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RESEARCH

General minimum velocity threshold for one-repetition maximum prediction in two squat variations: does the load–velocity profiling approach matter?

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Abstract

Purpose Most studies examining the predictive value of the load–velocity relationship in determining one-repetition maximum (1RM) in the back squat implemented its direct determination to enable testing movement velocity within a predetermined set of relative loads (e.g., 50, 60, 70, 80, and 90% 1RM). We determined whether a different approach of load–velocity profiling affects the accuracy of estimating 1RM.

Methods Predictions based on a practical 2-point approach (no pre-determination of 1RM) were compared to those obtained with the conventional multipoint and 2-point approach (pre-determination of 1RM). 1RM was estimated relying on a reference minimum velocity threshold (MVT) of 0.3 ms^{-1}. Analyses were conducted for separate back-squat variations ($n = 13$ Smith machine; $n = 13$ free-weight). Slopes and y-intercepts were compared. The accuracy of 1RM prediction was determined by contrasting actual vs. predicted 1RM values.

Results The individual MVT did not differ from the general 0.3 ms^{-1} value in either back-squat variation. Slopes and y-intercepts were similar between all determination approaches. For the Smith machine, estimated 1RM did not differ from the actual value with either approach (mean misestimate: −1.83 to 0.02 kg). However, the limits of agreement were wide (~ 12 kg) and the absolute percent error was significantly different from 0 with all approaches ($p < 0.05$).

Conclusion 1RM can be estimated with similar accuracy with all profiling methods, irrespectively of the back squat variation. However, the free-weight variation displays higher systematic and random errors. It can be concluded that the wide limits of agreement preclude accurate 1RM estimations on an individual basis.

Keywords Maximum strength · Resistance training · Neuromuscular capacities · Velocity-based training

Introduction

The one-repetition maximum (1RM) method is ubiquitously used among resistance training coaches and practitioners for prescribing exercise load in relative terms (i.e., %1RM) [1]. Despite being a highly valid approach, 1RM is not without limitations and this topic has been a matter of intense debate over the past few years. For instance, while some authors argue that it may be impractical for testing large groups of practitioners, others claim that the determination of 1RM is also time-consuming, may exacerbate the individual risk of injury when performed incorrectly, and can induce muscle damage and fatigue potentially deteriorating training performance in the short term [2].

The use of the relationship between load and movement velocity has been recently introduced as an alternative to

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1RM testing with the purpose of overcoming some of the described limitations [3–7]. Since the load–velocity relationship displays strong linearity (R^2 usually ≥ 0.9) in response to several multi-joint exercises (e.g., bench-press, squat, military press), it has been argued that 1RM can be predicted using linear regression modeling [3, 8–10].

An important factor to consider when assessing the individual load–velocity relationship is the selected exercise to be performed and the critical aspects related to its execution. Not only it is well known that the properties of this relationship (e.g., slope and y intercept) vary between different exercises, as it has also been suggested that profound discrepancies arise when testing a given person using the same movement, but under different conditions (e.g., type of equipment and mode of execution [11, 12]). For instance, while the free-weight back squat is compatible with lower reliability of 1RM mean concentric velocity, this may not be the case when using methods that reduce the likelihood of technical flaws or unwanted three-dimensional displacements (e.g., Smith machine) [12–14].

Most often, the load–velocity relationship is modeled using a multipoint approach, involving 4 to 9 different individual loads and velocities [8, 15]. Then, a linear function is extracted from the data as:

(1) Load = a x Velocity + b

where *a* represents the slope of the relationship and *b* represents the y intercept. More recently, the two-point approach was introduced to improve the efficiency of extracting the individual load–velocity relationship [16]. As shown in past research, if each repetition is completed with the intent of reaching maximal concentric velocity, the relationship between these two variables remains strong, even when using the 2-point method [17]. However, it is important to note that the selection of these two loads should not be chosen arbitrary and may even be exercise dependent [18–20]. For the back-squat exercise, it was shown that choosing higher relative loads improved the accuracy of 1RM prediction (first load > 40; second load of ~ 80/90% 1RM) [19]. However, to our knowledge, the direct predetermination of 1RM was not implemented only in three past studies (two focusing on the bench-press exercise and one on the half-squat) examining the predictive value of the load–velocity relationship [21–23]. In all the remaining studies, 1RM was determined before obtaining the individual load–velocity profile. This was done to enable measuring movement velocity within a predetermined set of relative loads (e.g., 50, 60, 70, 80, 90% 1RM) [21–23]. Additionally, to our knowledge, the 1RM prediction in the free-weight back squat was only performed via the 2-point method in one previous report [19]. In that study, participants performed a squat variation which involved a 2-s pause in the bottom position and the 1RM prediction was performed using the individual minimum velocity threshold (MVTs). The MVT corresponds to the velocity compatible with the last repetition completed in a set performed to failure. When applied to testing with maximal loads, it corresponds to the velocity of the 1RM [24]. Whether the 2-point approach results in accurate predictions of the back-squat 1RM in eccentric-concentric free-weight back squat without requiring its previous determination, remains unknown. If that were the case, this approach would be of high practical value. Therefore, the purpose of this study was three-fold. First, we sought to compare the load–velocity relationship obtained with the conventional multipoint and 2-point approach (conventional approach: movement velocity in response to a predetermined set of %1RM) with that obtained when modeling the 2-point approach using absolute loads eliciting a predefined range of movement velocities (practical approach: without requiring the previous determination of 1RM). Second, we aimed to assess if a general MVT value allows an accurate prediction of 1RM for the back-squat exercise (when using the conventional and practical approaches). Third, we explored whether 1RM predictions based on the load–velocity relationship are affected by back squatting with a fixed vs. free barbell (Smith machine concentric squat—SMCS vs. free-weight eccentric-concentric squat—FWECS).

Methods

Participants

Based on the differences found in 1RM estimation methods, a total sample size of 10 participants would be sufficient to achieve a statistical power of 80% (G*Power software, version 3.1.9.2) [25]. Conservatively, we studied 26 young healthy male, physical education students, on no medications (13 assigned to the SMCS: 23.3 ± 3.8 years and 13 to the FWECS: 22.9 ± 3.2 years). All participants were active, accumulating 9 h of physical activity per week as part of their academic work. Participants were well accustomed to resistance training, but were not highly trained (they all had past experience in performing the back-squat exercise with both variations). Participation involved two testing sessions of ~ 45 min. The risks implicated in the experimental design were carefully explained to each participant, and written informed consent was obtained at study entry. Participants were all non-obese, non-smokers, and free from any known diseases as assessed by a health-screening questionnaire. The study complied with the principles set forth in the Declaration of Helsinki and was approved by the Faculty's Ethics Committee (CE*******).

Study design

All testing sessions were performed during the morning period, between 08:00 and 12:00 h, in a laboratory at a temperature between 22 and 24 °C and a relative humidity between 44–56%. Participants were asked to avoid intense physical exercise for at least 24 h before each visit. During the first testing session, body mass and height were taken with the participants wearing lightweight clothes and no shoes. Height was obtained using a stadiometer to the nearest 0.5 cm (SECA® 213, Hamburg, Germany). Body mass was measured on a digital scale to the nearest 0.01 kg (TANITA® BF-350, Arlington Heights, IL). Subsequently, all participants were familiarized with their respective exercise protocol. On a randomized fashion (based on a computer-generated algorithm), thirteen participants performed 3 sets of 5 back-squats on a Smith machine (Matrix Fitness® G1 Smith machine, WI, USA) and another thirteen participants performed the same number of repetitions for the free-barbell back squat (BOXPT®, Póvoa do Varzim, Portugal) (empty bar mass: 15 and 20 kg for the Smith machine and free barbell, respectively). On each set, loading was incremented to enable a proper familiarization using a wide range of loads. For all repetitions, the participants were asked to perform the concentric phase of the lift as fast as possible. On the second testing session (72 h after the first testing session), a protocol with progressive load increments was completed up to the actual 1RM (compatible with the completion of a single maximal lift) [11, 17, 26]. The endpoint of each lift was defined as the full extension of both knees and hips. All repetitions were performed at maximal intended concentric velocity throughout the entire range of motion.

Load-velocity relationship

A warm-up consisting of five minutes of unloaded cycling (Monark Ergomedic 828E cycle ergometer, Monark Exercise AB, Vansbro, Sweden), followed by three sets of ten callisthenic full squats preceded each test. For the specific warm-up, each participant completed 3 sets of 5 back squats using the Smith machine or the free barbell, with an empty bar and with the concentric phase being performed as fast as possible. Squatting was performed with feet shoulder width apart or slightly wider and vertically aligned with the bar, while the bar rested on the upper trapezius.

