Original Article

# Predicting relative load by peak movement velocity and ratings of perceived exertion in power clean

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**ABSTRACT**

Evaluating an individual's maximal strength is considered a key factor in prescribing and regulating resistance training programs in athletes. The present study analyzed the suitability of predicting the relative load lifted in the power clean exercise from the peak movement velocity and perceived exertion. In order to determine the full-load velocity and load-perceived exertion relationships, 154 young, resistance-trained male athletes performed a 4- to 6-set progressive test up to the one-repetition maximum. Longitudinal regression models were used to predict the relative load from the peak velocity and the OMNI-RES 0-10 scale, taking sets as the time-related variable. Load associated with peak velocity and with perceived exertion scale values expressed after performing 1 or 2 repetitions, were used to construct two adjusted predictive equations: Relative load = 128.85 – 25.86 × peak velocity; and Relative load = 31.10 + 7.26 × OMNI-RES 0–10 scale value. Although both models provided effective estimates of relative load, the coefficient of determination ($R^2$) of the OMNI-RES perceived exertion scale was larger than when using the peak movement velocity model (88% vs. 46%). These findings highlight the importance of perceived exertion to estimate strength performance in the power clean exercise. **Key words:** OMNI-RES SCALE, ONE REPETITION MAXIMUM (1RM), LOADING INTENSITY, WEIGHTLIFTING.

**Cite this article as:**
Naclerio, F., & Larumbe-Zabala, E. (2018). Predicting relative load by peak movement velocity and ratings of perceived exertion in power clean. *Journal of Human Sport and Exercise, 13*(3), 639-650. doi:https://doi.org/10.14198/jhse.2018.133.14

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Submitted for publication December 2017
Accepted for publication April 2018
Published *in press* May 2018
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

**doi:10.14198/jhse.2018.133.14**

## INTRODUCTION

Power clean is a type of weightlifting exercise commonly incorporated into strength and conditioning programs for athletes. Unlike traditional resistance exercises such as the bench press or squat that are performed at a relatively low movement velocity, the power clean is an explosive but highly controlled movement (Faigenbaum et al., 2012). In the power clean exercise, a barbell is lifted from the platform to the shoulders in a single, continuous, forceful movement (Ratamess, 2012). The power clean requires lifters to exert high forces from the beginning of the movement to accelerate the bar through the entire range of pulling without actively decelerating the barbell as happens during the last part of the concentric phase in squat or bench press (Faigenbaum et al., 2012). Success with the power clean exercise may represent a better expression of athletes' whole body power relative to other resistance exercises. In fact, in athletes the power clean assessment provides a highly reliable measure of maximum mechanical power (McGuigan & Winchester, 2008), which is one of the most important determinants of athletic performance. High achievements in weightlifting movements, such as the power clean, have been associated with improved performance in isometric strength (Beckham et al., 2013), 10-m sprint (Baker & Nance, 1999), 20-m sprint, and countermovement jump (Hori et al., 2008) endeavors.

The most commonly used methodology to evaluate strength performance in resistance exercises is the determination of the maximum weight that an individual could lift one time without support (1RM) (Naclerio, Jimenez, Alvar, & Peterson, 2009; Singh, Foster, Tod, & McGuigan, 2007). Even though the 1RM power clean test is unique because it can be used to assess both strength and power, in some cases, its regular assessment would be impractical over the entire training cycle. Consequently, to regularly monitor athletes' strength and power performance, alternative methodologies have been proposed. Some researchers have used the relationship between movement velocity and load to monitor changes in the ability to apply force and to estimate the relative load (% 1RM) represented by the used resistance in the bench press (Gonzalez-Badillo & Sanchez-Medina, 2010; Jidovtseff, Harris, Crielaard, & Cronin, 2011) and squat (Bazuelo-Ruiz et al., 2015). Even though measured movement velocity within or between sets is a reliable criterion for monitoring performance variations during resistance exercises (Izquierdo et al., 2006) including power cleans (Haff et al., 2003), this method requires the use of additional devices (velocity transducers or accelerometers) that are not always available to athletes and coaches. Thus, perceived exertion scales have been successfully used as an alternate means of monitoring resistance exercise intensities (Gearhart et al., 2002) and changes in movement velocity within a singular set using different relative loads (Naclerio et al., 2011) or between sets using different training configurations (Mayo, Iglesias-Soler, & Fernandez-Del-Olmo, 2014), as well as to select the initial training load (Lagally, Amorose, & Rock, 2009).

