Can the velocity of a 1RM hang power clean be used to estimate a 1RM hang high pull?

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ABSTRACT

The purpose of this study was to estimate the one repetition maximum hang high pull (1RM HHP) using the peak barbell velocity of a 1RM hang power clean (HPC). Fifteen resistance-trained men (age = 25.5 ± 4.5 years, body mass = 88.3 ± 15.4 kg, height = 176.1 ± 8.5 cm, relative 1RM HPC = 1.3 ± 0.2 kg·kg^{-1}) with previous HPC experience participated in two testing sessions that included performing a 1RM HPC and HHP repetitions with 20, 40, 60, and 80% of their 1RM HPC. Peak barbell velocity was measured using a linear position transducer during the 1RM HPC and HHP repetitions performed at each load. The peak barbell velocity achieved during the 1RM HPC was determined as the criterion value for a 1RM performance. Subject-specific linear regression analyses were completed using slope-intercept equations created from the peak velocity of the 1RM HPC and the peak barbell velocities produced at each load during the HHP repetitions. The peak barbell velocity during the 1RM HPC was 1.74 ± 0.30 m·s^{-1}. The average load-velocity profile showed that the estimated 1RM HHP of the subjects was 98.0 ± 19.3% of the 1RM HPC. Although a 1RM HHP value may be estimated using the peak barbell velocity during the HPC, strength and conditioning practitioners should avoid this method due to the considerable variation within the measurement. Additional research examining different methods of load prescription for weightlifting pulling derivatives is needed.

Keywords: one repetition maximum, weightlifting derivative, Olympic lift, maximal strength

INTRODUCTION

The hang high pull (HHP) is a weightlifting pulling derivative that removes the catch phase of the clean or snatch while emphasizing the rapid triple extension of the hip, knee, and ankle (plantar flexion) joints and propelling the barbell to chest height (30). Despite similarities in movement mechanics with the hang power clean (HPC), researchers have shown that unique force-time (37) and power-time (38) characteristics are produced during the HHP, which may be advantageous to the development of speed-strength characteristics. Specifically, greater magnitudes of force, velocity, and power output were produced during the HHP compared to the HPC, especially at lighter loads (i.e., <50% one repetition maximum [1RM]) (37, 38, 40, 42). It is important to note that the existing cross-sectional and longitudinal research on weightlifting pulling derivatives has primarily used percentages of a 1RM catching derivative to prescribe loads. For example, researchers have used loads based on the 1RM HPC or power clean of participants to examine the differences between weightlifting catching and pulling derivatives (9, 18, 19, 31, 32, 37, 38, 40, 41) and the effect of load during different pulling derivatives (6, 8, 15, 24, 25, 27-29) as well as during training prescription (5, 33-35). While prescribing loads in this manner may serve as an efficient strategy, these loads may not accurately represent the actual relative percentages of the exercise being performed. In contrast to catching variations, pulling derivatives lack specific criteria to determine a 1RM. For example, researchers have measured a theoretical 1RM HHP using the “nipple line” of their subjects marked by elastic bands as a height criteria (4); however, it should be noted that the physical characteristics of an individual, and the clothing they may be wearing, may alter the height requirements. Thus, due to lack of objective 1RM criteria, an alternative method to assess the maximal strength of an individual during a pulling derivative may be needed.

A method of 1RM estimation that has gained popularity within the strength and conditioning literature is the use of load-velocity profiles. Using this method, participants perform an exercise with at least two loads (typically several) that range across the loading spectrum (0-100% 1RM) while the barbell velocity is measured. Numerous researchers have examined the ability of load-velocity profiles to predict the 1RM of various traditional resistance training exercises (e.g., back squat, bench press, military press, etc.) (1-3, 16, 17, 26). It should be noted that the findings of the previous studies were mixed, with fixed (e.g., Smith machine) versions of exercises demonstrating lower variability compared to free weight versions of the exercises (16). However, only a handful of studies have examined the use of load-velocity profiles to predict the 1RM of weightlifting derivatives (4, 11, 14). The authors of the previous studies indicated that load-velocity relationship may not accurately assess 1RM performance of the 1RM power clean from the knee (4, 11), high pull from the knee (4), or mid-thigh clean pull (4) or the power clean when using mean barbell velocity (14). While the lack of research on weightlifting derivatives may be due to the barbell traveling independently from the body, further research examining additional exercises is needed.

