhead position, and the point at which the barbell makes contact with the body at the onset of the second pull. These differences in technique may cause alterations in the power output of the snatch movement when compared to the clean. Many attempts to implement different movements that produce high levels of lower body muscular power have been made by using weightlifting derivatives. A previous study (Suchomel, Wright, Kernozek, & Kline, 2014) showed that common movements used to teach the hang clean, such as the jump shrug (JS) and the high pull (HP) may actually produce greater amounts of power during the second pull than the full HC movement alone. A more recent study (Suchomel, T. J., Beckham, G. K., & Wright, G. A., 2013) also demonstrated that the JS possess superior force production characteristics (relative peak force, impulse, and rate of force development) compared to the HP and HC across multiple loads.

Two previous studies by Comfort et al. (2011) compared differences in weightlifting movements including the catch and weightlifting pulling derivatives. The mid-thigh pull produced greater kinematic and kinetic magnitudes when compared with the power clean and the HC but showed no difference when compared to the mid-thigh power clean. However, all of the previous research comparing weightlifting derivatives has been completed using clean derivatives and thus further research examining similar variables with snatch derivatives is warranted.

A previous study on HC power production found that loading to produce peak power in the HC was between 60-80% of one repetition-maximum (1RM) (Kawamori & Haff, 2004) while another study suggested the loading to produce maximal power output in the power clean (pulled from the floor) was between 50-90% of 1RM (Cormie, McCaulley, Triplett, & McBride, 2007; Kawamori et al., 2005; Kilduff, L.P., Bevan, H., Owen, N., 2007). Other studies noted that the loading for maximal power output in the power clean occurred at 70% (Cormie, McCaulley, et al., 2007; Kawamori & Haff, 2004) or 80% (Baker et al., 2001; Cormie, McCaulley, et al., 2007; Kawamori et al., 2005; Stone et al., 2003) of the load relative to the athlete's 1RM. In order for athletes to improve their muscular power and overall athletic performance the ideal load must be selected for the specific exercise being performed (Newton & Kraemer, 1994; Kawamori & Haff, 2004).

The purpose of this study was to compare power characteristics between hang snatch derivatives without a catch phase to the hang snatch movement with a catch phase, at different loads relative to an athlete's HS 1RM. The results from this study could provide information on the power output of the HS, HP, and JS, while also providing information on the loading of the HS movement to produce maximal power output. It was hypothesized that the JS would produce the greatest peak power, peak force, and peak velocity at each relative intensity (30, 45, 65, and 80% of 1RM). It was also hypothesized that the greatest power output for the HS would occur between 65-80% HS

1RM. While previous evidence shows that the JS and HP produced the greatest power at the lightest loads examined, additional information on training certain portions of the force-velocity (power) curve could be determined from this research.

LITERATURE REVIEW

INTRODUCTION

The clean exercise has been much more extensively investigated when compared to the snatch exercise in regards to kinematic variables produced during the snatch and variations. Thus, information provided by researchers on the power clean and its derivatives was reviewed, as well as the implementation of the power clean for increasing performance in athletes through training lower body muscular power. Researchers have provided information on the power clean and its derivatives involving maximal power output, ideal relative loads for maximal power output, and comparing kinematic variables of the power clean to power clean derivatives. The vast amounts of information on the power clean has changed the way the movement and its derivatives have been programmed by strength and conditioning professionals due to its importance and applicability of training lower body muscular power for athletic performance. This review will also discuss the lack of scientific research on the snatch and snatch variations.

RELATIONSHIP OF LOWER BODY MUSCULAR POWER TO ATHLETIC PERFORMANCE

Many research studies have investigated the relationship between improvements in lower body muscular power and increases in athletic performance. In a study by Baker et al. (2001), rugby players were measured for maximal strength and maximal power generated during exercises with similar movement patterns. The HC was used in this study to determine its effects on upper body strength and power versus lower body strength and power. The results of this study indicated that the HC was related more to lower body strength and power than upper body strength and power; therefore, the HC may be a viable option for training lower body muscular power.

A review paper (Garhammer, 1979) discussed the high levels of power development during the second pull of a clean compared to other movements. The authors described the power clean as an explosive movement that can be used to train a sequence, or movement that produces a high velocity at release or impact. The authors also discussed the abundance of high power movements involved in sports such as jumping, changing direction, and accelerating (Newton & Kraemer, 1994). The example of a basketball player jumping for a rebound was used in this paper, with the concept that the higher the velocity with which an athlete can leave the floor, the higher the athlete will jump. Therefore, the more force an athlete can generate into the floor, the higher the velocity with which they will leave the floor. This is just one of many scenarios that show the importance of lower body muscular power in athletics.

LOADING FOR PEAK POWER

Many researchers have investigated the load for peak power production of the power clean or HC in order to properly program the clean into training programs. A study by Cormie et al. (2007) found that the load for producing peak power during the power clean occurred at 80% of 1RM, but no significant differences between power production ranging from 50-90% of 1RM were noted. This study also determined that peak power during the squat occurred at 56% of 1RM, and peak power during the jump squat occurred at 0% of 1RM (body weight). The information gathered from this study shows that maximal power output occurs at different relative intensities of 1RM in the jump squat, squat, and power clean.

A study by Kilduff et al. (2007) examined the optimal load needed to produce peak power output during the ballistic bench throw and squat jump in professional rugby players. Results showed that maximum peak power output took place at 30% of 1RM and that relative intensity had a significant effect on peak power output during the ballistic bench throw. Results from the squat jump showed that maximum peak power output took place at body weight or 0% of 1RM which was significantly higher than all other intensities. Peak power output was also significantly different at all relative intensities of the jump squat.

