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The impact of load on lower body performance variables during the hang power clean

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Abstract
This study examined the impact of load on lower body performance variables during the hang power clean. Fourteen men performed the hang power clean at loads of 30%, 45%, 65%, and 80% 1RM. Peak force, velocity, power, force at peak power, velocity at peak power, and rate of force development were compared at each load. The greatest peak force occurred at 80% 1RM. Peak force at 30% 1RM was statistically lower than peak force at 45% ($p = 0.022$), 65% ($p = 0.010$), and 80% 1RM ($p = 0.018$). Force at peak power at 65% and 80% 1RM was statistically greater than force at peak power at 30% ($p < 0.01$) and 45% 1RM ($p < 0.01$). The greatest rate of force development occurred at 30% 1RM, but was not statistically different from the rate of force development at 45%, 65%, and 80% 1RM. The rate of force development at 65% 1RM was statistically greater than the rate of force development at 80% 1RM ($p = 0.035$). No other statistical differences existed in any variable existed. Changes in load affected the peak force, force at peak power, and rate of force development, but not the peak velocity, power, or velocity at peak power.

Keywords: *Power training, power clean variations, lower body power, optimal load*

Introduction

It is well documented that the development of lower body muscular power is directly related to the overall performance of an athlete (Comfort, Fletcher, & McMahon, 2012; Hori et al., 2007; Hori, Newton, Nosaka, & Stone, 2005). In order to train lower body power, weightlifting variations such as the hang power clean are prescribed by strength and conditioning practitioners (Comfort et al., 2012; Cormie, McBride, & McCaulley, 2007b; Hori et al., 2007) because of the similarities that exist between the lower body action during the second pull (rapid extension of the hip, knee, and ankle) inherent to the lifts and many sports activities (Hori et al., 2005). The hang power clean is a power clean variation in which the athlete starts in a standing position with the barbell at the mid-thigh, lowers the barbell down to a position just above their knee, returns to the mid-thigh position, performs the second pull, elevates the barbell, rapidly rotates their elbows under the bar, and catches the

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bar across their shoulders in a semi-squat position (Kawamori et al., 2005). The hang power clean can be performed from a static position with the barbell at the mid-thigh position or just above the knee. Furthermore, the hang power clean can be performed with a countermovement as described by Kawamori et al. (2005). Despite being a commonly prescribed exercise to train lower body power, little research exists to indicate how the external load impacts the variables associated with lower body power development.

The majority of research that has examined the power clean (Comfort et al., 2012; Cormie, McBride, & McCaulley, 2007a; Cormie et al., 2007b; Cormie, McCaulley, Triplett, & McBride, 2007), hang power clean (Kawamori et al., 2005; Kilduff et al., 2007; Suchomel, Wright, Kernozek, & Kline, 2013), and other power clean variations has sought to identify the optimal load where peak power production occurs. Previous research indicates that the optimal load for the power clean and hang power clean occurs at either 70% (Comfort et al., 2012; Kawamori et al., 2005) or 80% 1RM (Cormie et al., 2007a, 2007b; Cormie et al., 2007; Kilduff et al., 2007). However, it should be noted that several studies displayed no statistical differences in power development between the loads that produced the greatest power and 60–80% 1RM (Comfort et al., 2012) or 50–90% 1RM (Cormie et al., 2007; Kawamori et al., 2005; Kilduff et al., 2007). In line with these ranges, Suchomel et al. (2013) indicated that the highest peak power for the hang power clean occurred at 65% 1RM. However, their study only examined main effect differences. Furthermore, little is known about the impact of load on lower body performance variables during the hang power clean.

The purpose of this study was to examine the impact of load on lower body performance variables during the hang power clean exercise. Based on the previous research that has examined the power clean and hang power clean, it was hypothesised that the greatest peak force, peak velocity, and peak power during the hang power clean would occur at 80%, 45%, and 80% 1RM, respectively, and that statistical differences would exist between all lower body performance variables at different loads.