While traditional exercises (e.g., squat, press, pull, etc.) may use mean barbell velocity within their prediction equations, and when measuring barbell velocity during a 1RM test (12), weightlifting derivatives and ballistic exercises may benefit from using peak barbell velocity given that the intent of the exercise is to maximize the velocity of the barbell. Haff et al. (14) indicated that a load-velocity profile using peak barbell velocity may be used to estimate a 1RM power clean; however, the coefficient of variation (stronger subjects = 7.6% and 7.5%; weaker subjects = 11.6% and 13.3% using four- and three-point calculations, respectively) may negatively impact the ability of strength and conditioning practitioners to monitor changes in maximal strength during the exercise. Because the peak velocity produced during a 1RM catching derivative provides a standard of maximal weightlifting derivative performance, it may be possible to use this value as the criteria of a 1RM performance for biomechanically similar weightlifting pulling derivatives, such as the HHP. Therefore, the purpose of this study was to estimate the 1RM of the HHP using the peak velocity of a 1RM HPC in resistance-trained men. Due to the biomechanical similarities between the HHP and HPC exercises, it was hypothesized that the predicted HHP 1RM would be less than the measured 1RM HPC performance due to the differences in the lift criteria of reaching the xiphoid process of the sternum while the hip, knee, and ankle joints are fully extended during the HHP, while the catch height of the HPC can be more variable (i.e., top of thighs parallel to the ground, or above).

METHODS

Experimental Approach to the Problem

A cross-sectional design was used to measure the peak barbell velocity during a 1RM HPC test and peak barbell velocities during the HHP performed across five relative loads. Each subject attended two testing sessions within a week that included 1RM HPC and HHP testing sessions. The HHP testing session repetitions were performed using percentages of each subject's 1RM HPC.

Subjects

Resistance-trained men with previous training experience with the HPC exercise agreed to participate in this study (n = 15, age = 25.5 ± 4.5 years, body mass = 88.3 ± 15.4 kg, height = 176.1

± 8.5 cm, relative 1RM HPC = 1.3 ± 0.2 kg·kg^{-1}). Each subject had been consistently participating in resistance training sessions at least three times per week for the last year and incorporated the HPC or other weightlifting derivatives into their training regimen at least once per week. Each subject previously competed in American football, basketball, soccer, track and field, ice hockey, or baseball. Because none of the subjects were competitive weightlifters, the principal investigator screened the HPC technique of each individual prior to the study to ensure that appropriate technique was used and that a 1RM could be performed safely. The current study was approved by the Carroll University Institutional Review Board (#19-015; approved April 15, 2019) and each subject read an informed consent form and provided their written consent prior to participating in any testing.

An *a priori* sample size estimation for a linear regression was completed. At a statistical power level of 0.94, it was determined that 15 subjects were needed to display a large correlation (i.e., r = 0.70; R^2 = 0.49).