A study by Comfort et al. (2012) aimed to determine the load at which peak power was achieved during the power clean in collegiate athletes. This study provided information that loads between 60-80% of 1RM should be used when training to maximize force and power output in the power clean for collegiate athletes, and supports the findings of Cormie et al. (2007).

Kawamori et al. (2005) investigated the load at which maximal peak power occurs during the HC. Peak power was measured for the HC at 30-90% of 1RM. The results indicated that optimal peak power occurred at 70% of 1RM, but was not significantly different from peak power at 50%, 60%, 80% or 90% of HC 1RM. The differences in these two studies show the uncertainty that still exists when determining the optimal load at which maximal peak power occurs during derivatives of the clean.

POWER CLEAN PULLING DERIVATIVES

A recent review discussed weightlifting pulling derivatives and their potential training benefits (Suchomel et al., Sports Med 2015). Given the potential benefits of weightlifting pulling derivatives, researchers have examined the kinetic and kinematic differences between the power clean and its variations. Two studies (Comfort et al., 2011a; Comfort et al., 2011b) aimed to determine differences in peak power, peak vertical ground reaction forces, and rate of force development (RFD) between the power clean, HC, mid-thigh power clean, and the mid-thigh clean pull. Each exercise was performed on a force plate for 1 set of 3 repetitions. The results of this study revealed a significantly greater peak power output during the mid-thigh power clean and the mid-thigh clean pull when compared to both the power clean and HC. These results were also true for peak vertical ground reaction forces and RFD.

A more recent study by (Suchomel et al., 2014a) compared the peak power output, peak force, and peak velocity of the HC, HP, and JS at different relative loads. The purpose of this study was to better understand the relative load at which each of these clean variations produced the most power to be better implemented into training programs for athletes. The results showed that at all relative intensities the JS produced the highest peak power output, peak force, and peak velocity and that the optimal load for peak power output of the HC occurred at 65% of HC 1RM. Both of these studies provided support for the use of power clean variations over the power clean or HC at certain relative loads to produce a greater power output. A second study by Suchomel et al. (2016) compared joint velocities of the JS and HC at different relative intensities. The results of this study showed the JS provided higher peak joint velocity at all loads examined in the study, which indicated a great explosiveness in the triple extension movement of the JS. This information provides further evidence on the ability of weightlifting derivatives, especially the JS, to train muscular power at lower relative loads.

A study involving force-time curve comparison between weightlifting derivatives by Suchomel et al. (2016) compared the peak force, peak RFD (PRFD), impulse, and entire force-time curve of three different weightlifting derivatives at four different relative loads. The results showed that the JS produced greater PF, impulse, and PRFD at all relative loads examined. It was also shown that the HP produced statistically greater impulse than the HC.

A recent study by Kipp et al. (2016) investigated the joint and load-dependent changes that occur in the mechanical demands of lower extremity joints during the HC and the JS. Results from this study showed that the JS produced greater hip and knee positive joint work, and greater knee and ankle peak concentric joint power than the HC; this was most notable at loads of 30% and 50% of 1RM HC.

CONCLUSION

A large amount of research mentioned in this literature review shows the importance of the power clean and variations of the power clean to train lower body muscular power and therefore increase athletic performance. Improvements in power movements such as running, jumping, and changing direction are important in all forms of athletics and can be improved by increasing lower body muscular power by training with the power clean. The power clean has become an essential lift in strength and conditioning programs for all ages and levels of athlete. However, the evidence mentioned in this review supports the implementation of power clean variations when training for peak power at certain relative loads. Minimal research has been completed on the kinetic and kinematic differences between the HS and other snatch derivatives. The similar movement patterns of the snatch and clean suggest that the snatch may also be a very productive method for training lower body muscular power. A recent study by Ayers et al. (2016) compared the power and strength gains when training with the HS versus training with the HC. Results from this study showed that both groups improved significantly from pre-testing to post-testing in the vertical jump, 1RM back squat, and 40-yard sprint time. However, when comparing the HS to the HC, no significant difference was found between the two groups in the three variables tested. Information from this study provides evidence that although the HS is less researched, it may be just as beneficial as training with the HC from training lower body muscular power

METHODOLOGY

SUBJECTS

Nine athletic males with a minimum of 2 years previous training experience with the hang snatch (HS) exercise, but no previous competitive weightlifting experience, agreed to participate in the study. Subjects had no musculoskeletal injuries in the previous 6 months. A crossover design was used with all subjects completing each exercise at each relative load. The Appalachian State University Institutional Review Board approved the study, and all subjects were informed of possible risks associated with participating in the study and signed informed consent forms prior to participating.

Table 1

Subject demographics and performance characteristics

Age (y)	21.33 ± 2.55
Height (cm)	177.58 ± 4.34
Body mass (kg)	86.41 ± 9.63
1RM Hang snatch (kg)	74.72 ± 11.35
Hang snatch training experience (y)	2.56 ± 0.68

STUDY DESIGN

A repeated measures design was used to investigate the relationships between hang snatch variations. Hang snatch (HS), jump shrug (JS), and high pull (HP) repetitions were performed at different relative loads (30, 45, 65, and 80% 1RM HS) and the kinetic values produced during the repetitions of each exercise and load. The exercises (HS, JS, and HP) and loads (30,45,65, and 80% 1RM HS) were independent variables used to compare the kinetics produced during each repetition to determine if any differences existed between the respective exercises and loads. The specific relative loads were based on previous literature and chosen to cover a wide range of light, moderate, and heavy training loads (Suchomel et al., 2015). The peak power output (PP), peak force (PF), and peak velocity (PV) of each repetition were dependent variables since they are frequently examined when investigating weightlifting movements. Since power is a product of force and velocity, these variables were used to examine the factors contributing to power production. Subjects first completed a single familiarization session followed by the data collection session. Testing sessions for each subject were completed at the same time of day and separated by a minimum of 2 days and a maximum of 7 days between sessions. The familiarization session was used to obtain the subject's 1RM HS and to familiarize the subjects with the JS and HP exercises. During the data collection session subjects completed a randomized order of the exercises (HS, JS, or HP) and loads (30, 45, 65 and 80%) on a force plate (AMTI, BP6001200, Watertown, MA). PP and PF were collected using the force plate PV of the barbell was measured by potentiometers (Celesco Transducer Products. PT5A-150, Chatsworth, CA). PP was calculated by PF collected from the force plate multiplied by PV calculated by potentiometers.