Methods

Participants

Participants in this study included 14 athletic males (mean ± *SD* age 21.6 ± 1.3 years, height 179.3 ± 5.6 cm, body mass 81.48 ± 8.70 kg, and 1RM hang power clean 104.89 ± 15.10 kg) with at least two years of previous training experience with the hang power clean, but no competitive powerlifting or weightlifting experience. At the time of this study, the participants were performing weightlifting movements, including the hang power clean, 2–3 times per week. This study was approved by the University of Wisconsin-La Crosse Institutional Review Board. All participants were informed of the possible risks of involvement in the study and provided written informed consent.

Procedures

The participants completed a single familiarisation session, followed by a single testing session 2–7 days later. The purpose of the familiarisation session was to determine the 1RM hang power clean of each participant. During the testing session, participants completed three single repetitions of the hang power clean at relative loads of 30%, 45%, 65%, and 80% 1RM on a portable force platform in a randomised order.

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Upon arrival at the laboratory for the familiarisation session, every participant completed the same standardised dynamic warm-up that included 3 min of light cycling and the following dynamic stretches that each covered 10 m: walking forward lunge, walking backward lunge, lateral lunges in both directions, walking hamstring stretch, and walking quadriceps stretch. The participants then completed five slow body weight squats, five fast body weight squats, and five countermovement jumps of increasing intensity. Following a 2 min rest period, participants then completed submaximal hang power clean sets at approximately 30%, 50%, 70%, and 90% of each participant's estimated 1RM. This protocol was modified from previously established 1RM hang power clean methodology from Winchester, Erickson, Blaak, and McBride (2005). Based on the performance of the previous repetition, the load was increased approximately 2–5 kg until two failed attempts at a given load occurred. No more than three loading increases were needed to determine the 1RM of each participant.

All repetitions of the hang power clean were performed using the technique described by Kawamori et al. (2005). Briefly, the participants started the hang power clean by holding the bar in a standing position, with their knees slightly bent, and the bar positioned at the mid-thigh. The participants performed a countermovement by flexing at the hip, while maintaining their knee angle, and lowering the bar to a position just above the knee. Upon reaching this position, the participants immediately changed direction to transition back to the mid-thigh position by flexing their knees and extending the torso to an upright position. From the mid-thigh position, the participants performed the second pull movement by explosively extending their hips, knees, and ankles and by shrugging their shoulders. The participants lifted the bar upward with maximum effort and caught the bar on their shoulders in a semi-squat position. Any repetition of the hang power clean caught in a squat position where the upper thigh of the participant was below parallel to the floor was determined to be unsuccessful.

Participants returned for the testing session 2–7 days following the familiarisation session. Before testing, every participant completed the same standardised warm-up that was completed during the familiarisation session, rested for 2 min, and then completed one set of three repetitions of the hang power clean at 30% and 50% 1RM. Following 2 min of rest, participants then performed three, single repetitions each with maximal explosive effort of the hang power clean at relative loads of 30%, 45%, 65%, and 80% 1RM in a randomised order. Therefore, participants completed 12 total repetitions during the testing session. Participants were given 1 min of recovery between the repetitions (Hardee, Triplett, Utter, Zwetsloot, & McBride, 2012), and 2 min of recovery was provided between each load. The barbell was placed on the safety bars of a squat rack in between the repetitions in order to prevent fatigue.

Participants were asked to refrain from physical activity that may affect testing performance, the consumption of alcohol and caffeine, and other ergogenic aids at least 24 h prior to the testing session. If these standards were not met upon arrival, participants rescheduled their testing session within the 2–7 days window previously described. Finally, all participants completed their familiarisation and testing sessions at the same time of day in order to prevent Circadian rhythms from affecting performance.

Data collection and analysis

Participants performed all of their hang power clean repetitions on a portable Kistler Quattro Jump force platform (Type 9290AD, Kistler, Winterthur, Switzerland). The force platform sampled at 500 Hz and was interfaced with a laptop computer. The force platform

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methodology used in this study is supported by previous research by Hori et al. (2007) and Hori, Newton, Nosaka, and McGuigan (2006). The force platform directly measured vertical ground reaction forces of the lifter plus bar system, and the data were exported into a custom template created in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). From the force platform data, the velocity and power of each repetition were calculated using forward dynamics. Peak force, velocity, and power values were extracted from the raw force–time, velocity–time, and power–time data, respectively. Force at peak power and velocity at peak power were the respective force and velocity that occurred at peak power. Finally, the instantaneous rate of force development was calculated by dividing the difference between the current and previous force value by the time elapsed between the values (i.e. 0.002 s). The peak value of each variable was used for comparison.

