1-1-2023

Using the Load-Velocity Profile for Predicting the 1RM of the Hexagonal Barbell Deadlift Exercise

Marcel Lopes dos Santos
Oklahoma State University, mlopess@okstate.edu

J. Bryan Mann
University of Miami

Ricardo Berton
University of Sao Paulo, Brazil

Brent A. Alvar
Point Loma Nazarene University

Robert G. Lockie
California State University, Fullerton

See next page for additional authors

Recommended Citation

Lopes dos Santos, Marcel; Mann, J. Bryan; Berton, Ricardo; Alvar, Brent A.; Lockie, Robert G.; and Dawes, J. Jay, "Using the Load-Velocity Profile for Predicting the 1RM of the Hexagonal Barbell Deadlift Exercise" (2023). *Faculty Publications - Kinesiology and Recreation*. 26.
https://ir.library.illinoisstate.edu/fpknr/26

Authors

Marcel Lopes dos Santos, J. Bryan Mann, Ricardo Berton, Brent A. Alvar, Robert G. Lockie, and J. Jay Dawes

This is the accepted manuscript version of an article first published in *Journal of Strength and Conditioning Research* 37, no. 1 (2023): 220-223. DOI: 10.1519/JSC.0000000000004216

Using the Load-Velocity Profile for Predicting the 1RM of the Hexagonal Barbell Deadlift Exercise

Lopes dos Santos, Marcel; Mann, J. Bryan; Berton, Ricardo; Alvar, Brent A.; Lockie, Robert G.; Dawes, J. Jay

Abstract

Using the load-velocity profile for predicting the 1RM of the hexagonal barbell deadlift exercise. *J Strength Cond Res* 37(1): 220–223, 2023—The aim of this study was to determine whether bar velocity can be used to estimate the 1 repetition maximum (1RM) on the hexagonal bar deadlift (HBD). Twenty-two National Collegiate Athletic Association Division I male ice hockey players (age = 21.0 ± 1.5 years, height = 182.9 ± 7.3 cm, and body mass = 86.2 ± 7.3 kg) completed a progressive loading test using the HBD at maximum intended velocity to determine their 1RM. The mean concentric velocity was measured for each load through a linear position transducer. The a priori alpha level of significance was set at $p = 0.05$. The mean concentric velocity showed a very strong relationship to %1RM ($R^2 = 0.85$). A nonsignificant difference and a trivial effect size (ES) were observed between the actual and predicted 1RM ($p = 0.90$, ES = −0.08). Near-perfect correlations were also discovered between the actual and predicted 1RM ($R = 0.93$) with low typical error and coefficient of variation (5.11 kg and 2.53%, respectively). This study presented results that add the HBD to the list of exercises with established load-velocity relationships. The predictive ability for 1RM HBD indicates that this is a viable means of prediction of 1RM.

Keywords:
bar velocity; 1 repetition maximum; exercise testing; strength training

Introduction

Traditionally, at the beginning of a training program, a percentage of an individual's 1 repetition maximum (1RM) is used to establish the training loads to be used for a specific exercise. However, the use of previously established 1RM values to prescribe exercise intensity may result in individuals using suboptimal training loads as the training program progresses ([8]). Furthermore, using previously established values over time may lead to an accumulation of fatigue that may contribute to overtraining syndrome and negatively affect individual results

([16]). Consequently, prescription of training load based on barbell velocity has recently gained attention ([23]). This method provides immediate feedback, which allows for greater sensitivity, when assigning daily training intensity.

The hexagonal bar deadlift (HBD) is a variation of the deadlift that has been shown to put less stress on the lumbar region ([4,5,13,15,22]). This is partially because of the fact that when performing the HBD, there is approximately 75% less horizontal displacement compared with the straight bar deadlift (SBD) ([22]). These differences result in the lifter moving the load over a shorter distance, which also increases the amount of weight that can be lifted for a single repetition ([15]). The HBD not only reduces biomechanical stress to the lumbar spine but also elicits greater peak force, velocity, and power outputs when compared with the SBD at similar loads ([4,15,22]). For these reasons, the HBD may be a more advantageous option than the SBD when training certain populations.