Table 2

Study procedures

Familiarization Session	**Testing Session**
Read and signed informed consent	Performed standardized warm-up
Performed standardized warm-up	Performed 3 maximal effort repetitions at each of the 3 exercises (HP, HS, JS) at each load (30, 45, 65 and 80% HS 1RM)
Performed 1RM HS testing	
Familiarization of the JS and HP exercises	
Randomization of testing session exercises and loads	

PROCEDURES

One Repetition Maximum Hang Snatch Testing: Each subject's 1RM HS was determined using the protocol previously described (Winchester, Erickson, Blaak, & McBride, 2005). Before performing any maximal HS attempts, each subject completed a standardized warm-up. After completing the warm-up, subjects performed submaximal repetitions of the HS exercise (e.g., 30 and 50% of estimated 1RM HS) as part of the 1RM HS warm-up. Briefly, the HS exercise started from a standing position with the subject holding the bar using a pronated grip, with hands positioned wider than shoulder-width. Subjects then lowered the bar down to their thighs to just above knee level (Figure 1), and lifted the bar explosively upward (triple extension), and caught the bar in an overhead squat position (Figure 2). The HS attempt was determined unsuccessful if it was observed that the subject's upper thigh fell below parallel to the floor during the catch phase. After the subject's 1RM HS had been established, subjects were familiarized with the technique of JS and HP exercises. The JS and HP exercises required the subject to start in a standing position and lower the bar down their thighs until the bar was just above knee level, identical to the beginning of the HS. The JS then required the subject to maximally jump with the barbell while shrugging their shoulders (Suchomel et al., 2014d). A successful repetition of the JS required the subject to leave the surface of the force platform (Figure 3). To successfully perform the HP exercise the subject lowered the bar to a position just above knee level, as described above, then the subject explosively extended their hips, knees, and ankles, shrugged their shoulders, drove their elbows upward, and elevated the barbell to chest height (Figure 4)(Suchomel et al., 2014c).

Figure 1. Barbell lowered to the countermovement hang position from the starting position.

Figure 2. Finishing position of the hang snatch.

Figure 3. Finishing position of the jump shrug.

Figure 4. Finishing position of the high pull.

Power Testing: The barbell warm-up and light exercise sets (e.g., 30, 50% 1RM HS) were performed before testing. The randomized order of the movements and the randomized order of the relative loads that were determined during the 1RM session were used for testing. Subjects performed 3 maximal effort repetitions at each of the relative loads (30, 45, 65, and 80% of their 1RM HS) for each movement (HS, JS, and HP) using the predetermined randomized order. Therefore, the second testing session required the subject to perform 36 total repetitions. In addition, the relative loads remained constant between each exercise. One minute of rest was provided between each repetition, whereas 2 minutes were provided between each load and each exercise. The bar was placed on standards in a rack surrounding the force plate in between all repetitions to prevent fatigue. All repetitions of each exercise were performed on the force plate with potentiometers attached to the barbell. Subjects were encouraged to complete each repetition with maximal effort.

Data Processing: A custom-made program using LabVIEW (National Instruments, Austin, TX, USA) was used for data collection and analysis. The greatest PP, PF, and PV values produced by each subject during the HP, HS, and JS at each load were used for comparison.

STATISTICAL ANALYSIS

All data was reported as the mean ± SD. A series of 3 (exercise) x 4 (load) repeated measures analysis of variance was used to compare the main effect differences of the PPO, PF, and PV produced between the HS, JS, and HP exercises and the various loads (30, 45, 65, 80% of 1RM HS). When necessary, a Fisher’s LSD post hoc analysis was performed. For all statistical tests, the alpha value was set at 0.05. All statistical comparisons were made using SPSS 24 (IBM, Armonk, NY).

RESULTS

EXERCISE

Exercise PF main effect results are displayed in Figure 5. Significant differences in PF occurred between the HP, HS, and JS exercises. Post hoc analysis revealed a significantly greater PF during the HS (2977.49 ± 266.91 N) (p = 0.029) and JS (3062.57 ± 259.51 N) (p = 0.014) when compared with the HP (2821.98 ± 248.27 N). There was no significant difference between the HS and JS (p = 0.273) exercises.