Recently, Naclerio & Larumbe-Zabala (2016), analyzed the accuracy of two regression models for predicting the relative load in the bench press from both the mean movement velocity and ratings of perceived exertion (RPE), as measured by the OMNI-RES (0–10) scale. Both models were capable of estimating the relative load with an accuracy of 84% and 93%, respectively. No study has applied this prediction method to estimating the relative load during the power clean exercise. Thus, the current investigation analyzed and compared two regression models to estimate the relative load from the vertical peak movement velocity (PV), and from ratings of perceived exertion (RPE) in the power clean (PC) exercise in resistance-trained male athletes.

 

## METHODS

### *Study Design*
The present study used a correlational research design measuring the movement velocity and the perceptual response during an incremental load test in the power clean exercise. Following a familiarization period of 12 sessions, participants performed a progressive PC strength test with increasing loads up to the 1RM for the individual determination of the load to peak velocity and load to RPE relationships (Naclerio, Colado, Rhea, Bunker, & Triplett, 2009). Longitudinal regression models were constructed to predict the relative load in terms of %1RM from PV and RPE based on the best-fit regression line, and taking sets as the time-related variable.

### *Participants*
One hundred and fifty-four young, healthy, resistance-trained male athletes (Mean ± SD: age = 26.5±4.4 y, height = 1.76±0.061 m, body mass = 75.9±8.4 kg, body mass index (BMI) = 24.2±1.9 kg·m$^{-2}$), volunteered to take part in this study. Even though all the participants regularly used weightlifting exercises as a part of their conditioning program for a minimum of 1 and a maximum of 3 years, none of them have experience as a weightlifting athlete.

All participants reported not having taken any banned substances as declared by the International Olympic Committee 2014 anti-doping rules (International Olympic Committee, 2014). No physical limitations or musculoskeletal injuries that could affect strength performance were reported. All participants provided written informed consent in accordance with the Declaration of Helsinki. The University Ethics Committee approved procedures.

### *Procedures*
All 154 participants underwent 12 familiarization sessions performed over a month (3 times per week) to use the OMNI-RES (0–10) scale proposed by Robertson et al. (Robertson et al., 2003). The OMNI Scale for resistance exercises has both verbal and mode-specific pictorial descriptors distributed along a comparatively narrow response range of 0–10. These characteristics make the OMNI scale a useful methodology to control the intensity of resistance exercises (Naclerio, Chapman, & Larumbe-Zabala, 2015).

During the familiarization period, the participants followed their normal resistance-training workouts that comprised 2–4 sets of 6–8 repetitions of 6–8 exercises of different muscle groups (upper, middle, and lower body) including the power clean. For this particular exercise each repetition was separated from the next one by 5 to 10 sec, sets involved only 6 repetitions, proper technique and lifting procedures that included instructions on how to safely ‘‘miss’’ a lift were reinforced.

During these sessions, standard instructions and RPE OMNI-RES (0-10) anchored procedures were explained to the participants in order to properly reflect the rating of perceived effort for the overall body (Robertson et al., 2003) after performing the first and the last repetition in each set of every exercise (Lagally et al., 2009; Naclerio et al., 2011).

### *Progressive Test*
Two to four days after completing the familiarization period, all the participants performed a progressive test with increasing loads up to the 1RM for the individual determination of the load to peak velocity and load to RPE relationships in the PC exercise. The PC exercise was performed using free weights on a weightlifting platform according to the technique described by Ratamess (2012). Briefly, participants were instructed to

grip the barbell with a slightly wider-than-shoulder width, keeping their hips lower than the shoulders and the barbell about 3 cm in front of the lower leg region (shank) with their feet about hip-width apart, ‘‘chest up,’’ elbows rotated outward, and eyes looking forward. The participants started the lifting with a forceful extension of their knees and hips while keeping their shoulders directly over the barbell. As the barbell rose above the knees, participants explosively extended their hips, knees, and ankles, passing from the first pull to the second pulling phase. When their lower body reached full extension, the participants forcefully shrugged their shoulders with both elbows fully extended. As the barbell continued to rise, the participants flexed their elbows, hips, knees, and ankles, positioned their body under the barbell to catch the weight in a quarter-squat position, placing the barbell across their shoulders with both elbows pointing forward. Although the PC exercise comprises different phases, this movement consists in lifting the barbell from the floor to the front of the shoulders in one continuous movement maintaining the bar displacement as vertical as possible (Souza & Shimada, 2002). Feedback from a strength and conditioning coach ensured that athletes used proper PC technique. The progressive test was programmed in a way that allowed every participant to reach the 1RM between 4 and 6 sets of 2 to 1 repetitions. Each set had inter-set rest periods of 4–5 minutes, depending on the magnitude of the resistance to be overcome.

