Reliability of three landmine-punch-throw variations and their load-velocity relationships performed with the dominant and nondominant hands

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Abstract: ***Purpose:*** This study assessed the reliability and load-velocity profiles of three different landmine punch throw variations (seated without trunk rotation [LPwo], seated with trunk rotation [LPw], and standing whole body [LP]) with different loads (20 kg, 22.5 kg, and 25.0 kg), all with the dominant (DH) and non-dominant hand (NH). ***Methods:*** In a quasi-randomized order, fourteen boxers (24.1 ± 4.3 y, 72.6 ± 10.1 kg) performed three repetitions of each variation with DH and NH, with maximal effort and 3 minutes inter-set rest. Peak velocity (PV) was measured via GymAware power tool. The interclass correlation coefficients and their 95% confidence intervals were used to determine the intra-session reliability of each variation×load×hand combination. Additionally, a 2(hand)×3(variation) repeated measures ANOVA assessed the load-velocity profile slope, and a 3(variation)×2(hand)×3(load) repeated measures ANOVA assessed the PV of each variation. ***Results:*** Most variations were highly reliable (ICC > 0.91), with the NH being as reliable or more reliable than the DH. Very strong linear relationships were observed for the group average for each variation ($R^2 \geq 0.96$). However, there was no variation×hand interaction for the slope, and there was no main effect for variations or hands. Additionally, there was no interaction for the PV, but there were main effects for variation, hand, and load ($p < 0.01$). ***Conclusion:*** Each variation was reliable and can be used to create upper body ballistic unilateral load-velocity profiles. However, as with other load-velocity profile research, individual data allowed for more accurate profiling than group average data.

Keywords

resistance training, combat sports, boxing, ballistic medicine ball throw, bench throw

INTRODUCTION

There are numerous methods of assessing muscular strength such as repetition maximum tests[20], isokinetic strength[29,30,43],and others[3]. Although a large selection of strength tests exists, testing ballistic power output is largely limited to movements that encompass jumps[5,19] and throws[11,18,44]. Indeed, jump testing is widely used, especially for most athletes who perform jumps during training, which likely reduces the variability and need for further familiarization prior to testing. However, jumps are essentially limited to the lower body, necessitating similar solutions for upper body power assessments. To test upper body power output, one common choice includes throwing a medicine ball for distance[17], but the resultant data can largely depend on the throwing technique and size of the implement, variations of which may result in large variability and unreliable test results. It is true that bench press throws include fewer degrees of freedom especially if performed on a Smith machine, for example, which should result in more reliable data. However, bilateral exercises cannot always be used for testing unilateral movements[41] which might be desired for specific purposes such as quantifying asymmetries[15,26,40], assessing training adaptations between limbs[31], or performing exercises where each limb may necessitate a different loading pattern.

The landmine punch throw is a fairly novel unilateral ballistic upper body exercise that is commonly used not only in training, but also for testing. During the landmine punch throw, an athlete grabs the end of one barbell sleeve and throws it with a linear upward push (approximately 40-60° from parallel) while the other sleeve (i.e., the opposite end of the barbell) is fixed to a 3-dimensional moveable attachment on the floor[37]. As such, this exercise allows for upper body unilateral ballistic testing, requires minimal equipment, and is extremely portable. The movement is often performed in a standing position using the whole body, but different variations of the landmine punch throw can allow for isolated testing of the upper body, upper body and trunk, and the whole body including the lower limbs. Along these line, it is possible that the different involvement of body segments will alter the characteristics of load-velocity profile of the landmine punch throw, as is for example affecting peak velocity in real boxing punch[14]. In terms of testing, a linear position transducer can be attached to the thrown end of the barbell to assess peak velocity, and the sleeve can be loaded to assess a wider range of external forces which could ultimately lead to the creation of individualized upper body ballistic load-velocity profiling. In fact, using a unilateral load-velocity profile could be very useful for exploring asymmetry between limbs. Additionally, this load-velocity profile could also be useful to track adaptations over time, specifically when using different body segments.

In practice, the landmine punch throw is already used in training and testing for sports that share similar movement patterns such as combat sports, rugby, American football, and other sports where the arm and hand require rapid extension in front of the body. Next to that, landmine push throw without throwing has been investigated, especially its load-velocity profile and reliability[16,32]. However, to the best of our knowledge, the reliability of the landmine punch throw test in addition to the load-velocity profile derived from the landmine punch throw have not been scientifically addressed in the literature. Specifically, the reliability of different variations of the exercise performed with different loads with the dominant and non-dominant hand, and their load-velocity relationships, are all some of the foundational points that should be addressed before promoting the widespread use of testing procedures that may be unreliable.