The SMCS lifts started at the bottom of the squat position, which ensured that all participants had their thighs parallel to the floor. From this position, the participants were instructed to complete the concentric phase of the lift as fast as possible until full extension was attained. Between each repetition, the participants had to hold the bottom position for at least 3 s to ensure that the eccentric phase would not interfere with their concentric performance [11]. The bottom position hold was completed with the barbell resting on the Smith machine's adjustable stops to make sure that it did not cause excessive and undue fatigue. The FWECS lifts started at a fully extended position. Then, the participants descended at a natural speed (controlled manner) until feeling their hip touching an elastic band previously placed at a height that ensured that the thighs would be parallel to the floor. From this point, and without imposing a pause, the concentric phase was performed as fast as possible until full extension was attained at the level of the hip and knee joints.

During all executions, the heels were allowed to lift off from the floor, but jumping was not allowed. The load was progressively incremented until 1RM was determined directly with the completion of a single successful maximal lift. All participants began the progressive loading protocol with an empty bar and subsequent increments were based on the individual body mass [27]. The second load was set at 20% of body mass and additional increments of 20% were added until reaching a bar mean concentric velocity (MCV) equivalent to 0.7 ms^{-1} [28]. From then on, the loading increments varied between 2.5 and 10 kg until 1RM was finally achieved [28]. When approaching 1RM, load increments were set by a skilled investigator after reaching a consensus with the participant. For lighter ($MCV > 1.15\ ms^{-1}$), medium ($0.7 > MCV > 1.15\ ms^{-1}$) and heavy loads ($MCV < 0.7\ ms^{-1}$) the number of attempts varied from 3–5, 2–4 and 1–2, respectively [28]. The MCV was taken from the start of the concentric phase of each lift to the instant corresponding to the maximum height of the bar, with a previously validated Chronojump linear position transducer, which sampled the displacement–time data at a frequency of 1000 Hz (Chronojump, Barcelona, Spain) [29]. The tether of the linear position transducer was attached to the barbell using a Velcro strap and remained perpendicular to the ground during testing. The inter-set pause corresponded to 3 min and the duration of the resting period between repetitions in each set was consistently < than 5 s (only the best attempt for each load was recorded) [28].

Data analysis

The individual load–velocity profiles were obtained based on the MCVs measured at different loads. The conventional multipoint approach involved measuring MCV in response to four predetermined relative loads (between 40 and 90%1RM) [30]. Following a similar methodology, the conventional 2-point approach implicated measuring MCV corresponding to two different relative loads (first load between 40–60% and second load between 70 and 90%1RM) [19, 20]. Finally, the practical 2-point approach involved obtaining the absolute loads corresponding to two different ranges of MCV (first between 0.7 and 1.15 $m.s^{-1}$ and second between 0.4 and 0.6 $m.s^{-1}$). These MCV ranges were selected as they correspond to approximately 40–60% and 70–90% 1RM in the back squat exercise, respectively [24].

Statistical analysis

All data are presented as mean ± SD. Data were tested for normality with the Shapiro–Wilk test and for homoscedasticity with the Levene's test. One-way repeated measures ANOVAs with load–velocity profiling method as within-subject factor were computed to assess possible main effects on slope, y intercept and on the loads and MCVs selected to model the relationship. This analysis was done separately for SMCS and FWECS.

The accuracy of the 1RM predictions was tested using paired *t* tests (conventional multipoint vs. actual 1RM; conventional 2-point vs. actual 1RM and practical 2-point vs. actual 1RM). Again, this was done separately for SMCS and FWECS. As a complement to this method, we computed the absolute percent error using the following expression:

(2) $\left| (\text{actual 1RM} - \text{estimated 1RM}) \times 100/\text{actual 1RM} \right|$

We then conducted unilateral *t* tests to evaluate if the absolute percent error significantly differed from zero. In addition, a one-way repeated measures ANOVA was performed to assess a profiling method effect on the absolute percent error. Post hoc analyses were performed with Bonferroni's correction. Bland–Altman plots were used to determine the level of agreement between the actual and estimated 1RM [31]. Bland–Altman plots were analyzed for heteroscedasticity by examining the significance of the Pearson's correlation coefficient between the absolute difference and mean values of each variable [31]. Data analyses were performed using SPSS software version 27.0 (SPSS Inc., Chicago, IL, USA) and statistical significance was set at $p < 0.05$.