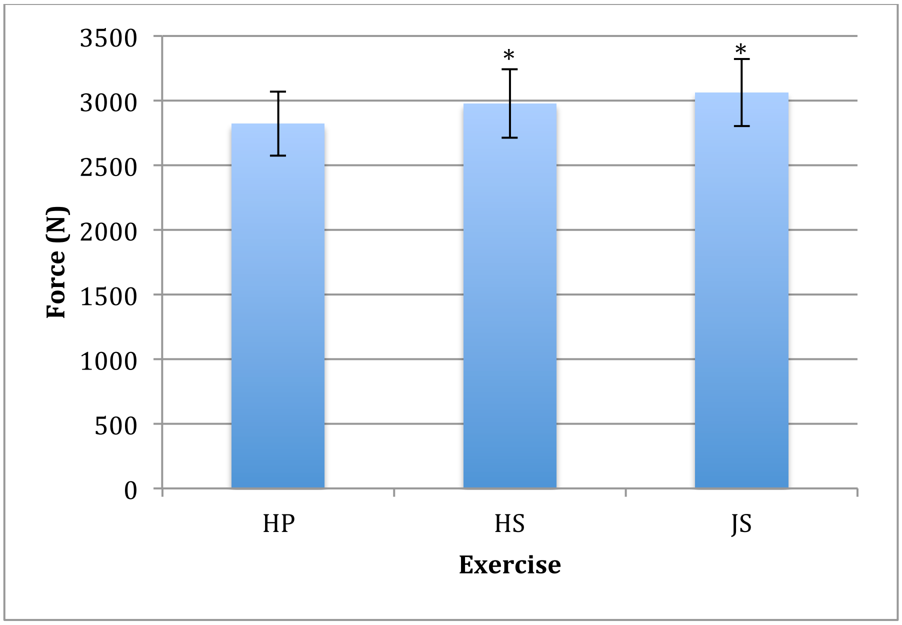

Figure 5. Exercise main effects for peak force. *Significantly greater than HP.

Exercise PV main effect results are displayed in Figure 6. Significant differences in PV were identified between HP, HS, and JS exercises. Post hoc analysis revealed a significantly greater PV for the HS (3.01 ± 0.30 m/s) compared with the JS (2.55 ± 0.36 m/s) exercise (p = 0.007). However, no significant difference in PV existed between the HP (2.79 ± 0.20 m/s) and HS (p = 0.54) or the HP and JS (p = 0.141) exercises.

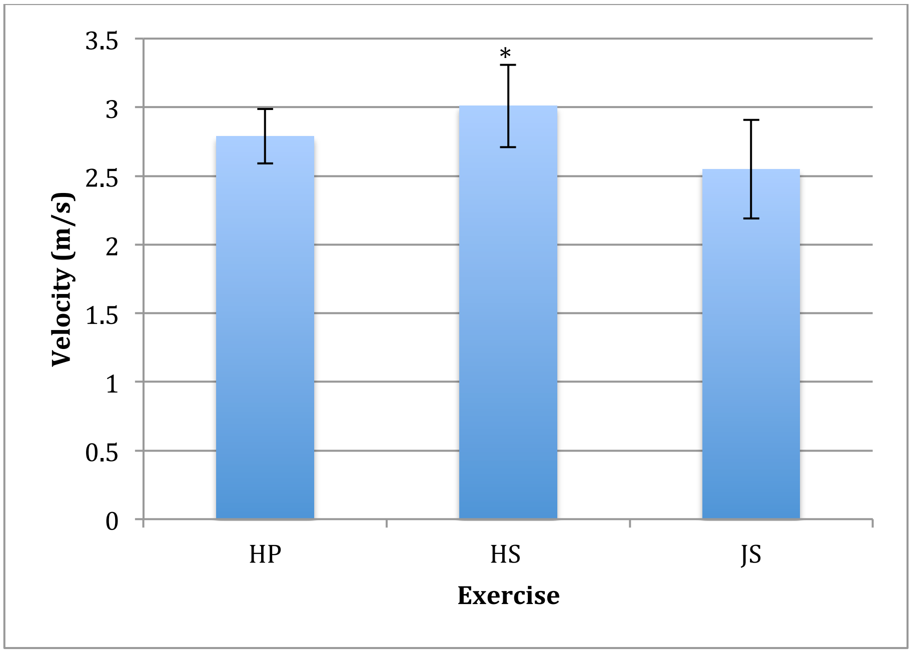

Figure 6. Exercise main effects for peak velocity. *Significantly greater than JS.

Exercise PP main effect results are displayed in Figure 7. ($p = 0.090$). No significant differences were found between HP (4629.42 ± 548.85 W), HS (4812.43 ± 527.3 W), and JS (5234.33 ± 739.97 W) exercises ($p = 0.065$).

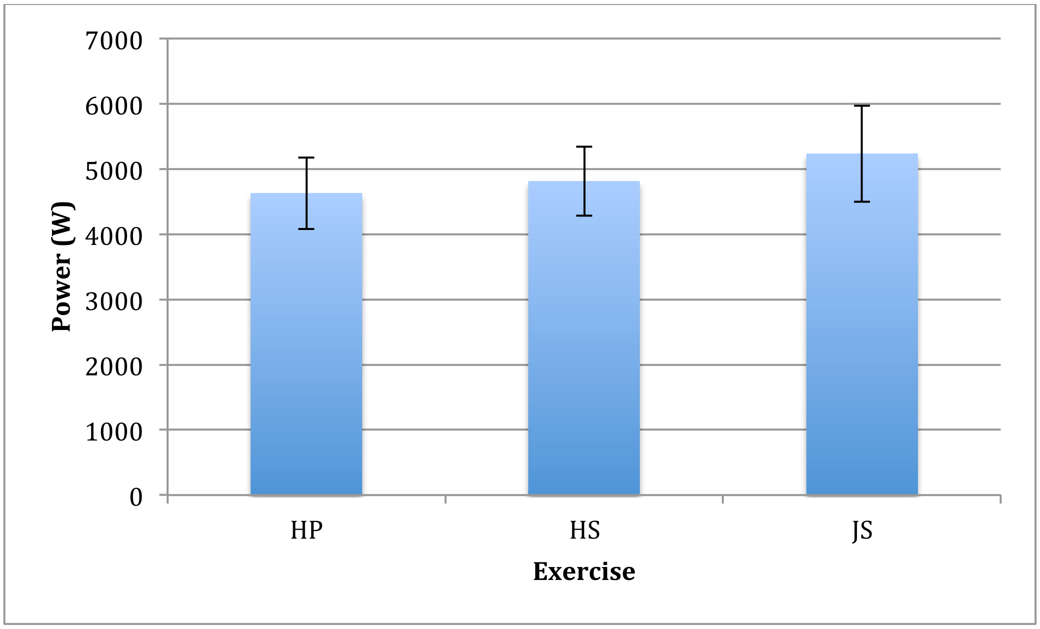

Figure 7. Exercise main effects for peak power output.