Therefore, one aim of the present study was to determine the peak velocity reliability of the three independent variations of the landmine punch throw (whole body landmine punch throw [LP], landmine punch throw in a seated position with trunk rotation [LPw], and landmine punch throw in seated position without trunk rotation [LPwo]) each with three different loads (only barbell [20 kg], 22.5 kg, and 25 kg) with the dominant (DH) and non-dominant hand (NH). Additionally, another purpose was to evaluate the differences in the characteristics of load-velocity profiles of three landmine punch throw variations using three different loads with the DH and NH. According to previous studies on a variety of exercises[24,31,33,37,] it was hypothesized that landmine punch throw peak velocity would result in at least moderate reliability. Additionally, according to previous study[1], it was hypothesized that the velocity-intercept would significantly differ between variations and hands. The same was expected for the load-intercept and the area under the line of the load-velocity profiles.

METHODS

EXPERIMENTAL APPROACH TO THE PROBLEM

During a single laboratory visit, fourteen trained boxers performed, in a quasi-randomized order, the three different landmine punch throw variations with three different loads, all with the DH and the NH. The peak velocity of the landmine punch throws was assessed using a linear position transducer.

SAMPLE SIZE

To calculate the sample size required to estimate the intraclass correlation coefficients of 0.85 with the lower bound of 95% confidence interval greater than 0.50 (the threshold for moderate reliability), we used Zou's formula as implemented in *ICC.Sample.Size* package (version 1.0.) in R[45]. Assuming three ratings per subject, desired power of 80%, and using a two-sided 0.05 significance level, the required sample size is 12. To account for possible drop-outs or technical issues, we required 14 subjects.

SUBJECTS

All 14 healthy boxers (24.1 ± 4.3 y, 72.5 ± 10.1 kg, 176.9 ± 8.3 cm, 12 orthodox and 2 southpaw boxers) had at least one competitive boxing bout and at least one year of structured strength and conditioning training during which they regularly performed the landmine punch throw exercise. Each subject was informed of the potential risks and possible benefits of this project, and then read and signed a written informed consent approved by the local university ethics committee (ER19357858).

PROCEDURES

All procedures were performed during one testing visit and consisted of 3 phases: (1) warm-up, (2) individual set-up and familiarization, and (3) landmine punch throw assessment.

Warm-up. The standardized warm-up included 120 seconds of rope skipping, mobilization exercises for the upper-limbs, lower-limbs, hips, and dynamic stretching for the upper- and lower-body for 10 minutes, which was followed by 6 squat jumps and 6 countermovement jumps.

Individual set-up and familiarization. The landmine punch throw was performed in three different conditions: LP, LPw, and LPwo, all of which were performed with both the DH and NH independently. In the standing position, each subject stood in their preferred boxing stance (orthodox or southpaw). In the seated position, the seated height of the subject was adjusted with jerk blocks to ensure a 90° knee joint angle. A hand-operated Goniometer was used to determine knee joint angle for each subject. Then, subjects fully extended their legs and rested their heels on a slightly elevated surface to minimize the use of the lower limbs during the movement. The proper technique was demonstrated for each variation. Before each testing set, subjects performed 3 trials of landmine punch throw for each variation and load, with an estimated 50% maximal effort, using the same load as the subsequent test.

Landmine punch throw assessment. Each subject performed 3 repetitions of the landmine punch throw variations for each hand with 3 loads (20, 22.5, 25 kg) with 3 minutes of inter-set rest. The testing loads were set up based on pilot testing that showed that greater differences between each load did not allow participants to perform the seated variations correctly. Furthermore, the lightest load of 20 kg was chosen because the large majority of landmine base equipment is built to fit the sleeve of a standard 20 kg barbell, making lighter loads not ecologically valid and not possible for the majority of users. A constant time of 3 seconds was provided between each repetition. The initial position for the LP was similar to a true boxing stance. The barbell was held in the rear hand as close as possible to shoulder height, with the elbow fully flexed and knees slightly flexed. The lead hand was positioned at chin with elbow flexed. Upon instruction, subjects proceeded to rotate their trunk on the rear side from a stationary position into a squat before forcefully extending the ankle, knee, hip, and elbow, whilst simultaneously throwing the barbell in a forward direction[37]. The LPw was performed with the same initial position of the lead and the rear hand and the same technique (i.e., with rotation of the upper body, but now without lower body involvement). The LPwo was the same as for the LPw, but a broomstick was positioned behind the back of each participant to avoid the rotation of the trunk (Figure 1). The subjects were required to maintain the same level of contact with the broomstick throughout the movement in order to minimize occurrence of trunk rotation. Each variation was performed with the DH and NH.