Statistical analyses

A series of one-way repeated measures ANOVA tests were used to compare the differences in the peak force, peak velocity, peak power, force at peak power, velocity at peak power, and rate of force development within the hang power clean exercise at the various relative loads (30%, 45%, 65%, and 80% 1RM). If the assumption of sphericity was violated, Greenhouse–Geisser adjusted values were used. The Bonferroni technique was used for *post hoc* analyses when necessary. Statistical power of each ANOVA was calculated and is represented by c. Effect sizes for *post hoc* tests were calculated using Cohen's d and were interpreted using the scale developed by Hopkins (2013) where effect sizes were interpreted as trivial, small, moderate, large, very large, and nearly perfect when Cohen's d was greater than or equal to 0.0, 0.2, 0.6, 1.2, 2.0, and 4.0, respectively. In addition, 95% confidence intervals (CIs) for mean difference were calculated for all pairwise comparisons. Finally, the test–retest reliability of the measured variables was determined by intraclass correlation coefficients (ICCs), and the values are presented in Table I. All statistical analyses were carried out using SPSS 21 (IBM, New York, NY, USA), and the α value was set at 0.05 for all statistical measures.

Results

The peak force, peak velocity, peak power, force at peak power, velocity at peak power, and rate of force development data are presented in Table II. Statistically significant differences in peak force ($F_{1.67,21.64} = 10.963$, $p = 0.001$, $c = 0.97$), force at peak power ($F_{1.40,18.14} = 22.088$, $p < 0.001$, $c = 0.99$), and rate of force development ($F_{2.17,28.22} = 3.659$, $p = 0.035$, $c = 0.65$) existed between the loads examined in this study. In contrast, no statistically significant differences in peak velocity ($F_{1.34,17.41} = 1.505$, $p = 0.244$, $c = 0.24$), peak power

Table I. ICC ranges of each performance variable during the hang power clean ($n = 14$).

Variable	ICC range
Force	0.96–0.97
Velocity	0.86–0.94
Power	0.88–0.96
Force at peak power	0.94–0.99
Velocity at peak power	0.84–0.94
Rate of force development	0.90–0.97

Note: The ICC ranges represent the ICC values that occurred at each load for each variable.

Table II. The impact of load on hang power clean performance variables ($M \pm SD$; $n = 14$).

Load	Performance Variable					
	PF (N)	PV (m/s)	PP (W)	F_{PP} (N)	V_{PP} (m/s)	RFD (N/s)
30% 1RM	2,804.4 ± 535.2	1.71 ± 0.38	3,527.25 ± 1,248.97	2,388.0 ± 409.9	1.45 ± 0.31	16,185.1 ± 6,709.9
45% 1RM	3,100.3 ± 555.0[a]	1.73 ± 0.31	3,862.82 ± 1,100.50	2,583.3 ± 389.4[a]	1.49 ± 0.26	14,719.9 ± 6,279.9
65% 1RM	3,157.6 ± 509.2[a]	1.66 ± 0.18	3,967.10 ± 773.66	2,759.6 ± 359.1[a,b]	1.45 ± 0.17	14,111.7 ± 4,307.3[c]
80% 1RM	3,225.1 ± 580.6[a]	1.61 ± 0.21	4,014.89 ± 974.06	2,848.2 ± 416.7[a,b]	1.42 ± 0.17	11,790.6 ± 5,199.3

Notes: PF, peak force; PV, peak velocity; PP, peak power; F_{PP}, force at peak power; V_{PP}, velocity at peak power; RFD, rate of force development; [a] Statistically greater than the value at 30% 1RM ($p < 0.05$); [b] Statistically greater than the value at 45% 1RM ($p < 0.05$); [c] Statistically greater than the value at 80% 1RM ($p < 0.05$).