PEAK FORCE AND LOAD

Significant main effect differences are displayed in Figure 8. and occurred during the HP, HS, and JS exercises for PF at all loads ($p < 0.001$).

EXERCISE AND LOAD INTERACTION FOR PEAK FORCE

Exercise and load interaction for peak force are also displayed in Figure 8. Post hoc tests revealed that significant differences in PF were observed between loads and exercises during the HP, HS, and JS exercises ($p < 0.001$). At 30% 1RM HS, significant differences of PF were observed between the HP (2216.73 ± 344.36 N) and the JS (2816.97 ± 252.84 N) exercises ($p < 0.001$) as well as the HS (2263.20 ± 314.32 N) and the JS exercises ($p < 0.001$). At 45% 1RM HS, significant differences of PF were observed between the HP (2502.37 ± 280.13 N) and the JS (2932.45 ± 256.50 N) exercises ($p = 0.004$) as well as the HS (2553.88 ± 275.80 N) and the JS exercises ($p = 0.012$). Once more, at 65% 1RM HS significant differences in PF were observed between the HP (2868.13 ± 319.40 N) and the JS (2969.63 ± 263.28 N) exercises ($p = 0.009$) and between the HS (2762.27 – 221.4 N) and the JS exercises ($p = 0.010$). Finally, at 80% 1RM HS significant differences in PF were observed between the HP (2818.40 ± 243.76 N) and HS (2963.90 ± 236.46 N) exercises ($p = 0.039$) as well as the HP and JS (3017.89 ± 284. 34 N) exercises ($p = 0.02$).

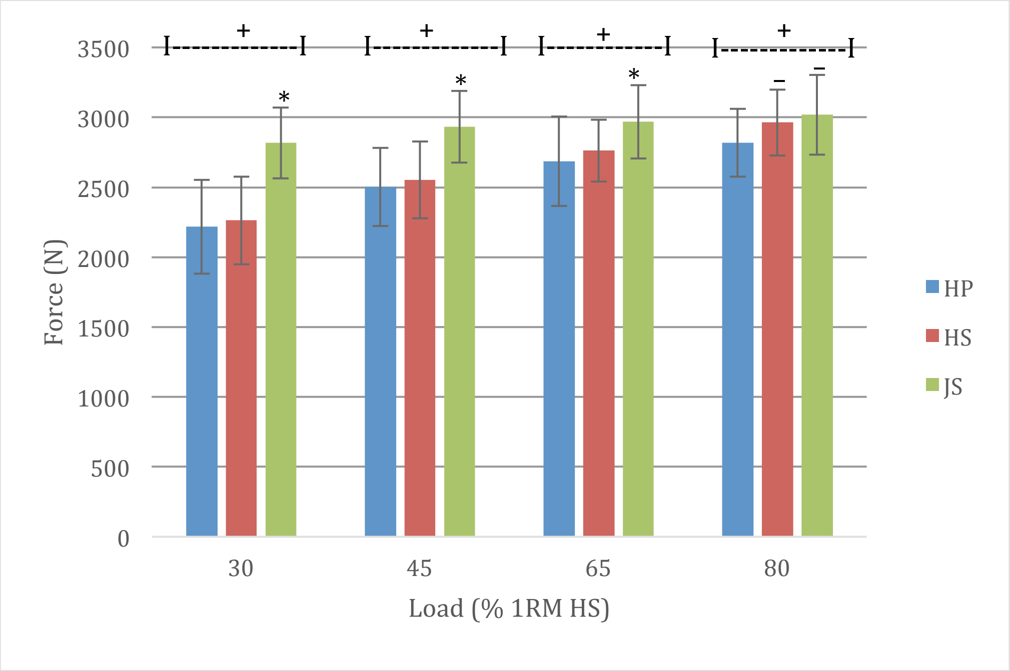

Figure 8. Exercise and load interaction for peak force ($p < 0.001$). *Significantly greater than HP and JS. – Significantly greater than HP. +Significant differences between all load interactions.

PEAK VELOCITY AND LOAD

Load main effect differences in PV are displayed in Figure 9. There were observed differences between all loads of 30% 1RM HS (2.76 ± 0.07 m/s), 45% 1RM HS (2.57 ± 0.05 m/s), 65% 1RM HS (2.36 ± 0.05 m/s), and 80% 1RM HS (2.19 ± 0.07 m/s) ($p < 0.02$).

EXERCISE AND LOAD INTERACTION FOR PEAK VELOCITY

Exercise PV main effect is displayed in Figure 9. No post hoc analysis was completed due to no significant interaction between exercise and load for PV (p = 0.419).