[Figure 1]

DATA ACQUISITION AND DATA ANALYSES

Data Acquisition. The peak velocity (PV) of all variations of landmine punch throw and different loads was collected with a validated linear position transducer (GymAware Power Tool, Kinetic Performance Technologies, Canberra, Australia)[33]. The cable of the GymAware was attached to the barbell, on the internal side, as close as possible to the collar, on the side where the participants held the barbell. The obtained data from the GymAware were transmitted via Bluetooth to a tablet (iPad, Apple, Inc., Cupertino, California) using the GymAware v2.4.1 app, and to the online cloud before being exported to Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA) for future analysis.

Data Analysis: The intra-session reliability of each variation-load-hand combination was determined by intraclass correlation coefficients (A,1)[28] with their 95% confidential intervals, using irr package (version 0.84.1) in R, version 3.5.2. The coefficient of variation (CV) was calculated using the mean squared error method as implemented in SimplyAgree package (version 0.1.2). The standard error of measurement (SEM) was calculated using the consecutive pairwise difference method with confidence intervals based on chi squared distribution as implemented in reel package (version 1.4.2). The magnitude of intraclass correlation coefficient was interpreted based on its lower-bound of the 95% of confidence interval (LCI), as follows: < 0.50, *poor reliability*; 0.50 to 0.75, *moderate reliability*; 0.75 to

0.90, *good reliability*; and > 0.90, *excellent reliability*[23]. The relationship between PV and the prescribed loads was established via a linear regression, using Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA).

Data are presented as means and standard deviations. Individual 2(hand [DH and NH])×3(variation [LPwo, LPw, and LP]) repeated measures ANOVA with Bonferroni post-hoc test was applied to compare the slope and velocity-intercept, load-intercept, and area under the line of the regression lines of each variation and hand. Lastly, individual 2(hand [DH and NH])×3(variation [LPwo, LPw, and LP])×3(load [20, 22.5, and 25 kg]) repeated measures ANOVA with Bonferroni post-hoc test was also applied to compare the PV attained at each variation, hand, and load. Statistical significance was set at an alpha level of $p < 0.05$, whereas this part of statistical analyses was performed using the software package JASP (version 0.16.2, Amsterdam, Netherlands). Hedges' *g* effect sizes with 95% confidence intervals were used to determine the magnitude of the difference between LPwo, LPw, and LP for the slope, velocity-intercept, load-intercept, and area under the line of linear regression and were interpreted for highly trained subjects as: *trivial*, $g < 0.25$; *small,* $g = 0.25$ to 0.50; *moderate*, $g = 0.50$ to 1.00; *and large*, $g > 1.00$[36]. Hedges' *g* was computed as an unbiased version of Cohen's *d,* adjusting for the small sample size[22].

RESULTS

The PVs attained against each load, variation, and hand with their effect size are shown in Table 1. The reliability results of each variation-load-hand combination are shown in Table 2. Based on the LCI, most variations displayed good reliability (LCI ranking from 0.75 to 0.89 for individual variations), especially for the NH (LCI = 0.76 to 0.89) with a few demonstrating moderate reliability (LCI = 0.54 to 0.72) for the DH. In general, the variations performed with the NH were as reliable, or more reliable, than with the DH.

[Table 1]

[Table 2]

Very strong linear relationships were observed for group averages for LPwo, LPw, and LP performed by DH ($R^2 = 0.96$, $R^2 = 0.99$, and $R^2 = 0.99$), and NH for each variation ($R^2 = 0.99$).

The slopes of the linear regression with their effect size are shown in Table 3. The two-way repeated measures ANOVA indicated that there was no variation×hand interaction for the slope of regression lines ($p = 0.221$, $\eta_p^2 = 0.111$), and there was no main effect for variation ($p = 0.098$, $\eta_p^2 = 0.168$) or hand ($p = 0.972$, $\eta_p^2 = 0.0001$).