To determine the initial load of the progressive test, the first set was performed with approximately 50% of the estimated 1RM, as agreed between participants and coaches after completing the familiarization period. Resistances were progressively increased based on a 10% slot in order to reach the maximum weight in 6 sets, e.g., first set ~50%; second set ~60%; third set 70%; fourth set ~80%; fifth set ~90%; and sixth set 100% (1RM value). When more than one repetition was performed, the repetition that produced the greatest PV was selected for analysis.

### *Equipment*

An optical rotary velocity transducer (Winlaborat®) with a minimum lower position register of 1 mm connected to the proprietary software Real Speed Version 4.20 was used for measuring the position and calculating the peak velocity achieved during each repetition of the PC exercise. For the purpose of this study the peak velocity was determined from the velocity–time curve generated by using the displacement–time data generated by the Real Speed 4.20 software.

The cable of the transducer was connected to the center of bar (middle distance between the sides) in such a way that the exercise could be performed freely and minimizing differences in the displacement produced between the opposite sides of the barbell. The reliability of the progressive test, including load sequences, velocity profile, and the OMNI-RES (0-10) scale values, was demonstrated in a series of previous pilot studies [intraclass correlation coefficients (ICC) >0.95]. For the present investigation, thirty participants were randomly selected to assess the repeatability of the measures provided by the progressive test. The ICCs for the 1RM, peak velocity, and RPE values were 0.95, 0.82, and 0.92 respectively.

### *One Repetition Maximum Determination*

When participants approached the estimated 1RM, they were asked to perform two repetitions separated by a 30-second rest period (to recover the proper starting position and minimize the risk of technique distortion). If participants were able to successfully complete the second repetition, they rested for 3–5 minutes before attempting another 1RM trial (Freitas de Salles et al., 2009). All participants were able to achieve their 1RM within 4–6 sets of the progressive test.

### *OMNI-RES (0–10) scale instructions*

Participants were instructed to report the RPE value indicating a number from the OMNI-RES (0–10) scale immediately after completing each set of the progressive test. Participants were asked to use any number on the scale to rate their overall exertion of the effort they felt during the exercise (Pageaux, 2016), and the investigators used the same question each time: "how hard do you feel your muscles are working during the exercise?" (Pageaux, 2016). In our study, a rating of 0 was associated with no exertion (seating or resting), and a rating of 1 was anchored with the perception of exertion while lifting an extremely easy weight (Lins-Filho et al., 2012). A rating of 10 was considered to be maximal exertion and associated with the most stressful exercise ever performed (Lagally et al., 2009). An experienced and certified strength-and-conditioning coach supervised all testing and recorded the RPE value at the end of all sets of the progressive test. The OMNI–RES scale was in full view of participants at all times during the procedures.

Participants were asked to abstain from any unaccustomed or hard sets, including repetitions to failure, during the week before the test. Additionally, they agreed no to perform any exercise related to resistance training during the 72 hours preceding the progressive test assessment session. Furthermore, the participants were instructed to maintain their regular diet and avoid caffeine ingestion for 48 hours before the assessment session.

### *Analysis*

For each RPE value expressed immediately after performing a 1–2 repetitions set, the peak velocity attained and % 1RM loads used in each set of the progressive test were summarized as mean and 95% confidence intervals. Since each participant was assessed repeatedly, longitudinal regression models were used to predict the %1RM from peak velocity and RPE, taking sets as the time-related variable. Three models were estimated for each predictor: pooled ordinary least squares (OLS) regression model, fixed-effects model, and random-effects model. Hausman's specification test and the Breusch-Pagan Lagrange multiplier test were used to compare the consistency and efficiency of the models. The significance level was set at 0.05. Data analyses were performed with Stata 13.1 (StataCorp, College Station, TX).