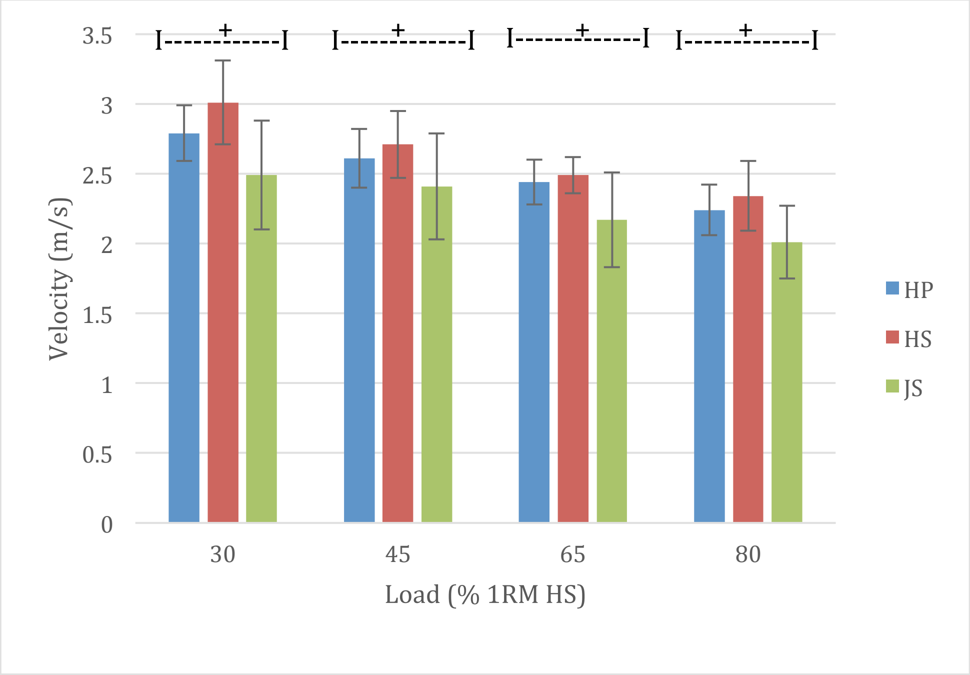

Figure 9. Exercise and load interaction for PV (p = 0.419). +Significant differences between all loads.

PEAK POWER AND LOAD

Load PP main effects shown in Figure 10. displayed no differences between loading interactions of the HP, HS, and JS (p = 0.470).

EXERCISE AND LOAD INTERACTION FOR PEAK POWER

Exercise and load interactions for PP are displayed in Figure 10. Post hoc analysis showed that significant differences in PP were observed at 30% 1RM HS between the HS (4086.30 ± 776.78 W) and JS (4941.55 ± 1086.92 W) exercises (p = 0.031). What about HP? At

45% 1RM HS significant differences in PP were observed between the HP (4205.14 ± 468.88 W) and the JS (4913.59 ± 1006.65 W) exercises (p = 0.038). Lastly, at 80% 1RM HS significant differences in PP were observed between HP (4176.54 ± 665.67 W) and HS (4594.52 ± 594.72 W) exercises (p = 0.036).

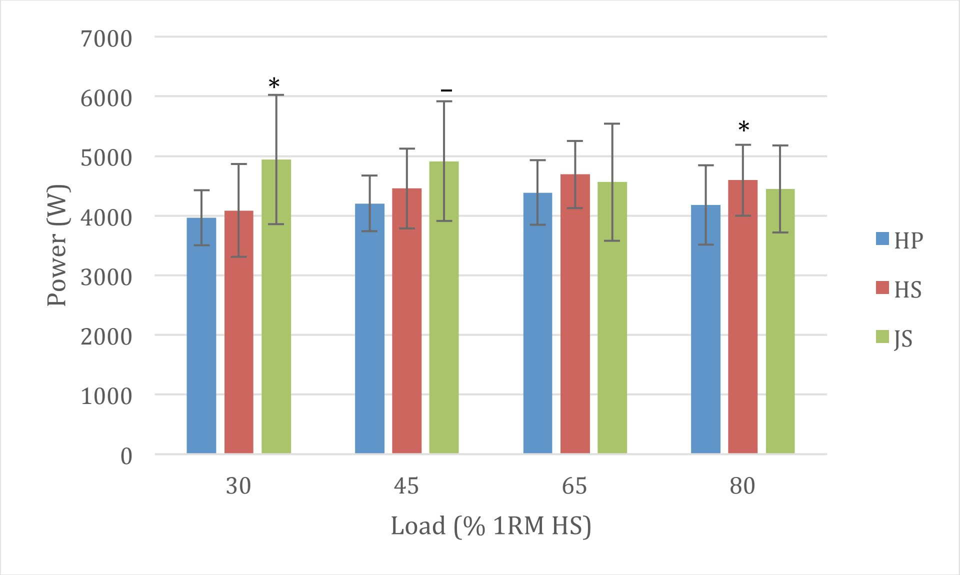

Figure 10. Exercise and load interaction for peak power output. *Significantly greater than HP. –Significantly greater than HS and HP.

DISCUSSION

Research studies have shown that the ideal stimulus for improving muscular power involves training sport-specific movements in which maximal power is produced (Kilduff, L.P., Bevan, H., Owen, N., 2007). The main purpose of this study was to compare the power production of the HP, HS, and JS exercises when performed at different loads relative to the 1RM HS of each subject. The first finding of this study is that no main effect differences in the PP existed between the HP, HS, and JS exercises (p = 0.090); however, main effect differences for PF and PV did exist between the HP, HS, and JS exercises. The results show that these differences are likely due to the PF and PV differences that existed between the exercises. Secondly, this study included main effect differences in PF and PV between the different exercise loads but no significant differences in PP between loads. Lastly, there were significant interactions between the exercises and loads for PP and PF, but no significant interactions for PV between exercise and load interactions. The JS produced the greatest PP, followed by the HS and the HP, respectively. The order of PP and PF of the HP, HS, and JS differ from a previous study using hang clean derivatives (Suchomel, T.J., Sole, C.J., & Stone, M.H., 2016). This information shows that differences in technique of the HS and the HC produce different kinematic values when performing similar movements. When examining the addition of the catch phase we see that the HP and JS can produce higher PF and PP than the movement including the catch phase during the HC movement. In the snatch movements it is shown that the HP and JS produce lower PF and PP than the movement including the catch phase. This may be due to the greater displacement of the barbell during the hang snatch movement and greater barbell velocities over that displacement.