[Table 3]

The velocity-intercept and load-intercept of the linear regression with their effect sizes are shown in Table 3. The two-way repeated measures ANOVA indicated that there was no variation×hand interaction for the velocity-intercept of regression lines ($p = 0.233$, $\eta_p^2 = 0.107$, and there was no main effect for variation ($p = 0.103$, $\eta_p^2 = 0.167$) or hand ($p = 0.490$, $\eta_p^2 = 0.037$). Additionally, there was no variation×hand interaction for the load-intercept of regression lines ($p = 0.624$, $\eta_p^2 = 0.021$), and there was no main effect for variation ($p = 0.101$, $\eta_p^2 = 0.189$) or hand ($p = 0.870$, $\eta_p^2 = 0.002$).

The area under the line with their effect sizes are shown in Table 3. There was no variation×hand interaction for the area under the line ($p = 0.596$, $\eta_p^2 = 0.024$), and there was no main effect for hand ($p = 0.628$, $\eta_p^2 = 0.019$). However, there was main effect for variation ($p = 0.005$, $\eta_p^2 = 0.426$). Post-hoc testing showed that the area under the line of LP was greater than LPw (mean difference = 24.343 [2.836 to 45.849], $p_{bonf} = 0.023$, g = 0.61 [0.08 to 1.15]) and LPwo (mean difference = 36.195 [14.688 to 57.701], $p_{bonf} < 0.001$, g = 0.93 [0.38 to 1.48]). However, the area under the line of LPw was not significantly different than LPwo (mean difference = 11.852 [-9.655 to 33.358], $p_{bonf} = 0.511$, g = 0.83 [0.28 to 1.37]).

Additionally, there were no variation×hand×load, variation×hand, variation×load, or hand×load interactions for PV ($p = 0.128$, $\eta_p^2 = 0.126$; $p = 0.932$, $\eta_p^2 = 0.005$; $p = 0.093$, $\eta_p^2 = 0.140$; $p = 0.737$, $\eta_p^2 = 0.023$), respectively. However, there was main effect for variation, load, and hand ($p < 0.001$, $\eta_p^2 = 0.934$; $p < 0.001$, $\eta_p^2 = 0.941$;, and $p = 0.006$, $\eta_p^2 = 0.451$), respectively. Post-hoc testing showed that the PV of LP was greater than LPw (mean difference = 0.666 [0.523 to 0.809], $p_{bonf} < 0.001$, g = 2.21 [1.27 to 3.15]) and LPwo (mean difference = 0.940 [0.767 to 1.113], $p_{bonf} < 0.001$, g = 3.02 [1.93 to 4.10]), and PV of LPw was less than LPwo (mean difference = 0.274 [0.191 to 0.357], $p_{bonf} < 0.001$, d = 1.05 [0.26 to 1.84]). Additionally, PV was greater with 20 kg than 22.5 kg (mean difference = 0.171 [0.132 to 0.211], $p_{bonf} < 0.001$, g = 0.36 [-0.38 to 1.11]) and 25 kg (mean difference = 0.338 [0.282 to 0.394], $p_{bonf} < 0.001$, g = 0.71 [-0.05 to 1.47]), and PV of 22.5 kg was greater than 25 kg (mean difference = 0.167 [0.126 to 0.207] , $p_{bonf} < 0.001$. g = 0.34 [-0.40 to 1.09]). Lastly, the PV was greater with DH than NH (mean difference = 0.091 [0.031 to 0.151], $p_{bonf} = 0.006$, g = 0.20 [-0.18 to 1.33]).

DISCUSSION

This study was designed to determine the PV reliability of the three variations of the landmine punch throw performed with different load and DH and NH. Additionally, this study evaluated the load-velocity profile of each variation and DH and NH. In the current study the PV achieved was affected by the variation, hand, and load. Regardless of the specific variation, load, or hand used, most combinations of the landmine punch throw achieved good reliability (LCI = 0.75 to 0.89). When considering both the DH and NH, the goodness of fit demonstrated similarity for the group average of each variation of landmine punch throw. Additionally, neither the slope nor velocity-intercept or load-intercept of regression line have not been affected by hand or variation of landmine punch throw. However, the area under the line was affected by the variation. Although, some studies have determined the load-velocity reliability of upper-body bilateral pushing exercise[8,9,12] to the best author knowledge, this is the first study to determine the reliability of upper-body unilateral ballistic exercises that can be used for field testing and monitoring.