## RESULTS

The participants performed a median of 5 sets until 1RM was reached (interquartile range was 5–6, the minimum was 4, and the maximum was 7). In total, 798 assessments were analyzed from the 154 participants. Maximum 1RM at PC was 71.3±11.8 kg. The peak velocity attained with the 1RM load was 1.60 ± 0.30 $m{\cdot}s^{-1}$. The median RPE value expressed by the participants after performing the last set (1RM) of the Power Clean was 10, interquartile range 9–10.

### *Relationship between relative load, RPE value, and peak velocity*

As shown in Table 1, the relative load was below 50% of 1RM when RPE was rated as 0 or 1. Greater than 7 RPE values were associated with very heavy relative loads (>90% of 1RM). Indeed, 10 RPE rate was close to 1RM (99.95%, 95% C.I.= 99.86 to 100). An inverse relationship was found between RPE and PV starting around ~2.70 $m{\cdot}s^{-1}$ for the 0-1 RPE values and declining gradually to ~1.60 $m{\cdot}s^{-1}$ for the 10 RPE rate.

Table 1. Mean (SD) and 95% Confidence Interval of %1RM and Peak Velocity Corresponding to each RPE Score.

| | | *%1RM* | | | *Peak Velocity* ($m{\cdot}s^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| RPE | n | M | SD | 95% CI | M | SD | 95% CI |
| 0 | 1 | 46.15 | – | – | 2.68 | – | – |
| 1 | 17 | 46.92 | 4.25 | 44.73–49.10 | 2.75 | 0.51 | 1.75–2.51 |
| 2 | 57 | 49.64 | 9.43 | 47.13–52.05 | 2.47 | 0.38 | 1.73–2.37 |
| 3 | 74 | 52.56 | 7.44 | 50.92–54.32 | 2.42 | 0.48 | 1.48–2.31 |
| 4 | 93 | 59.10 | 6.84 | 57.88–60.64 | 2.41 | 0.47 | 1.49–2.32 |
| 5 | 77 | 67.17 | 6.64 | 65.89–68.81 | 2.19 | 0.42 | 1.37–2.09 |
| 6 | 83 | 74.64 | 5.63 | 73.52–75.95 | 2.04 | 0.35 | 1.35–1.96 |
| 7 | 97 | 83.43 | 6.98 | 82.23–84.93 | 1.91 | 0.34 | 1.24–1.84 |
| 8 | 75 | 90.34 | 6.78 | 88.96–91.93 | 1.81 | 0.28 | 1.27–1.75 |
| 9 | 77 | 96.94 | 3.70 | 95.20–96.62 | 1.67 | 0.30 | 1.08–1.61 |
| 10 | 84 | 99.95 | 0.44 | 99.86–100.05 | 1.57 | 0.30 | 0.97–1.5 |

*Note: %1RM= relative load in percentage of 1 repetition maximum; RPE=rate of perceived exertion with OMNI RES 0-10 scale.*

Table 2 shows the fit of all regression models estimated to predict relative load from peak velocity or RPE.

R-squared values were high and significant for the three models (Pooled OLS, fixed effects, and random effects) using peak velocity to predict %1RM ($R^2 = .46$). The F-test for individual errors ($u_i$) resulted statistically significant ($p < .001$) whereas the Breusch-Pagan test for OLS vs. random effects did not show differences. Additionally, the random effects model showed similar $R^2$ and Hausman's test did not support significant differences between random and fixed effects models. Consequently, consistency and efficiency tests for peak velocity models suggested the adoption of the OLS model. This model was able to explain 46% of overall variation in the relative load (%1RM). The recommended equation (1) to estimate the relative load from peak velocity was determined as:

1) Relative load (% 1RM) = 128.84 – 25.85 (peak velocity)

On the other hand, RPE-based models predicted 88% of overall variation in relative load. The F-test of individual errors was significant ($p < .001$), the Breush-Pagan LM test was significant ($p < .001$), and the SEE was higher for OLS model, indicating that OLS model was less appropriate. Both the random effects and fixed effects models explained 18% of between-participants variation and 94% of over-time (sets) variation. Hausman's test did not determine statistically significant differences to support the random effects model over the fixed effects model. Consequently, to estimate the relative load from the RPE expressed at the end of each particular set, the authors suggest following equation (2) from the fixed effects model:

(2) Relative load (% 1RM) = 31.10 + 7.26 (RPE)

 