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($F_{1.41,18.38} = 2.282$, $p = 0.141$, $c = 0.35$), or velocity at peak power ($F_{1.29,16.71} = 0.682$, $p = 0.457$, $c = 0.13$) existed between the loads. The peak force at 30% 1RM was statistically lower than the peak force at 45% ($p = 0.022$, $d = 0.54$, CI = 36.25–555.52), 65% ($p = 0.010$, $d = 0.68$, CI = 75.56–630.83), and 80% 1RM ($p = 0.018$, $d = 0.75$, CI = 62.88–778.55), but no other statistical differences existed between the loads ($p > 0.05$). The force at peak power at 30% 1RM was statistically lower than the force at peak power at 45% ($p = 0.004$, $d = 0.49$, CI = 57.59–332.97), 65% ($p = 0.001$, $d = 0.96$, CI = 162.47–580.65), and 80% 1RM ($p = 0.002$, $d = 1.11$, CI = 170.91–749.41). In addition, the force at peak power at 45% 1RM was statistically lower than the force at peak power at 65% ($p = 0.002$, $d = 0.47$, CI = 60.70–291.85) and 80% 1RM ($p = 0.007$, $d = 0.66$, CI = 64.43–465.31). The rate of force development at 65% 1RM was statistically greater than the rate of force development at 80% 1RM ($p = 0.035$, $d = 0.49$, CI = 126.54–4515.69). No other statistically significant relationships existed ($p > 0.05$).

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Discussion and implications

The purpose of this study was to examine the impact that the external load had on lower body performance variables associated with peak power during the hang power clean. The main findings of this study were that statistical differences in peak force, force at peak power, and rate of force development existed between the loads during the hang power clean. However, our results indicate that no statistical differences in peak velocity, peak power, and velocity at peak power existed between the loads examined. Therefore, our hypothesis was partially supported in that differences in peak force, force at peak power, and rate of force development existed between the loads. However, in regard to the lack of statistical differences in peak velocity, peak power, and velocity at peak power, our hypothesis was not supported. It is clear from our results that the amount of force that the participants needed to produce in order to complete the hang power clean was affected to a greater extent by load as compared with the other variables examined.

Perhaps the most unique findings of this study had to do with the force at peak power and velocity at peak power. To the knowledge of the authors, this is the first study that has compared force at peak power and velocity at peak power at different loads during the hang power clean exercise. The force at peak power and velocity at peak power were analyzed in order to provide insight on contributing factors to peak power production during the hang power clean. In this study, the greatest force at peak power occurred at 80% 1RM, but was not statistically different from the value that occurred at 65% 1RM. As expected, force at peak power increased throughout the loading spectrum due to the increasing external load. Despite the statistical differences in force at peak power that existed, no statistical differences in velocity at peak power existed throughout the loading spectrum. This result suggests that the largest contributing factor to the overall power development during the hang power clean may be force production. According to our results, it appears that the participants were able to maintain the velocity of the movement throughout the loading spectrum. However, the amount of force needed to maintain that velocity increased throughout the loading spectrum. Because this is the first study that has examined the force at peak power and velocity at peak power during the hang power clean, future research should consider investigating the contributing factors that lead to power output.

The peak force produced by the participants at 45%, 65%, and 80% 1RM was not statistically different from each other indicating that participants were able to produce a similar amount of peak force despite the increasing load. However, the peak force at 30% 1RM was statistically lower than all of the remaining loads producing 10.0%, 11.9%, and

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14.0% less force than 45%, 65%, and 80% 1RM, respectively. In line with previous research, the peak force increased as the external load increased (Kawamori et al., 2005; Kilduff et al., 2007; Newton, Kraemer, Hakkinen, Humphries, & Murphy, 1996). Because this study only examined the peak force at 30%, 45%, 65%, and 80% 1RM loads, it is somewhat difficult to make certain comparisons with other research studies. However, participants in this study produced 2804.4 N at 30% 1RM as compared with 2799.6 and 2672.2 N reported by Kilduff et al. (2007) and Kawamori et al. (2005), respectively. Furthermore, participants in this study produced 3225.1 N at 80% 1RM as compared with 3487.0 and 3390.9 N reported by Kilduff et al. (2007) and Kawamori et al. (2005), respectively. It should be noted that the differences in peak force values were likely the result of differences in system masses between this study and those previously mentioned. Despite having different subject populations, the current results with regard to peak force are in line with previous research (Kawamori et al., 2005; Kilduff et al., 2007), making a case that the peak force produced during the hang power clean may follow the same trend in many populations. Thus, it may be possible to prescribe similar peak force training stimuli for these populations.