As expected, the more body segments that were involved in the landmine punch throw, the greater the resultant PV was in the present study. In a similar fashion, others have found the same pattern during punching with the whole body, with the legs fixed, and with legs and trunk fixed[14]. Another expected outcome was that PV decreased as the load increased, which abides by the inverse load-velocity relationship[4,13,21]. Additionally, PV was greater with the DH compared to NH, which is similar to previous research assessing punch velocity[27].

This aligns with a previous study in which the landmine push throw demonstrated moderate reliability for the right hand (ICC = 0.73) and excellent reliability for the left hand (ICC = 0.92) at 20kg. Moreover, it showed excellent reliability for the right hand (ICC = 0.90) and good reliability for the left hand (ICC = 0.81) at 25kg[32]. The first hypothesis was confirmed. In this study, the most possible combinations of the landmine punch throw were reliable (LCI = 0.75 to 0.89), regardless of the variation, load, or hand, meaning that all of the different landmine punch throws performed could be used in practice. However, it was interesting that trials performed with the NH hand were more reliable than those performed with the DH. This may have occurred because PV was greater with the DH, indicating that perhaps the fastest DH trial may have been performed with greater PV than the other repetitions, with the NH moving at a slower speed but more consistently. In support of this idea, previous research showed similar results for peak force in trained boxers, where the non-dominant hand was more reliable (ICC = 0.89) than the dominant hand (ICC = 0.73)[25]. In a real-life boxing bout, boxers most often perform straight punches with their lead hand, which is often the non-dominant hand[6,7], which might influence the lower variability of the non-dominant and reflect greater within-session reliability of non-dominant hand compared to dominant hand straight punches[25]. Considering that the landmine punch throw used in this study was performed in different variations, with the DH and NH, and with different loads, it seems that each of those variations could be used as a reliable unilateral ballistic test as part of an upper-body force velocity profile[10,34,38].

Each landmine punch throw variation performed with the DH and NH had a very strong linear relationship with the slopes of the regression lines which were not affected by hand or variation. In a previous study by Balsalobre-Fernández et al.[1], the slopes of the regression lines in bilateral and unilateral knee extensions were similar to those of the present study, but that study did not indicate whether differences existed between bilateral and unilateral knee extensions or between the dominant and non-dominant leg. In resistance training exercises, the velocity typically demonstrates a linear decrease as the load increases[38]. This inverse relationship between velocity and load is an important factor in understanding an individual's performance as it can shed a light on the neuromuscular capacities of the athlete accompanied with its alternations after a training period[39]. However, the velocity-intercept, load-intercept, and area under the line, which represents the baseline velocity when the load is zero, the baseline load when the velocity is zero, and power capacities, respectively, can also provide valuable information about a person's performance[35]. Analyzing both the velocity-load relationship and its characteristics can help to develop a comprehensive understanding of an individual's performance capabilities in resistance training exercises. In our study, the velocity-intercept and load-intercept of the regression lines were not affected by hand or variation, but in aforementioned study, the velocity-intercept of the regression line was significantly different between the bilateral and unilateral knee extension. However, area under the line was affected by variation, especially by LP compared to LPw and LPwo. The effect was influenced by the achieved resultant PV during landmine punch throw variation. The area under the line is calculated as the product of the load-intercept multiplied velocity-intercept divided by 2[35]. In our study, the resultant PV was influenced by the body segments involved, using the LP as an example, achieved greater resultant PV compared to LPw or LPwo.