Recently, investigators have focused on assessing the load-velocity profile during the SBD ([2,14,17,19]) and reported very strong relationships ($R^2 \geq 0.91$, $p < 0.05$) between these variables. Moreover, the load-velocity profile during the SBD has shown to be very stable, despite the relative strength level ([2,17]). However, the biomechanical stimulus may be altered by the utilization of different variations of the deadlift ([22]). When compared with the SBD, the HBD elicits significantly greater peak velocity, peak force, and peak power ([22]). For these reasons, the load-velocity profile of the HBD must be determined because the profile from the SBD may not be directly applicable to this exercise variation. Thus, the purpose of this study was to explore the load-velocity relationship of the HBD and to determine whether bar velocity can be used to estimate 1RM HBD. Considering the very high and consistent load-velocity relationship along a wide range of loads in the SBD, we hypothesize that a stable load-velocity profile specific for the HBD can also be established.

Methods

Experimental Approach to the Problem

A cross-sectional design was used to investigate the load-velocity relationship across a wide range of intensities during the HBD. Subjects reported to the weight room on a single occasion, in which the 1RM was assessed. Before the visit, they were instructed to refrain from strenuous activity for a minimum of 24 hours that preceded the testing session. All subjects performed the HBD with a normal grip on a low-handle hexagonal barbell. They were not allowed to use chalk, lifting belts, or lifting straps. After a standardized general warm-up, subjects performed submaximal incremental sets based on relative percentages of their previous season 1RM values. Incremental sets were set at 65, 75, 80, 90, and 95% of subjects estimated 1RM. After that, subjects attempted to lift the load that corresponded to their previous 1RM, and increments of 2–5 kg were made until they were unable to complete a single lift. Subjects were instructed to perform all repetitions at maximum intended velocity. The fastest repetition at each submaximal set was considered for the calculations. These data were collected as part of the team's normal yearly training program. All testing took place at the same room and at the same time of the day, under the supervision of certified strength and conditioning specialists. The study conformed to the Declaration of Helsinki and was approved by Oklahoma State University's Institutional Review Board for studies involving human subjects (IRB approval: ED-19-117-STW).

Subjects

Performance testing data for 22 National Collegiate Athletic Association Division I male ice hockey players (age = 21.0 ± 1.5 years, height = 182.9 ± 7.3 cm, and body mass = 86.2 ± 7.3 kg) were analyzed. All subjects had more than 2 years of experience with resistance training before the study. Institutional review board approval (IRB #) was obtained before analysis. This research also conformed to the guidelines set forth by the tenets of the Declaration of Helsinki, and all subjects provided written informed consent before participation.

Procedures

Subjects completed 1 testing session during the preseason, and all assessments occurred in the team weight room. Before performing the 1RM protocol, subjects' age, body mass, and weight were recorded. Height was recorded using a portable stadiometer (Seca, Hamburg, Germany), and body mass was recorded using a digital scale (Tanita Corporation, Tokyo, Japan). The 1RM protocol was administered in a single session under the supervision of certified strength and conditioning specialists.

1 Repetition Maximum Protocol for Hexagonal Bar Deadlift

The proper procedures for the HBD have been previously detailed ([15,22]). In summary, with the hexagonal bar resting on the ground, subjects assumed a position with the knees flexed and the arms straight, although maintaining a straight back and neutral spine. They then grasped the low handles of the hexagonal bar and stood up, although maintaining a straight back until reaching an erect position with the shoulders retracted.

The initial load for the incremental protocol was based on 1RM values recorded in the previous season. The incremental test protocol for the 1RM HBD was adapted from similar procedures reported in the literature ([6–8,12,20]). Each subject refrained from strenuous activity for 24 hours before the testing. After a standardized dynamic warm-up protocol, initial load was set at 65% and increased to 75, 80, 90, and 95% of estimated 1RM. Three repetitions were performed for intensities ≤80% 1RM, 2 for 90% 1RM, and 1 for 95% 1RM. After that, increments of 2–5 kg were made until the subjects were unable to complete a single lift throughout the entire range of motion with proper form (i.e., technical failure). The heaviest load lifted by each subject with proper form was defined as his 1RM. All subjects reached their 1RM before reaching the NSCA-recommended number of attempts for 1RM tests (i.e., 5 trials). A rest interval of 3 minutes after each set was provided.

Bar Velocity Assessment

The mean concentric velocity (MV) in meters per second ($m \cdot s^{-1}$) was collected through a linear position transducer (GymAware PowerTool, Kinetic Performance Technology, Mitchell, Australia). The linear position transducer was placed on the floor directly underneath the bar with the cable attached on the front of the bar ([15]). Velocity of the bar was recorded at 50 Hz. The linear position transducer recorded data for every repetition for each subject throughout the 1RM test. From the individualized linear regression equations, the MV at 1RM of each subject was applied to predict the 1RM value. Only subjects with complete data for each repetition at the corresponding load were considered for analysis.