Although the HS can be a highly beneficial exercise, it may be more time efficient to teach an HS variation compared to the HS. Since our results only showed minor differences in PP between the HP, HS, and JS at different loads, using the HP and JS as teaching tools for the HS may still be beneficial. It has been recommended by previous authors to substitute less technical exercises (HP, JS) to train lower body muscular power (Ayers, 2016; Kawamori, 2005). Training with the HP or JS movements may allow an inexperienced or injured athlete to still effectively produce high levels of force, velocity, and power, which may transfer to sport performance. For example, if an athlete struggles with the HS technique they could substitute the HP or JS exercise to effectively train lower body muscular power and likely improve fitness characteristics important to performance.

As mentioned previously, it is important that strength and conditioning professionals prescribe exercises that allow athletes to produce maximal levels of lower body muscular power during training (Otto III, 2012). Moreover, it is equally important to prescribe the proper loading of that movement to produce maximal power output. By training with the ideal load for a given exercise, athletes will be able to optimally improve their muscular power and overall sports performance (Kawamori, 2004). The main effects of load interaction present in this study indicated that no significant differences in PP occurred between loads. However, main effect differences did occur in PV and PF when comparing the loading of the HP, HS, and JS exercises. Results show that the greatest barbell PV occurred at 30% 1RM HS and PV decreased as the load increased. The greatest PF occurred at 80% 1RM HS; as relative loads increased so did the PF produced with each repetition.

Analysis of the interaction between exercise and load revealed that the greatest PP and PF were produced by the JS and the greatest barbell PV was produced by the HS. The greatest differences in in PP, PF, and PV between the exercises occurred at the lower loads (30 and 45% 1RM HS) and the smallest differences between the higher loads (65 and 80% 1RM HS). In general, as the load increased so did the amount of force produced for each exercise. The opposite occurred with velocity, as the load increased the velocity for each exercise decreased. In regards to the PP of each exercise, it should be noted that the JS PP dropped as load increase, while the largest drop took place between 45 and 65% 1RM HS, which is similar to previous research (Suchomel et al., 2014). This highlights the usefulness of training with the JS at lighter loads (30 and 45 % 1RM HS) so that the athlete can effectively produce high levels of lower body muscular power (Suchomel et al., 2013, Suchomel et al., 2017). Both the HS and HP increased up to 65% 1RM HS and then dropped in PP for the repetitions at 80% 1RM HS. It should also be noted that the HS produced higher PP at all loads than the HP. This information shows that the load that produced the greatest PP for the HS and HP both occurred at 65% 1RM HS. The drops in PP at 80% 1RM could be due to technique break downs at heavier loads. The decreases displayed in PV make sense due to the difficulty of producing high levels of velocity with loads closer to 1RM HS.

A limitation of this study may have been the population selected for participation. Athletic males with at least two years of HS training experience but no competitive weightlifting experience were selected to participate in the study. No woman trained or untrained subjects were selected to participate. The subjects in the current study fit the population that has been frequently examined throughout the literature, allowing the best comparison with other studies. Lastly, this study used loads relative to the 1RM HS of each subject for all three exercises examined. This was done so that similar absolute loads in all exercises could be examined. The use of the loading spectrum (30 - 80% 1RM) was thought to be able to justify and identify differences in PF that may be apparent between exercises. Our results show that it is likely that the 1RM for the HP and JS are most likely higher than that of the 1RM for HS due to greater PF values for the JS than the HS. This being said, a 1RM test for the JS and the HP in an athletic setting may not be practical.

The true optimal load for PP for each exercise may be similar to those reported in the study; however, future research may consider using smaller loading increments to better determine the optimal load for PP for each exercise. Future research may also consider the use of untrained men and both trained and untrained women in a similar study.

PRACTICAL APPLICATIONS

The results reported by this study may assist strength and conditioning professionals in selecting exercises and loads that maximize PP during training, which in turn may enhance the athlete's performance in sport. Since the JS produced higher amounts of PP at lower loads (30 and 45% 1RM HS), it is suggested that strength and conditioning professionals implement the JS to produce maximal PP when training at lower loads. Since the HS produced the greatest amount of PP at higher loads (65 and 80% 1RM HS), it is suggested that training with the HS at these higher loads will produce the greatest amounts of PP. However, since only minor significant interactions were present between the exercises and loads for PP, using the JS and HP as teaching tools for the HS will still produce similar results when attempting to produce the greatest amount of power during training. To optimize power production with the JS exercise, strength and conditioning professionals should consider using loads at 30 and 45% of an athlete's 1RM HS.

REFERENCES

Ayers, J. L., DeBeliso, M., Sevene, T. G., & Adams, K. J. (2016). Hang cleans and hang snatches produce similar improvements in female collegiate athletes. *Biol Sport, 33*(3), 251-256.

Baker, D., Nance, S., & Moore, M. (2001). The load that maximizes the average mechanical power output during jump squats in power-trained athletes. *The Journal of Strength & Conditioning Research, 15*(1), 92-97.

Comfort, P., Allen, M., & Graham-Smith, P. (2011a). Comparisons of peak ground reaction force and rate of force development during variations of the power clean. The Journal of Strength & Conditioning Research, 25(5), 1235-1239.

Comfort, P., Allen, M., & Graham-Smith, P. (2011b). Kinetic comparisons during variations of the power clean. *The Journal of Strength & Conditioning Research, 25*(12), 3269-3273.

Comfort, P., Fletcher, C., & McMahon, J. J. (2012). Determination of optimal loading during the power clean, in collegiate athletes. *The Journal of Strength & Conditioning Research, 26*(11), 2970-2974.