Results

Absolute and relative (i.e., 1RM/body mass) 1RMs were similar between groups (SMCS: 103.5 ± 23.4 kg and 1.35 ± 0.25; FWECS: 102.3 ± 10.5 kg and 1.40 ± 0.19, respectively). As depicted in Table 1, no main effect of the load–velocity profiling approach (conventional multipoint, conventional 2-point and practical 2-point) was found for the slope or y intercept in either the SMCS or the FWECS (slope: $p = 0.217$ and $p = 0.37$, respectively; y intercept: $p = 0.255$ and $p = 0.335$, respectively). The lightest load and the highest velocity selected to model the load–velocity relationship with the multipoint method were significantly different from those used in both two-point approaches, but only in the FWECS (conventional two-point: $p = 0.011$ and 0.011, respectively; practical two-point: $p = 0.011$ and 0.011, respectively). The individual MVT (velocity of 1RM) did not differ from the 0.30 ms^{-1} reference value (0.27 ± 0.11 and 0.31 ± 0.08 ms^{-1}, for the SMCS and the FWECS, respectively).

For the FWECS, the 1RM predictions based on the MVT method also differed significantly from actual 1RM, except with the multipoint approach ($p = 0.054$). In contrast, for the SMCS, the predictions of 1RM based on the MVT method were similar to the actual 1RM values with all three profiling approaches ($p = 0.890$, $p = 0.992$ and

Table 1 Differences in the load–velocity profiles (slope, y intercept, loads and velocities chosen to model the linear regressions) obtained with three different approaches (conventional multipoint, conventional two-point and practical two-point) in response to the back squat exercise (Smith machine concentric squat and free–weight eccentric-concentric squat)

	Smith machine concentric squat			Free-weight eccentric-concentric Squat		
	Conventional MP ($n = 13$)	Conventional 2P ($n = 13$)	Practical 2P ($n = 13$)	Conventional MP ($n = 13$)	Conventional 2P ($n = 13$)	Practical 2P ($n = 13$)
y intercept (kg)	133.3 ± 32.4	134.6 ± 31.9	137.4 ± 29.8	137.7 ± 15.4	141.2 ± 17.3	141.2 ± 16.5
Slope (kg/ms^{-1})	−100.3 ± 24.5	−103.6 ± 28.1	−107.0 ± 26.2	−98.1 ± 19.1	−101.7 ± 21.5	−101.7 ± 20.1
Heaviest load (%1RM)	86.5 ± 5.0	83.0 ± 5.9	82.2 ± 6.1	86.1 ± 3.9	85.0 ± 4.6	86.1 ± 3.9
Lightest load (%1RM)	45.0 ± 7.9	51.4 ± 7.5	51.5 ± 7.0	42.4 ± 3.6*	48.7 ± 4.7	48.7 ± 4.7
Highest MCV (ms^{-1})	0.88 ± 0.14	0.80 ± 0.14	0.80 ± 0.12	0.99 ± 0.11*	0.91 ± 0.10	0.91 ± 0.10
Lowest MCV (ms^{-1})	0.42 ± 0.09	0.47 ± 0.09	0.48 ± 0.10	0.52 ± 0.06	0.53 ± 0.07	0.52 ± 0.06

Note: values are mean ± standard deviation

Abbreviations: MP, multipoint, 2P, two-point

*Significantly different from other methods ($p < 0.05$)

$p = 0.301$ for the conventional multipoint, the conventional 2-point method and the practical 2-point approach, respectively) (Table 2).

As depicted in Table 2, the absolute percent error of 1RM predictions was significantly different from zero with all profiling approaches in both the SMCS and the FWECS ($p < 0.001$). The repeated measures ANOVA computed on the absolute percent errors revealed no main effects of profiling method in either squat variation ($p = 0.88$ and 0.20, for the SMCS and FWECS, respectively).

As can be seen in Figs. 1 and 2, the Bland–Altman analysis showed increased accuracy of 1RM estimation with the conventional 2-point (underestimation of 0.02 kg) and the conventional multipoint (overestimation of 5.95 kg) in the SMCS and the FWECS, respectively. As depicted in Table 2, the relationship between mean difference and mean values

Table 2 Validation of the predictions based on a reference minimal velocity threshold for predicting one-repetition maximum in response to the Smith machine concentric squat (SMCS) and the free-weight eccentric-concentric squat (FWECS)