Statistical Analyses

Statistical analyses were performed using IBM SPSS software version 23 (IBM, New York, NY) and a customized spreadsheet. A Shapiro-Wilk test was used to verify normal distribution of the sample. Relationships between the load and MV were assessed by fitting second-order polynomials to the data. It has been reported that there is no difference in linear functions and second-order polynomial fits ([1]). However, some studies have shown that nonlinear functions can provide better fits than linear functions ([9,17,21]). Individualized fitting second-order polynomials equation with each load and MV was also used to predict the %1RM estimate. The individualized MV at 100% 1RM was used to predict the 1RM value. Then, concurrent validity of the predicted 1RM with reference to the actual 1RM was examined through Hedge's *g* effect size (ES), Pearson's correlation coefficient (R), coefficient of determination (R^2), typical error (TE), coefficient of variation (CV) ([10]), and the associated 95% confidence intervals ([18]). For ES, the following thresholds were used: trivial (0–0.19), small (0.20–0.59), moderate (0.60–1.19), and large (1.20–1.99) ([11]). The strength of the R coefficient was interpreted as trivial (<0.1), small (0.1–0.3), moderate (0.3–0.5), strong (0.5–0.7), very strong (0.7–0.9), or near perfect (>0.9) ([11]). The Bland-Altman plot (limits of agreement at 95% and bias) was used to evaluate the agreement of the 1RM value between the actual 1RM and predicted 1RM ([3]). Finally, a paired samples t-test was performed between the actual 1RM and predicted 1RM. The significance level was set at $p \leq 0.05$.

Results

The Shapiro-Wilk test revealed that all data were normally distributed ($p > 0.05$). Figure 1 depicts the results of the second-order polynomial regression plotting MV against load (%1RM). A very strong relationship between MV and load was found, and a predictive equation was yielded: HBD Relative Load = $(27.17)\,MV^2 - (122.9)\,MV + 133.3$ ($R^2 = 0.85$, $SEE = 8.3\%$). Regarding the 1RM prediction, the load-velocity relationship underestimated the 1RM values (absolute difference: −0.18 ± 7.24 kg). However, a nonsignificant difference and a trivial ES between the actual and predicted 1RM was observed (Table 1). Moreover, the actual and predicted 1RM were near-perfectly correlated ($p < 0.001$) (Table 1). Finally, concurrent validity analysis, TE, and CV are presented in Table 1 and the Bland-Altman plot with the limits of agreement at 95% and bias in Figure 2.