Additionally, the load-velocity relationship has been explored for a wide range of exercises such as the bench press throw[11], deadlift[20,21], back squat[42], and others[2,24]. However, no previous research has compared the linearity of the load-velocity relationship for an upper-body unilateral ballistic exercise. Our results provided a fairly linear velocity relationship ($R^2 \geq 0.96$), similar to the bench press throw ($R^2 = 0.979$)[11], which is commonly used as an upper-body bilateral ballistic test. However, bilateral testing cannot observe the asymmetry of the upper-body, which makes the landmine punch throw an interesting option for athletes that perform sport actions one limb at a time. For example, two individual sets of data from the current study (Figure 2) show distinct differences between limbs within one fairly untrained subject while a well-trained subject displayed little-to-no between-limb asymmetry. Therefore, considering the findings of this paper, in addition to the data in Figure 2, using a unilateral test could help identify asymmetries that could not be identified using a bilateral test. Furthermore, putting asymmetries aside, the landmine punch throw also can be used to track an individual's progress over time thanks to its reliability, linearity, and goodness of fit. Additionally, further insight into neuromuscular capabilities of the athlete can be assessed with velocity and load intercepts as well as the area under curve[36]. These parameters could be used for optimizing training, monitoring performance progress in rea-life sports scenarios, identifying asymmetries, and implementing targeted interventions for performance enhancement. However, it is important to consider measurement error and variability that could occur within the landmine punch throw. The standard error of measurement and coefficients of variation are shown in Table 2. Thus, using this upper-body unilateral ballistic exercise could be suitable for different sports discipline where the movement is commonly performed unilaterally, such as punching or throwing.

[Figure 2]

PRACTICAL APPLICATION

The landmine punch throw can be used as a reliable upper-body unilateral ballistic test for athletes. By performing the test with the DH and NH with different loads (20, 22.5, and 25 kg), the different landmine punch throw variations assessed in this study can all be used to create upper-body unilateral load-velocity profiles. However, as with other exercises like the back squat, bench press, etc., the group's average results should not be used as a benchmark for each athlete, which requires load-velocity profiles to be compared within each athlete individually.

CONCLUSION

All of the landmine punch throw loads and variations were reliable for both hands. Therefore, from practical point of view, the landmine punch throw could be used as a reliable movement-specific test for upper-body ballistic strength and power. However, although the NH seemed to result in more reliable data than the DH, future research should confirm whether this holds true for boxers of different calibers, training experiences, weight categories, and the like. Additionally, the slope of the group average regression lines were similar for the LPwo, LPw, and LP for both the DH and NH. Despite the group averages showing a very strong linear relationship, the individual data is not as clear (similar to traditional resistance training exercises like the bench press and back squat) (Figure 2). However, it is important to consider that the difference between each load was 2.5 kg, meaning that it is possible that using different range of load during each landmine punch throw variation may influence to load-velocity profile, but future research is needed to investigate this hypothesis.

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References

1. Balsalobre-Fernández, C, Cardiel-García, M, and Jiménez, SL. Bilateral and unilateral load-velocity profiling in a machine-based, single-joint, lower body exercise. *PLoS ONE* 14: e0222632, 2019.
2. Balsalobre-Fernández, C, García-Ramos, A, and Jiménez-Reyes, P. Load–velocity profiling in the military press exercise: Effects of gender and training. *International Journal of Sports Science & Coaching* 13: 743–750, 2018.
3. Bartolomei, S, Rovai, C, Lanzoni, IM, and Di Michele, R. Relationships between muscle architecture, deadlift performance, and maximal isometric force produced at the midthigh and midshin pull in resistance-trained individuals. *Journal of Strength and Conditioning Research* 36: 299–303, 2022.
4. Bosquet, L, Porta-Benache, J, and Blais, J. Validity of a commercial linear encoder to estimate bench press 1 rm from the force-velocity relationship. *J Sports Sci Med* 9: 459–463, 2010.
5. Cormie, P, McBride, JM, and McCaulley, GO. Power-time, force-time, and velocity-time curve analysis of the countermovement jump: Impact of training. *Journal of Strength and Conditioning Research* 23: 177–186, 2009.
6. Davis, P, Connorton, AJ, Driver, S, Anderson, S, and Waldock, R. The activity profile of elite male amateur boxing after the 2013 rule changes. *Journal of Strength and Conditioning Research* 32: 3441–3446, 2018.
7. Davis, P, Wittekind, A, and Beneke, R. Amateur Boxing: Activity profile of winners and losers. *International Journal of Sports Physiology and Performance* 8: 84–92, 2013.
8. García-Ramos, A, Haff, GG, Padial, P, and Feriche, B. Reliability of power and velocity variables collected during the traditional and ballistic bench press exercise. *Sports Biomechanics* 17: 117–130, 2018.
9. García-Ramos, A, Padial, P, García-Ramos, M, et al. Reliability analysis of traditional and ballistic bench press exercises at different loads. *Journal of Human Kinetics* 47: 51–59, 2015.
10. García-Ramos, A, Pérez-Castilla, A, Villar Macias, FJ, et al. Differences in the one-repetition maximum and load-velocity profile between the flat and arched bench press in competitive powerlifters. *Sports Biomechanics* 20: 261–273, 2021.
11. García-Ramos, A, Pestaña-Melero, FL, Pérez-Castilla, A, Rojas, FJ, and Haff, GG. Differences in the load–velocity profile between 4 bench-Press Variants. *International Journal of Sports Physiology and Performance* 13: 326–331, 2018.
12. García-Ramos, A, Suzovic, D, and Pérez-Castilla, A. The load-velocity profiles of three upper-body pushing exercises in men and women. *Sports Biomechanics* 20: 693–705, 2021.
13. González-Badillo, JJ and Sánchez-Medina, L. Movement velocity as a measure of loading intensity in resistance training. *Int J Sports Med* 31: 347–352, 2010.
14. Gu, Y, Popik, S, and Dobrovolsky, S. Hand punch movement kinematics of boxers with different qualification levels. *IJBET* 28: 366, 2018.
15. Guan, Y, Bredin, SSD, Taunton, J, et al. Association between inter-limb asymmetries in lower-limb functional performance and sport injury: A systematic review of Prospective Cohort Studies. *JCM* 11: 360, 2022.
16. Gusciglio, B and Morin, J-B. Assessing the key physical capabilities in striking combat sports: Reliability and reproducibility of a new test. *International Journal of Strength and Conditioning* 3(1), 2023.
17. Harris, C, Wattles, AP, DeBeliso, M, et al. The seated medicine ball throw as a test of upper body power in older adults. *Journal of Strength and Conditioning Research* 25: 2344–