Table 2. Fit of Regression Models Predicting Relative Load (%1RM) in Power Clean Exercise from PV and RPE (n=154).

| | *Constant* | | *Peak Velocity* (m·s¹) | | *RPE* | | *Model* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $B_0$ | *p-values* | $B_{PV}$ | *p-values* | $B_{RPE}$ | *p-values* | *p-values* | $R^2$ | $R^2_{btw}$ | $R^2_{with}$ | SEE |
| Peak Velocity | | | | | | | | | | | |
| Pooled OLS | 128.85 | < .001 | –25.86 | < .001 | | | < .001 | 0.46 | | | 13.76 |
| Fixed effects | 162.19 | < .001 | –42.14 | < .001 | | | < .001 | 0.47 | 0.02 | 0.76 | 10.17 |
| Random effects | 128.85 | < .001 | –25.86 | < .001 | | | < .001 | 0.47 | 0.02 | 0.76 | 10.16 |
| RPE | | | | | | | | | | | |
| Pooled OLS | 34.13 | < .001 | | | 6.77 | < .001 | < .001 | 0.88 | | | 6.60 |
| Fixed effects | 31.10 | < .001 | | | 7.26 | < .001 | < .001 | 0.88 | 0.18 | 0.94 | 4.92 |
| Random effects | 33.24 | < .001 | | | 6.91 | < .001 | < .001 | 0.88 | 0.18 | 0.94 | 4.92 |

*Note: RPE = rate of perceived exertion with OMNI RES (0–10) scale; p-values are shown for each coefficient and for the model adjustment. $R^2$ = overall adjustment of the model; $R^2_{btw}$ = variation due to individual differences; $R^2_{with}$ = variation due to over-time differences, SEE = Standard Error of Estimate.*

## DISCUSSION

The main findings of the present study were that both the peak velocity attained with a given absolute load and the RPE values expressed immediately after performing 1 or 2 repetitions are acceptable predictors of the relative load (%1RM) in the PC exercise. However, the OMNI-RES model showed a better fit compared to the peak velocity method (88% vs. 46% variance explained, respectively).

To the best of the authors' knowledge, this is the first study to analyze the association between load with the peak velocity and the perceived exertion, and its suitability to predict the relative load in a weightlifting exercise such as PC in resistance-trained individuals. The sensitivity of the velocity model to estimate the relative load in PC was lower compared to previous studies using other types of resistance exercises such as the bench press (Gonzalez-Badillo & Sanchez-Medina, 2010; Naclerio & Larumbe-Zabala, 2016) or the squat (Bazuelo-Ruiz et al., 2015). Mechanical differences in the execution of weightlifting exercises compared to the more traditional resistance movements would explain the obtained results. In contrast with bench press and squat exercises, which are performed at a relatively low mean movement velocity (~0.20 $m{\cdot}s^{-1}$) when the load approaches the maximum (>90% 1RM), in weightlifting the velocity of the bar does not decrease to such lower levels, showing values ~ 1 and > 1.2 $m{\cdot}s^{-1}$ for the mean (Naclerio & Moody, 2015) and peak velocity (Ratamess, 2012) respectively when moving heavy to maximal loads. Similar to the present study, Naclerio & Larumbe-Zabala (2016) obtained a high level of accuracy (93%) of the RPE model to estimate the relative load in bench press. However, a different scenario was observed for the model based on the movement velocity, which was shown to be less sensitive in PC compared to the bench press study (46% vs. 84% respectively). Different from the aforementioned studies that used mean accelerative movement velocity (calculated from the accelerative portion of the concentric phase, during which the acceleration of the barbell was ≥ -9.81 $m.s^{-2}$), in the present investigation the second higher peak vertical velocity achieved during the second pull in the PC exercise was considered. Additionally, the full load-to-velocity and load-to-perceived exertion longitudinal regression models were calculated starting with a load of about 50%, while bench press models started at about 30% 1RM (Naclerio & Larumbe-Zabala, 2016). Technical differences related with the movement execution of the PC exercise compared to the bench press or the squat would be the main reason to explain higher coefficient of determination (Table 2) observed for the velocity model. PC requires a higher level of technical competency, demanding specific sequential coordinated muscle actions, centered on the control and postural stabilization of the spine (Naclerio & Moody, 2015). The bar is expected to follow a quasi-straight upward trajectory, including relatively small rearward movement during the ascending portion of movement (1st and 2nd pull). However, only highly qualified athletes show a very close vertical bar path trajectory using both submaximal and maximal relative loads (Winchester, Erickson, Blaak, & McBride, 2005). Although participants of the present study had been performing PC for a minimum period of 1 year, none of them were experienced weightlifters. Therefore, a relatively large amount of horizontal displacement of the bar could be expected, and this would be one of the main factors determining the inferior $R^2$ of the velocity model.