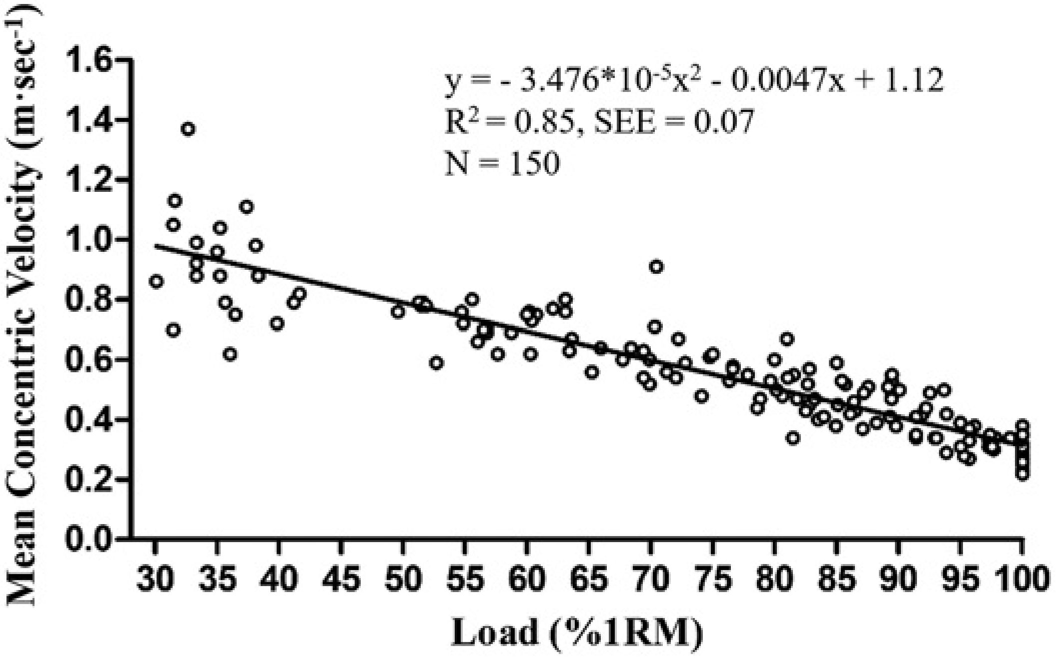

Figure 1. Relationship between the hexagonal bar deadlift relative load (%1RM) and mean concentric velocity. 1RM = 1 repetition maximum.

Table 1 - Concurrent validity analyses of the load-velocity relationship to predict 1 repetition maximum (1RM) of the hexagonal bar deadlift.*

Actual 1RM (kg) Mean ± *SD*	**Predicted 1RM (kg) Mean ± *SD***	***p***	**ES (95% CI)**	***R* (95% CI)**	**TE (95% CI)**	**CV (95% CI)**
201.4 ± 19.5	201.5 ± 20.1	0.90	−0.08 (−0.16 to 0.14)	0.93 (0.84 to 0.97)	5.11 (3.94 to 7.57)	2.53 (1.94 to 3.62)

*ES = Hedge's *g* effect size; *R* = Pearson's correlation coefficient; TE = typical error (kg); CV = coefficient of variation (%); CI = confidence intervals.