2348, 2011.

18. Ikeda, Y, Kijima, K, Kawabata, K, Fuchimoto, T, and Ito, A. Relationship between side medicine-ball throw performance and physical ability for male and female athletes. *Eur J Appl Physiol* 99: 47–55, 2006.

19. Janikov, MT, Pádecký, J, Doguet, V, and Tufano, JJ. Countermovement, hurdle, and box jumps: Data-driven exercise selection. *JFMK* 8: 61, 2023.

20. Jukic, I, García-Ramos, A, Malecek, J, Omcirk, D, and Tufano, JJ. Validity of load–velocity relationship to predict 1 repetition maximum during deadlifts performed with and without lifting straps: the accuracy of six prediction models. *Journal of Strength and Conditioning Research* Publish Ahead of Print, 2020.Available from: https://journals.lww.com/10.1519/JSC.0000000000003596

21. Jukic, I, García-Ramos, A, Malecek, J, Omcirk, D, and Tufano, JJ. The use of lifting straps alters the entire load-velocity profile during the deadlift exercise. *Journal of Strength and Conditioning Research* 34: 3331–3337, 2020.

22. Kline, RB. Beyond significance testing: Reforming data analysis methods in behavioral research. Washington: American Psychological Association, 2004.

23. Koo, TK and Li, MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine* 15: 155–163, 2016.

24. Kotani, Y, Lake, J, Guppy, SN, et al. Reliability of the squat jump force-velocity and load-velocity profiles. *Journal of Strength and Conditioning Research* 36: 3000–3007, 2022.

25. Lenetsky, S, Brughelli, M, Nates, RJ, Cross, MR, and Lormier, AV. Variability and reliability of punching impact kinetics in untrained participants and experienced boxers. *Journal of Strength and Conditioning Research* 32: 1838–1842, 2018.

26. Lockie, RG, Callaghan, SJ, Berry, SP, et al. Relationship between unilateral jumping ability and asymmetry on multidirectional speed in team-sport athletes. *Journal of Strength and Conditioning Research* 28: 3557–3566, 2014.

27. López-Laval, I, Sitko, S, Muñiz-Pardos, B, Cirer-Sastre, R, and Calleja-González, J. Relationship between bench press strength and punch performance in male professional boxers. *Journal of Strength and Conditioning Research* 34: 308–312, 2020.

28. McGraw, KO and Wong, SP. Forming inferences about some intraclass correlation coefficients. *Psychological Methods* 1: 30–46, 1996.

29. Merrigan, JJ, Jones, MT, Malecek, J, et al. Comparison of traditional and rest-redistribution sets on indirect markers of muscle damage Following Eccentric Exercise. *Journal of Strength and Conditioning Research* 36: 1810–1818, 2022.