In this study, no statistical differences existed between the loads for the peak velocity, which is in line with the findings of previous research (Kilduff et al., 2007), but in contrast to other research (Kawamori et al., 2005). Kilduff et al. (2007) found that the greatest peak velocity occurred at 50% 1RM, but no statistical differences throughout their loading spectrum (30–90% 1RM) existed. In contrast, Kawamori et al. (2005) displayed that the greatest peak velocity during the hang power clean occurred at 60% 1RM. Furthermore, the peak velocity at 60% and 70% 1RM was statistically greater than the peak velocity at 90% 1RM. It is interesting to note that their participants produced the greatest peak velocity at such a high percentage of 1RM. This may be due to a lack of effort given by the participants at the lower loads. Based on the current findings and those displayed by previous research, it appears that there is some controversial evidence that the hang power clean has an optimal training load for improving the peak velocity of the movement. Therefore, it is difficult to make recommendations for training loads when it comes to improving peak velocity during the hang power clean. Further research examining this topic is needed.

Previous research that examined the optimal load for the power clean or hang power clean indicated that the peak power occurs at either 70% (Comfort et al., 2012; Kawamori et al., 2005) or 80% 1RM (Cormie et al., 2007a, 2007b; Cormie et al., 2007; Kilduff et al., 2007). However, several studies indicated that no statistical differences existed between the loads that produced the greatest peak power and 60–80% 1RM (Comfort et al., 2012) or 50–90% 1RM (Cormie et al., 2007; Kawamori et al., 2005; Kilduff et al., 2007). In line with previous research, this study displayed that the greatest peak power occurred at 80% 1RM. However, no statistical difference existed between the peak powers over the entire loading spectrum examined (30–80% 1RM). The current results suggest that athletic males with previous experience with the hang power clean may be able to train at loads as low as 30% 1RM and as high as 80% 1RM, and produce a similar peak power. However, it should be noted that the participants produced 12.9%, 11.7%, and 9.1% higher peak power at the loads of 80%, 65%, and 45% 1RM as compared with the peak power at 30% 1RM, which provides some rationale at prescribing heavier loads for the hang power clean. Although statistical differences in peak power did not exist between the different loads examined in this study, previous research suggests that the optimal load for peak power may be at a higher percentage of 1RM in stronger athletes than in weaker athletes (Stone et al., 2003). Thus, it is possible that the previously suggested loads are not optimal for stronger athletes; however, further research examining the optimal load of the hang power clean is needed. Furthermore, caution should be taken when interpreting these results because they may not be applicable to athletes with more experience with the hang power clean (e.g. Olympic weightlifters).

The greatest value of rate of force development was displayed at a load of 30% 1RM, which was 9.5%, 13.7%, and 31.4% higher than the rate of force development at 45%, 65%, and 80% 1RM. In addition, the rate of force development at 45% 1RM was 4.2% and 22.1% higher than the rate of force development at 65% and 80% 1RM. However, due to large variations in the rate of force development data at 30% and 45% 1RM, the only statistical difference that existed in this study occurred between the loads of 65% and 80% 1RM, with the rate of force development at 65% 1RM being 17.9% higher than the rate of force development at 80% 1RM. Large variation in the rate of force development data is not uncommon. This finding is in contrast to Schmidtbleicher (1992), who reported that the peak rate of force development is equal for all loads higher than 25% maximum force. Previous research that examined the rate of force development during the hang power clean (Kawamori et al., 2005; Kilduff et al., 2007) displayed no statistical differences in the rate of force development across loading spectrums ranging from 30% to 90% 1RM. Something to consider is the ability of participants to perform maximal hang power cleans with loads as light as 30% 1RM the same way they would perform a maximal hang power clean at 80% 1RM. It is possible that the participants in this study found it difficult to perform maximal effort hang power clean repetitions with loads that would be considered to be warm-up loads (30% and 45% 1RM) as compared with training loads (65% and 80% 1RM), thus likely increasing the variation in the rate of force development data.