Procedures

Subjects arrived for the 1RM HPC testing session and were first taken through the informed consent procedures by the principal investigator. Following informed consent, the anthropometric information of each subject was collected before starting the warm-up procedures. Prior to HPC warm-up repetitions, the subjects completed a general warm-up that consisted of three minutes of light-moderate stationary cycling, dynamic stretches (e.g., lunges, walking quadriceps stretch, hurdle walks, etc.), bodyweight squats, and vertical jumps. Upon completion, each subject performed a specific warm-up that included a self-selected unloaded (i.e., barbell only) warm-up and HPC warm-up five, five, three, and one repetition(s) with 30, 50, 70, and, 90% of their self-estimated 1RM, respectively, in accordance with previous procedures (28). After the warm-up repetitions, the subjects performed maximal HPC attempts with 3-5 minutes of rest between lifts, until a 1RM was achieved. The minimum increase between attempts was 2.5 kg and all 1RM attempts required the subject to perform the lift without having the top of their thigh drop below parallel (visually monitored by principal investigator and testers) during the catch phase. The subjects all achieved their 1RM HPC within four maximal attempts. Following 1RM testing, the subjects were familiarized with the HHP exercise by performing light (<50% 1RM HPC) repetitions based on the technique described in previous literature (30).

Each subject returned to the laboratory for their HHP testing session one week following their 1RM HPC session. Upon arrival, the subjects performed the same general warm-up described above, self-selected 20 kg barbell warm-up, and finally, HHP warm-up repetitions using 30 and 50% of their 1RM HPC (29, 40). After a two-minute rest, subjects started performing maximal effort HHP repetitions with 20, 40, 60, and 80% of their 1RM HPC in a progressive order. Briefly, each subject held each respective load in the mid-thigh (power) position, received a countdown of "3, 2, 1, Go!", performed a hip hinge movement whereby the barbell was lowered to a position just above their patellae and without pausing, transitioned back to the starting (mid-thigh) position by flexing their knees and elevating the barbell back up their thighs, and rapidly extended their hip, knee, and ankle joints and shrugging their shoulders to perform the 2nd pull phase of the lift before flexing their elbows to elevate the barbell to the xiphoid process of the sternum while maintaining full extension of hip, knee, and ankle joints (30). Three repetitions were performed with each load with a minute of rest between trials and two minutes between each load.

Data Analyses

Peak barbell velocity during the concentric phase of the 1RM HPC and HHP repetitions were measured using a GymAware Powertool (Kinetic Performance Technology, Braddon, Australia) (39, 43) positioned on the sleeve of the barbell. This position was used to prevent any disruption to the subject's grip and the measurement of barbell displacement. The GymAware device was connected via Bluetooth to a tablet (iPad 2, Apple Inc., Cupertino, CA, USA) with the latest version of the application software available. Velocity data were collected using a variable sampling rate with level crossing detection while the displacement of the barbell was determined by the rotational movement of the GymAware cable and spool. Horizontal displacement of the barbell was accounted for by a sensor that measured the angle of the movement and adjusted the measured vertical displacement and velocity accordingly. While the peak barbell velocity achieved during the 1RM HPC of each subject is self-explanatory (i.e., single repetition), the average peak barbell velocity achieved across the HHP repetitions at each load were used for statistical comparison.

Statistical Analyses

The normality of data distribution was examined using the Shapiro-Wilks test. In addition, two-way mixed intraclass correlation coefficients and typical error expressed as coefficients of variation were used to evaluate relative and absolute reliability of peak barbell velocity data at each load during the HHP. In this regard, intraclass correlation coefficients (ICC) with a lower bound 95% confidence interval (CI) of <0.50, 0.50-0.74, 0.75-0.90, and >0.90 were interpreted as poor, moderate, good, and excellent, respectively (20), whereas coefficients of variation <10% were considered acceptable (10). Subject-specific linear regression analyses were completed using slope-intercept equations (y = mx + b) created based on the peak velocity of the 1RM HPC and the peak barbell velocities during the HHP performed at each relative load. A spreadsheet (Microsoft Excel, Microsoft Inc., Redmond, WA, USA) was then used to determine individual slopes (m) and y-intercepts (b). The estimated 1RM HHP for each subject was then calculated using individual 1RM HPC peak velocities (y) within the equations.