Cormie, P., McBride, J. M., & McCaulley, G. O. (2007). Validation of power measurement techniques in dynamic lower body resistance exercises. *Journal of Applied Biomechanics, 23*(2), 103.

Cormie, P., McBride, J. M., & McCaulley, G. O. (2009). Power-time, force-time, and velocity-time curve analysis of the countermovement jump: impact of training. *The Journal of Strength & Conditioning Research, 23*(1), 177-186.

Cormie, P., McCaulley, G. O., Triplett, N. T., & McBride, J. M. (2007). Optimal loading for maximal power output during lower-body resistance exercises. *Medicine and science in sports and exercise, 39*(2), 340.

Cronin, J., McNair, P. J., & Marshall, R. N. (2001). Developing explosive power: a comparison of technique and training. *Journal of Science and Medicine in Sport, 4*(1), 59-70.

Garhammer, J. (1979). Power production by Olympic weightlifters. *Medicine and science in sports and exercise, 12*(1), 54-60.

Hori, N., Newton, R. U., Nosaka, K., & Stone, M. H. (2005). Weightlifting Exercises Enhance Athletic Performance That Requires High-Load Speed Strength. *Strength & Conditioning Journal, 27*(4), 50-55.

Kawamori, N., Crum, A. J., Blumert, P. A., Kulik, J. R., Childers, J. T., Wood, J. A., . . . Haff, G. G. (2005). Influence of different relative intensities on power output during the hang power clean: identification of the optimal load. *The Journal of Strength & Conditioning Research, 19*(3), 698-708.

Kawamori, N., & Haff, G. G. (2004). The optimal training load for the development of muscular power. *The Journal of Strength & Conditioning Research, 18*(3), 675-684.

Kilduff, L. P., Bevan, H., Owen, N., Kingsley, M. I. C., Bunce, P., Bennett, M., & Cunningham, D. (2007). Optimal loading for peak power output during the hang power clean in professional rugby players. *International journal of sports physiology and performance, 2*(3), 260.

Kilduff, L. P., Bevan, H. R., Kingsley, M. I. C., Owen, N. J., Bennett, M. A., Bunce, P. J., . . . Cunningham, D. J. (2007). Postactivation potentiation in professional rugby players: optimal recovery. *The Journal of Strength & Conditioning Research, 21*(4), 1134-1138.

Kipp, K., Malloy, P. J., Smith, J., Giordanelli, M. D., Kiely, M. T., Geiser, C. F., & Suchomel, T. J. (2016). Mechanical Demands of the Hang Power Clean and Jump Shrug: A Joint-level Perspective. Journal of strength and conditioning research.

Newton, R. U., & Kraemer, W. J. (1994). Developing Explosive Muscular Power: Implications for a Mixed Methods Training Strategy. *Strength & Conditioning Journal, 16*(5), 20-31.

Otto III, W. H., Coburn, J. W., Brown, L. E., & Spiering, B. A. (2012). Effects of weightlifting vs. kettlebell training on vertical jump, strength, and body composition. *The Journal of Strength & Conditioning Research, 26*(5), 1199-1202.

Stone, M. H., O'Bryant, H. S., McCoy, L., Coglianese, R., Lehmkuhl, M., & Schilling, B. (2003). Power and maximum strength relationships during performance of dynamic and static weighted jumps. *The Journal of Strength & Conditioning Research, 17*(1), 140-147.

Suchomel, Timothy J., et al. "The hang high pull: A progressive exercise into weightlifting derivatives." Strength & Conditioning Journal 36.6 (2014c): 79-83.

Suchomel, Timothy J., et al. "The jump shrug: A progressive exercise into weightlifting derivatives." Strength & Conditioning Journal 36.3 (2014d): 43-47.

Suchomel, Timothy J., Paul Comfort, and Michael H. Stone. (2015). "Weightlifting pulling derivatives: Rationale for implementation and application." Sports Medicine 45.6: 823-839

Suchomel, T. J., Beckham, G. K., & Wright, G. A. (2013). Lower body kinetics during the jump shrug: impact of load. Journal of Trainology, 2(2), 19-22.

Suchomel, T. J., Comfort, P., & Lake, J. P. (2017). Enhancing the Force-Velocity Profile of Athletes Using Weightlifting Derivatives. Strength & Conditioning Journal.

Suchomel, T. J., Sole, C. J., & Stone, M. H. (2016). Comparison of Methods That Assess Lower-body Stretch-Shortening Cycle Utilization. *The Journal of Strength & Conditioning Research, 30*(2), 547-554.

Suchomel, T. J., Wright, G. A., Kernozek, T. W., & Kline, D. E. (2014a). Kinetic comparison of the power development between power clean variations. *The Journal of Strength & Conditioning Research, 28*(2), 350-360.

Suchomel, T. J., Wright, G. A., & Lottig, J. (2014b). *Lower extremity joint velocity comparisons during the hang power clean and jump shrug at various loads.* Paper presented at the XXXIInd International Conference of Biomechanics in Sports. Johnson City.

Winchester, J. B., Erickson, T. M., Blaak, J. B., & McBride, J. M. (2005). Changes in bar-path kinematics and kinetics after power-clean training. *The Journal of Strength & Conditioning Research, 19*(1), 177-183.

Vita

Garrett West Feimster was born in Taylorsville, North Carolina, to Robert and Cheryl Feimster. He graduated from Alexander Central High School in June 2011. The following year, he entered Appalachian State University to study Exercise Science, and in August of 2015 he awarded the Bachelor of Science degree. In the fall of 2015, he returned to Appalachian State University to begin study toward a Master of Science degree in Exercise Science.