A potential limitation to this study is the randomised order of exercise sets. In a practical setting, it is more likely that athletes will warm up using progressively heavier loads. This study used a randomised design to eliminate a potential order (potentiation or fatigue) effect and to isolate the impact of load on the variables of interest. However, in order to provide a more ecologically valid progression, it is suggested that future research considers performing a similar study with the hang power clean while progressively increasing the external load in order to replicate a typical resistance training session.

Conclusion

The external load used during a hang power clean altered peak force, force at peak power, and rate of force development, but not peak velocity, peak power, or velocity at peak power produced during the exercise. Loads of 45% 1RM and greater produced the greatest peak force values and should be prescribed to improve the peak force production during the hang power clean. Force appeared to be a greater determinant of peak power production as compared to velocity during the hang power clean. Therefore, practitioners should place their training emphasis on improving the strength of the athlete in order to improve their explosive force production and by extension, their power development. Similarly, it is suggested that athletes train with higher loads with the hang power clean exercise, with the intent to accelerate the lifter plus bar system as quickly as possible. Practitioners should prescribe loads at a higher percentage of 1RM for the hang power clean to improve lower body power because as athletes get stronger, their optimal load for power development may shift to higher percentage of 1RM. It is suggested that future research considers investigating force and velocity at peak power during the hang power clean and other weightlifting variations to provide insight on the contributing factors of power production. Finally, based on the training goal, practitioners should prescribe the proper loading schemes that will provide the best stimulus that will ultimately benefit the training and overall performance of their athletes.

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References

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

Cormie, P., McBride, J. M., & McCaulley, G. O. (2007a). The influence of body mass on calculation of power during lower-body resistance exercises. *Journal of Strength and Conditioning Research*, *21*, 1042–1049.

Cormie, P., McBride, J. M., & McCaulley, G. O. (2007b). Validation of power measurement techniques in dynamic lower body resistance exercises. *Journal of Applied Biomechanics*, *23*, 103–118.

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*, 340–349.

Hardee, J. P., Triplett, N. T., Utter, A. C., Zwetsloot, K. A., & McBride, J. M. (2012). Effect of interrepetition rest on power output in the power clean. *Journal of Strength and Conditioning Research*, *26*, 883–889.

Hopkins, W. G. (2013). A scale of magnitude for effect statistics. Retrieved from http://sportsci.org/resource/stats/effectmag.html

Hori, N., Newton, R. U., Andrews, W. A., Kawamori, N., McGuigan, M. R., & Nosaka, K. (2007). Comparison of four different methods to measure power output during the hang power clean and the weighted jump squat. *Journal of Strength and Conditioning Research*, *21*, 314–320.

Hori, N., Newton, R. U., Nosaka, K., & McGuigan, M. R. (2006). Comparison of different methods of determining power output in weightlifting exercises. *Strength and Conditioning Journal*, *28*, 34–40.

Hori, N., Newton, R. U., Nosaka, K., & Stone, M. H. (2005). Weightlifting exercises enhance athletic performance that requires high-load speed strength. *Strength and Conditioning Journal*, *27*, 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. *Journal of Strength and Conditioning Research*, *19*, 698–708.

Kilduff, L. P., Bevan, H., Owen, N., Kingsley, M. I., 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*, 260–269.

Newton, R. U., Kraemer, W. J., Hakkinen, K., Humphries, B., & Murphy, A. J. (1996). Kinematics, kinetics, and muscle activation during explosive upper body movements. *Journal of Applied Biomechanics*, *12*, 31–43.

Schmidtbleicher, D. (1992). Training for power events. In P. V. Komi (Ed.), *Strength and power in sport* (pp. 381–395). London: Blackwell Scientific.

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. *Journal of Strength and Conditioning Research*, *17*, 140–147.

Suchomel, T. J., Wright, G. A., Kernozek, T. W., & Kline, D. E. (2013). Kinetic comparison of the power development between power clean variations. *Journal of Strength and Conditioning Research* (Epub ahead of print).

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

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