Results

All velocity data were normally distributed. The ICCs ranged from 0.95-0.98 while coefficients of variation ranged from 2.2-4.6% across all the loads examined. The peak barbell velocity during the 1RM HPC was 1.74 ± 0.30 m·s^{-1}. The HHP peak velocities at 20, 40, 60, and 80% 1RM were 2.96 ± 0.36 m·s^{-1}, 2.55 ± 0.20 m·s^{-1}, 2.26 ± 0.17 m·s^{-1}, and 1.98 ± 0.20 m·s^{-1}, respectively. The group load-velocity profile and individual velocities achieved are displayed in Figure 1. Collectively, the individual load-velocity profiles showed that the estimated 1RM HHP was 98.0 ± 19.3% of the 1RM HPC.

(Figure 1 about here)

DISCUSSION

The purpose of this study was to estimate the 1RM HHP of resistance-trained individuals using individual load-velocity profiles and the peak velocity of their 1RM HPC as a criterion value. Our findings suggest that the estimated 1RM HHP is approximately 98% of the 1RM HPC, although there may be considerable variability (coefficient of variation = 19.7%) in this measurement. Thus, while these findings support our initial hypothesis, they should be interpreted with extreme caution. For example, the lowest and highest estimated HHP 1RM percentages relative to the 1RM HPC in the current study were 77.6% and 153.6%, respectively.

It should not be surprising that the predicted 1RM of the HHP was less (albeit similar) than the HPC due to the barbell height that is required during each exercise (HPC displacement = 47.8 ± 7.4 cm; HHP displacement = 60.9 ± 5.7 cm). For example, the HHP requires an individual to elevate the barbell to chest height (30) whereas the HPC simply requires the barbell to be elevated to a point where the individual can drop under and rack it on their shoulders in a front squat position at parallel depth or above (28). Given the potential differences in technique, the resultant height of the barbell during a HPC may vary considerably based on the exercise experience, anthropometrics, relative strength, and mobility of an individual. For example, if an individual has difficulty dropping under the barbell despite elevating it to an appropriate height, this may impact the peak velocity of barbell and their 1RM HPC. In this light, part of the variance of the predicted 1RM HHP may be explained by the variation of the HPC peak velocity (coefficient of variation = 17.2%). While the current subjects all had previous experience with the HPC and HHP exercises, it is important that researchers and practitioners understand this limitation when using the peak velocity of a weightlifting catching derivative when predicting the 1RM of a pulling derivative. Moreover, it should be noted that direct measurements of a 1RM power clean have shown ~5% of variation, despite being assessed with relatively inexperienced individuals (7, 13).

Another factor that may explain part of the predicted 1RM HHP variance was the range in height of the subjects (165-192 cm). Although individual regression equations were used for each subject, taller individuals may have achieved higher peak barbell velocities due to greater displacements of the barbell during the HHP repetitions, particularly those performed with lighter loads. While this is assuming that the taller subjects achieved greater displacements than shorter subjects within the same duration, researchers have shown that the height of an individual may significantly impact the velocities achieved during different exercises (12). Combined with differences in exercise technique noted previously, the differences in height and by extension barbell displacement, may lead to either over- or under-estimations of their respective 1RM HHP. While it is not impossible to perform the current study with homogeneous subjects, the ecological validity of doing so may not accurately represent the different athletes that strength and conditioning practitioners work with.

The current study is the first to estimate the 1RM of a weightlifting pulling derivative using the peak velocity of a similar catching derivative. While this approach may be novel, differences in subject training experience, technique, and anthropometrics may prevent its widespread use within the strength and conditioning field. As noted previously, weightlifting pulling derivatives are typically prescribed using percentages of a 1RM catching derivative (5, 6, 8, 15, 24, 25, 27-29, 33-35). While this may not be an issue if both weightlifting catching and pulling derivatives are prescribed, strength and conditioning practitioners only prescribing pulling variations may require a loading alternative. While some researchers have attempted to assess the 1RM of different pulling derivatives (4) or promoted the use of body mass percentages for loading (21, 22), the limitations of each method must be acknowledged. First, strength and conditioning practitioners must acknowledge that there is currently a lack of criteria for a 1RM weightlifting pulling derivative. The previous study used predetermined pulling heights for each subject (4); however, the displacement of the barbell may change based on the loads that are being used. Thus, heavier loads may continue to be implemented despite the predetermined height not being achieved. Moreover, a given barbell height may be achieved due to changes in an individual's technique (e.g., increased back extension). Regarding the use of body mass percentages, it is important to acknowledge that while individuals may achieve peak power at specific percentages during various weightlifting pulling derivatives (21, 23, 36), these findings can be influenced by an individual's relative strength, making it difficult to prescribe loads in this manner. Despite the current study and the other examined methods, there is a need for additional research that examines different loading alternatives for weightlifting pulling derivatives.