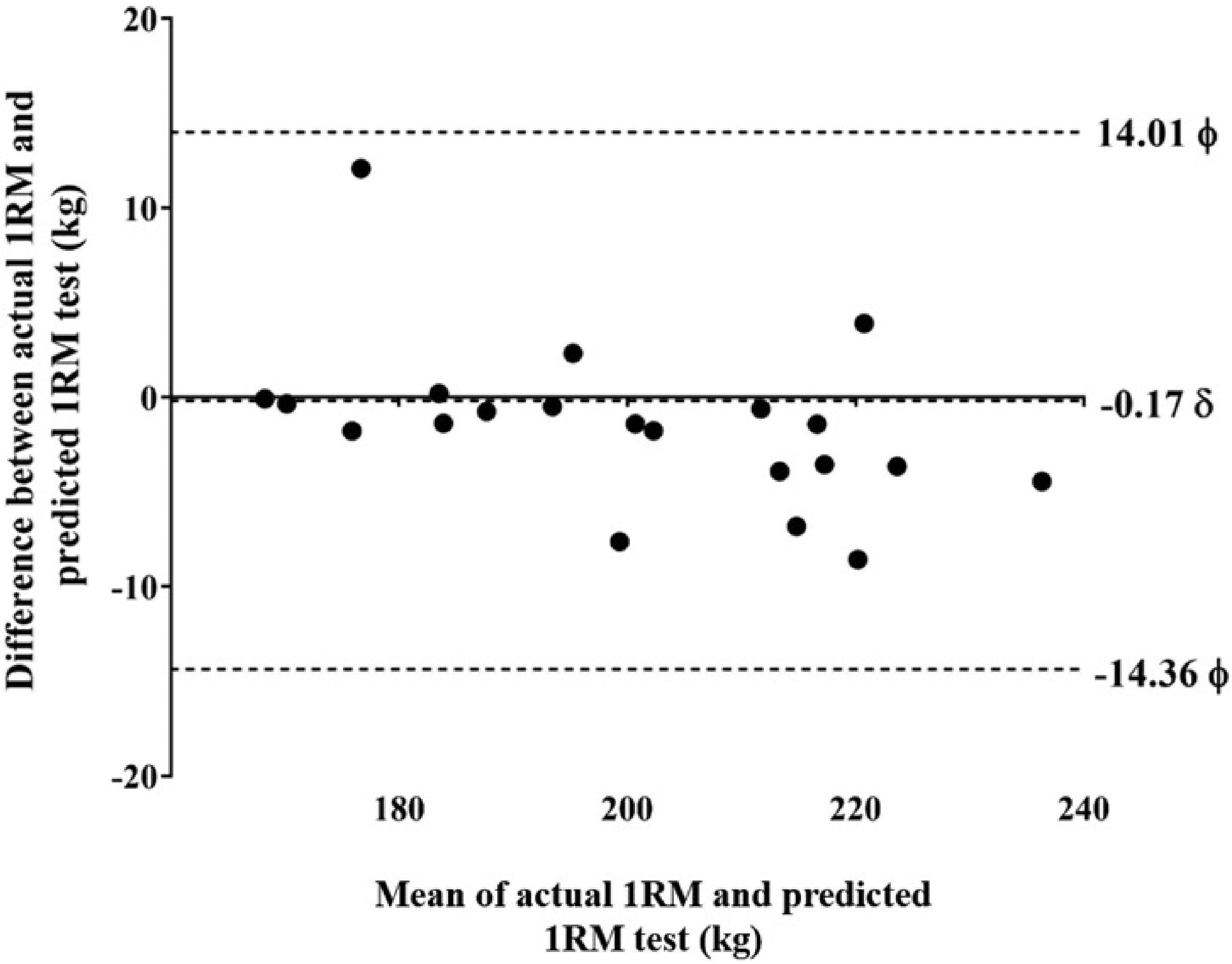

Figure 2. Bland-Altman plot depicts differences between the actual 1RM and predicted 1RM from the load-velocity relationship. θ: 95% superior and inferior limits of agreement; δ: bias. 1RM = 1 repetition maximum.

Discussion

The current data demonstrated a very strong relationship between the load and velocity during the HBD. These results make it possible for coaches and trainers to estimate HBD intensity based on the MV of the bar. In addition, the results showed excellent predictive ability for 1RM HBD with a CV of 2.53% and TE of 5.11 kg. These results may be useful for coaches, trainers, and individuals seeking to estimate appropriate training loads to optimize performance when using the HBD.

Supporting our hypothesis, a very strong load-velocity relationship was found (R^2 = 0.85) in the HBD. This finding corroborates with other studies that showed very strong load-velocity relationships in the SBD ([2,17]). In their studies, Morán-Navarro et al. ([17]), Benavides-Ubric et al. ([2]), and Jukic et al. (12) reported significant R^2 values of 0.96, 0.91, and 0.95, respectively. These results show the accuracy of general load-velocity regressions.

Interestingly, although the population of this study comprised ice hockey athletes, the velocities in this study were very similar to individuals with moderate resistance training experience who performed the SBD (2,17). This may be explained by the stability of the load-velocity profile regardless of relative strength levels of subjects. In their study with the SBD, Moran-Navarro et al. (17) divided their subjects in 2 groups based on individual strength levels. After analyzing the velocity parameters attained against each % 1RM, Moran-Navarro et al. (17) found no significant differences between the groups. The consistency of the velocity measures despite individual levels of strength has also been reported in other exercises. For example, Gonzalez-Badillo and Sanchez Medina illustrated how solid the load-velocity relationship was during a 6-week training block. Despite an observed increase in 1RM of 9.3%, the difference in the mean test velocity was approximately 0.01 $m\cdot s^{-1}$ decline for the posttest from the pretest in a paused smith machine bench press exercise (9). These results illustrate the stability of the load-velocity relationship regardless of relative strength levels.

Although this was the first study to explore the load-velocity relationship of the HBD, some limitations need to be acknowledged. The results from this study should be interpreted with caution and should not be extrapolated to other deadlift variations. Because small variations, such as the use of lifting straps, can alter the entire load-velocity relationship (12), the investigation of the load-velocity relationship in the HBD with different handles is warranted. This study did not include a subsequent session in which the test-retest reliability could be assessed. Future research should consider the addition of a second testing session in which the reliability of the prediction equation can be assessed.

Practical Applications

This study presented results that add the HBD to the list of exercises with established load-velocity relationships. This is particularly useful for coaches and trainers when using deadlifts in their training programs and opts for the HBD variation. With HBD velocity measurements at hand, coaches may have real-time performance feedback allowing them to determine exercise intensity and monitor neuromuscular fatigue. These data can also assist coaches when implementing velocity-based training as part of the training program. Finally, the results showed an excellent predictive ability for 1RM HBD. The prediction equation error was only 0.01% (i.e., 0.1 kg), which means that barbell velocity is a time-efficient and reliable way to assess exercise intensity during the HBD. By performing the HBD with submaximal loads at maximum intended velocity, athletes can have their %1RM estimated, which may exclude the need for submaximal or maximal tests for training load attainment.

Acknowledgments

The authors thank the athletes for their time and commitment throughout this study and are grateful to Justin Roethlingshoefer for his assistance with the data collection. This research was undertaken without additional research funding support. The content of the manuscript does not constitute endorsement of a product by the authors or the NSCA. The authors have no conflicts of interest to disclose.