Despite of the lower fit of the peak velocity model, both assessed methods (velocity and RPE) would allow coaches to have an acceptable estimation of the performance variation after performing only 1 set of 1–2 repetitions using a submaximal load in PC. The proposed methodology would help athletes to avoid long testing sessions involving high levels of neuromuscular stress that, in turn, would interfere with other training activities. As depicted in Table 1, the RPE model was more accurate than the peak velocity with a lower error of estimation (4.92% vs. 13.76%). The ability of perceived exertion for estimating the relative load (%1RM) and discriminating between different resistance-training intensities has been previously demonstrated (Lagally et al., 2009; Singh et al., 2007). Lagally et al. (Lagally et al., 2009) tested the application of RPE derived from the OMNI-RES (0-10) metric to select the initial relative load associated with specific resistance-training outcomes: muscle endurance (RPE ~3), hypertrophy (RPE ~6), or maximal strength (RPE ~9). However, in order to reduce inter-individual differences in the interpretation of the scale resulting from subjective perceptions of exercise intensities and the anchored procedures between the RPE values and the perceived effort, the application of perception scales must be preceded by a proper period of familiarization. Participants of the current investigation underwent a familiarization period of 12 sessions using the OMNI-RES (0-10) metric to select the load and estimate the level of fatigue at the end of each set for all the performed exercises included in the corresponding workout. Thus, the present results support the use of the OMNI-RES (0-10) scale as an accurate, easy, practical, and economic method for controlling performance variation in daily workouts and throughout the entire training process in male resistance-trained athletes provided they have completed an appropriate period of familiarization.

The results of the present study provide two useful predictive models to estimate the %1RM from a multiple linear regression fitting. In these models, the load lifted and the corresponding peak velocity or the estimated RPE values were able to explain 46% and 88% of the predicted %1RM respectively. Both models would facilitate coaches to monitor the athletes' performance on a regular basis avoiding frequent testing sessions that some times interfere with the training process. Consequently, a training program could then be easily modified according to the present day's performance level. Although the RPE method demands a period of familiarization, its better fit of the data compared to the peak velocity model makes is an attractive alternative for routine assessments in athletes from different discipline who use weightlifting type exercises as a part of their conditioning preparation. From a practical point of view, according to the model presented (Table 2), for each 0.2 $m·s^{-1}$ increase in barbell peak velocity achieved with a given weight, the corresponding relative load (%1RM) will decrease by about 5.2%. On the other hand, for each decrease in the RPE value expressed after performing a set of 1-2 repetitions, the relative load corresponding to the used weight will decrease by 7.26%.

The present results support the suitability of the peak velocity or RPE determined in a single 1–2 repetitions set to predict the relative load used in the power clean exercise. The proposed methodologies would allow a continuous control of the performance fluctuation over the training cycle. Although the SEE shows a higher accuracy for the RPE compared to the peak velocity model, both methods would be considered acceptable to provide a practical and reliable estimation of the relative load used during the PC in young male athletes that use the PC exercise for their conditioning preparation. However, further research is needed to assess the validity and accuracy of the proposed prediction models. Additionally, it is important to highlight that the two-resulted prediction models would be only applied to male athletes who use weightlifting exercises as a part of their conditioning program. Other population such as female athletes or high-performance experienced weightlifters would present different patterns of the load-velocity or load-perception relationship.

## CONCLUSIONS

A strong relationship was found between the load and the two analyzed variables (peak velocity and the RPE) measured during or at the end of a 1–2 repetitions set from moderate (~50% 1RM) to maximal intensities (100% 1RM) of PC exercise.

## ACKNOWLEDGMENTS

The authors would like to thank Dr. Devjani Roy from the University Writing Center at Texas Tech University Health Sciences Center for grammar review and editing of the manuscript.

## COMPETING INTERESTS

The authors declare no specific funding from grant agencies to support the present study. The authors recognize no conflicts of interest.

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