PRACTICAL APPLICATIONS

The estimated 1RM HHP in the current study was approximately 98% of the subjects' 1RM HPC; however, strength and conditioning practitioners should avoid using this method of 1RM prediction due to the considerable variation that may exist. The existing variation is likely due to subject exercise technique, anthropometrics, relative strength, and mobility. Based on the current findings, additional research examining different methods of load prescription for weightlifting pulling derivatives is needed.

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The authors report no conflicts of interest.

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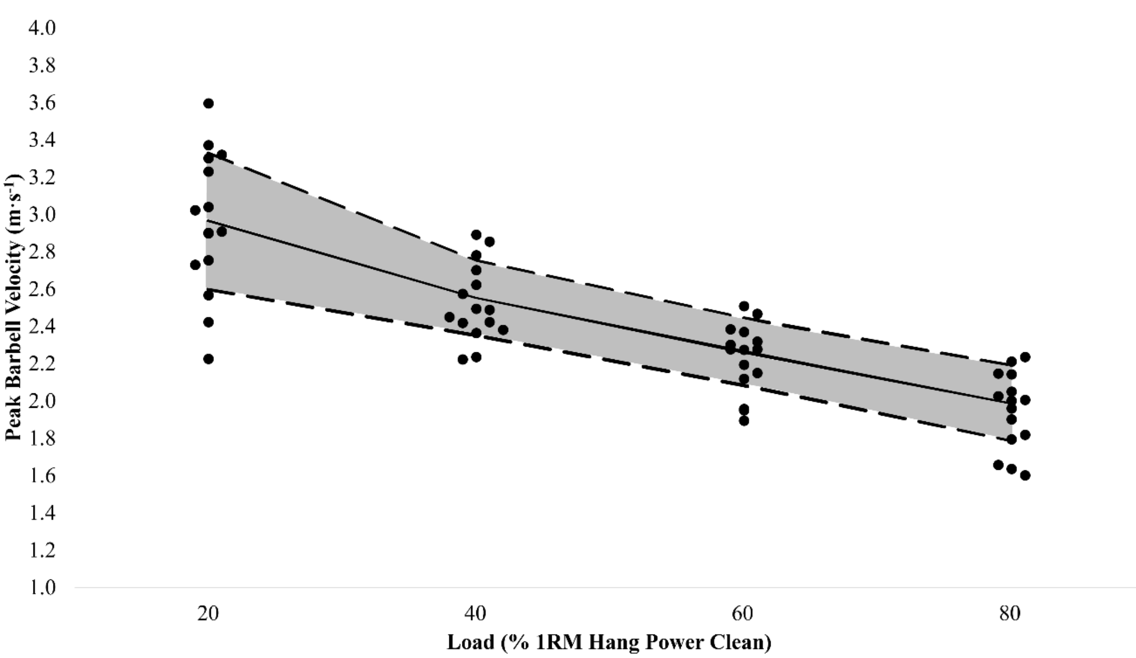

Figure Legend

Figure 1. Average load-velocity relationship for the hang high pull exercise performed with 20, 40, 60, and 80% of the subjects' one repetition maximum hang power clean. Solid line = mean; dashed lines = 95% confidence limits; black dots = individual subject peak barbell velocities at each load.