References

1. Banyard HG, Nosaka K, Vernon AD, Haff GG. The reliability of individualized load-velocity profiles. Int J Sports Physiol Perform 13: 763–769, 2018.

2. Benavides-Ubric A, Diez-Fernandez DM, Rodriguez-Perez MA, Ortega-Becerra M, Pareja-Blanco F. Analysis of the load-velocity relationship in deadlift exercise. J Sports Sci Med 19: 452–459, 2020.

3. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1: 307–310, 1986.

4. Camara KD, Coburn JW, Dunnick DD, et al. An examination of muscle activation and power characteristics while performing the deadlift exercise with straight and hexagonal barbells. J Strength Cond Res 30: 1183–1188, 2016.

5. Cholewicki J, McGill SM, Norman RW. Lumbar spine loads during the lifting of extremely heavy weights. Med Sci Sports Exerc 23: 1179–1186, 1991.

6. Conceicao F, Fernandes J, Lewis M, Gonzalez-Badillo JJ, Jimenez-Reyes P. Movement velocity as a measure of exercise intensity in three lower limb exercises. J Sports Sci 34: 1099–1106, 2016.

7. Dorrell HF, Moore JM, Gee TI. Comparison of individual and group-based load-velocity profiling as a means to dictate training load over a 6-week strength and power intervention. J Sports Sci 38: 2013–2020, 2020.

8. Dorrell HF, Smith MF, Gee TI. Comparison of velocity-based and traditional percentage-based loading methods on maximal strength and power adaptations. J Strength Cond Res 34: 46–53, 2020.

9. Gonzalez-Badillo JJ, Sanchez-Medina L. Movement velocity as a measure of loading intensity in resistance training. Int J Sports Med 31: 347–352, 2010.

10. Hopkins WG. Measures of reliability in sports medicine and science. Sports Med 30: 1–15, 2000.

11. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 41: 3–13, 2009.

12. Jukic I, Garcia-Ramos A, Malecek J, Omcirk D, Tufano JJ. The use of lifting straps alters the entire load-velocity profile during the deadlift exercise. J Strength Cond Res 34: 3331–3337, 2020.

13. Keogh JW, Winwood PW. The epidemiology of injuries across the weight-training sports. Sports Med 47: 479–501, 2017.

14. Lake J, Naworynsky D, Duncan F, Jackson M. Comparison of different minimal velocity thresholds to establish deadlift one repetition maximum. Sports (Basel) 5, 2017.

15. Lockie RG, Moreno MR, Lazar A, et al. The 1 repetition maximum mechanics of a high-handle hexagonal bar deadlift compared with a conventional deadlift as measured by a linear position transducer. J Strength Cond Res 32: 150–161, 2018.

16. Meeusen R, Duclos M, Foster C, et al. Prevention, diagnosis, and treatment of the overtraining syndrome: Joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. Med Sci Sports Exerc 45: 186–205, 2013.

17. Moran-Navarro R, Martinez-Cava A, Escribano-Penas P, Courel-Ibanez J. Load-velocity relationship of the deadlift exercise. Eur J Sport Sci 21: 678–684, 2021.

18. Nakagawa S, Cuthill IC. Effect size, confidence interval and statistical significance: A practical guide for biologists. Biol Rev Camb Philos Soc 82: 591–605, 2007.

19. Ruf L, Chery C, Taylor KL. Validity and reliability of the load-velocity relationship to predict the one-repetition maximum in deadlift. J Strength Cond Res 32: 681–689, 2018.

20. Sanchez-Medina L, Gonzalez-Badillo JJ, Perez CE, Pallares JG. Velocity- and power-load relationships of the bench pull vs. bench press exercises. Int J Sports Med 35: 209–216, 2014.

21. Sanchez-Medina L, Pallares JG, Perez CE, Moran-Navarro R, Gonzalez-Badillo JJ. Estimation of relative load from bar velocity in the full back squat exercise. Sports Med Int Open 1: E80–E88, 2017.

22. Swinton PA, Stewart A, Agouris I, Keogh JW, Lloyd R. A biomechanical analysis of straight and hexagonal barbell deadlifts using submaximal loads. J Strength Cond Res 25: 2000–2009, 2011.

23. Weakley J, Mann B, Banyard H, et al. Velocity-based training: From theory to application. Strength Cond J 43: 31–49, 2021.