30. Merrigan, JJ, Jones, MT, Padecky, J, et al. Impact of rest-redistribution on fatigue during maximal eccentric knee extensions. *Journal of Human Kinetics* 74: 205–214, 2020.

31. Merrigan, JJ, Stone, JD, Hornsby, WG, and Hagen, JA. Identifying reliable and relatable force–time metrics in athletes—considerations for the isometric mid-thigh pull and countermovement jump. *Sports* 9: 4, 2020.

32. Moreno-Azze, A, Arjol-Serrano, JL, Falcón-Miguel, D, Bishop, C, and Gonzalo-Skok, O. Effects of three different combined training interventions on jump, change of direction, power performance, and inter-limb asymmetry in male youth soccer players. *Sports* 9: 158, 2021.

33. Oleksy, Ł, Kuchciak, M, Bril, G, et al. Intra-rater and test–retest reliability of barbell force, velocity, and power during the landmine punch throw test assessed by the gymaware linear transducer system. *Applied Sciences* 13: 10875, 2023.

34. Orange, ST, Metcalfe, JW, Marshall, P, et al. Test-retest reliability of a commercial linear position transducer (GymAware powertool) to measure velocity and power in the back squat and bench press. *Journal of Strength and Conditioning Research* 34: 728–737, 2020.

35. Pérez-Castilla, A, García-Ramos, A, Padial, P, Morales-Artacho, AJ, and Feriche, B.

Load-velocity relationship in variations of the half-squat exercise: influence of execution technique. *Journal of Strength and Conditioning Research* 34: 1024–1031, 2020.

36. Pérez-Castilla, A, Jukic, I, and García-Ramos, A. Validation of a novel method to assess maximal neuromuscular capacities through the load-velocity relationship. *Journal of Biomechanics* 127: 110684, 2021.

37. Pérez-Castilla, A, Ramirez-Campillo, R, Fernandes, JFT, and García-Ramos, A. Feasibility of the 2-point method to determine the load−velocity relationship variables during the countermovement jump exercise. *Journal of Sport and Health Science* 12: 544–552, 2023.

38. Rhea, MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. *J Strength Cond Res* 18: 918, 2004.

39. Ruddock, AD, Wilson, DC, Thompson, SW, Hembrough, D, and Winter, EM. Strength and conditioning for professional boxing: Recommendations for physical preparation. *Strength and Conditioning Journal* 38: 81–90, 2016.

40. Ruf, L, Chéry, C, and Taylor, K-L. Validity and reliability of the load-velocity relationship to predict the one-repetition maximum in deadlift. *Journal of Strength and Conditioning Research* 32: 681–689, 2018.

41. Samozino, P, Rejc, E, Di Prampero, PE, Belli, A, and Morin, J-B. Optimal force–velocity profile in ballistic movements—altius. *Medicine & Science in Sports & Exercise* 44: 313–322, 2012.

42. Stephens, TM, Lawson, BR, and Reiser, RF. Bilateral asymmetries in max effort single-leg vertical jumps. *Biomed Sci Instrum* 41: 317–322, 2005.

43. Sugiyama, T, Kameda, M, Kageyama, M, et al. Asymmetry between the dominant and non-dominant legs in the kinematics of the lower extremities during a running single leg jump in collegiate basketball players. *J Sports Sci Med* 13: 951–957, 2014.

44. Thompson, SW, Rogerson, D, Ruddock, A, Banyard, HG, and Barnes, A. Pooled versus individualized load–velocity profiling in the free-weight back squat and power clean. *International Journal of Sports Physiology and Performance* 16: 825–833, 2021.

45. Tufano, JJ, Omcirk, D, Malecek, J, et al. Traditional sets versus rest-redistribution: a laboratory-controlled study of a specific cluster set configuration at fast and slow velocities. *Appl Physiol Nutr Metab* 45: 421–430, 2020.

46. West, DJ, Cunningham, DJ, Crewther, BT, Cook, CJ, and Kilduff, LP. Influence of ballistic bench press on upper body power output in professional rugby players. *Journal of Strength and Conditioning Research* 27: 2282–2287, 2013.

47. Zou, GY. Sample size formulas for estimating intraclass correlation coefficients with precision and assurance. *Statistics in Medicine* 31: 3972–3981, 2012.