Movement	Estimated 1RM (kg)	Absolute error ± SD (%)	$\bar{x}$ difference ± 1.96 SD	Trend (R)
SMCS				
Conventional multipoint	103.2 ± 26.6	4.7 ± 3.8#	0.25 ± 12.68	0.495
Conventional two-point	103.4 ± 25.8	5.2 ± 3.5#	0.02 ± 12.97	0.368
Practical two-point	105.3 ± 24.7	4.6 ± 3.1#	−1.83 ± 11.99	0.210
FWECS				
Conventional multipoint	108.2 ± 11.1	8.2 ± 5.9#	−5.95 ± 19.67	0.062
Conventional two-point	110.6 ± 11.9*	10.8 ± 8.8#	−8.12 ± 15.91	0.188
Practical two-point	110.7 ± 11.6*	10.8 ± 8.6#	−8.40 ± 15.37	0.149

Note: $\bar{x}$ difference ± 1.96 SD, limits of agreement of residual scores (actual – predicted values); trend, Pearson's coefficient of correlation between the difference of actual and predicted values and the mean of both values

*Significantly different from the actual 1RM

#Significantly superior from zero

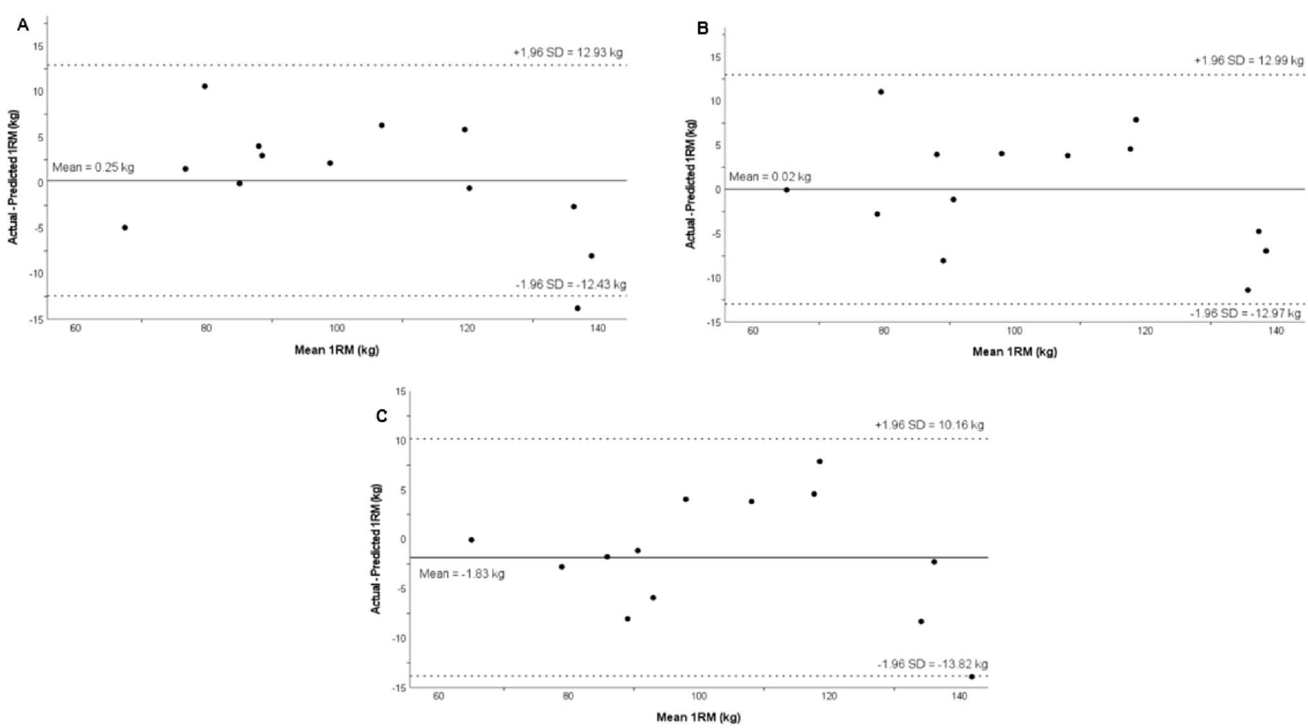

Fig. 1 Bland–Altman plots of the difference between actual and estimated 1RM through a reference MVT value in the Smith Machine Concentric Squat ($n = 13$) for the different load–velocity profiling approaches. (**A**) Conventional multipoint; (**B**) Conventional 2-point; (**C**) Practical 2-point. Solid and dashed lines represent mean difference and 95% limits of agreement (mean value ± 1.96 SDs), respectively

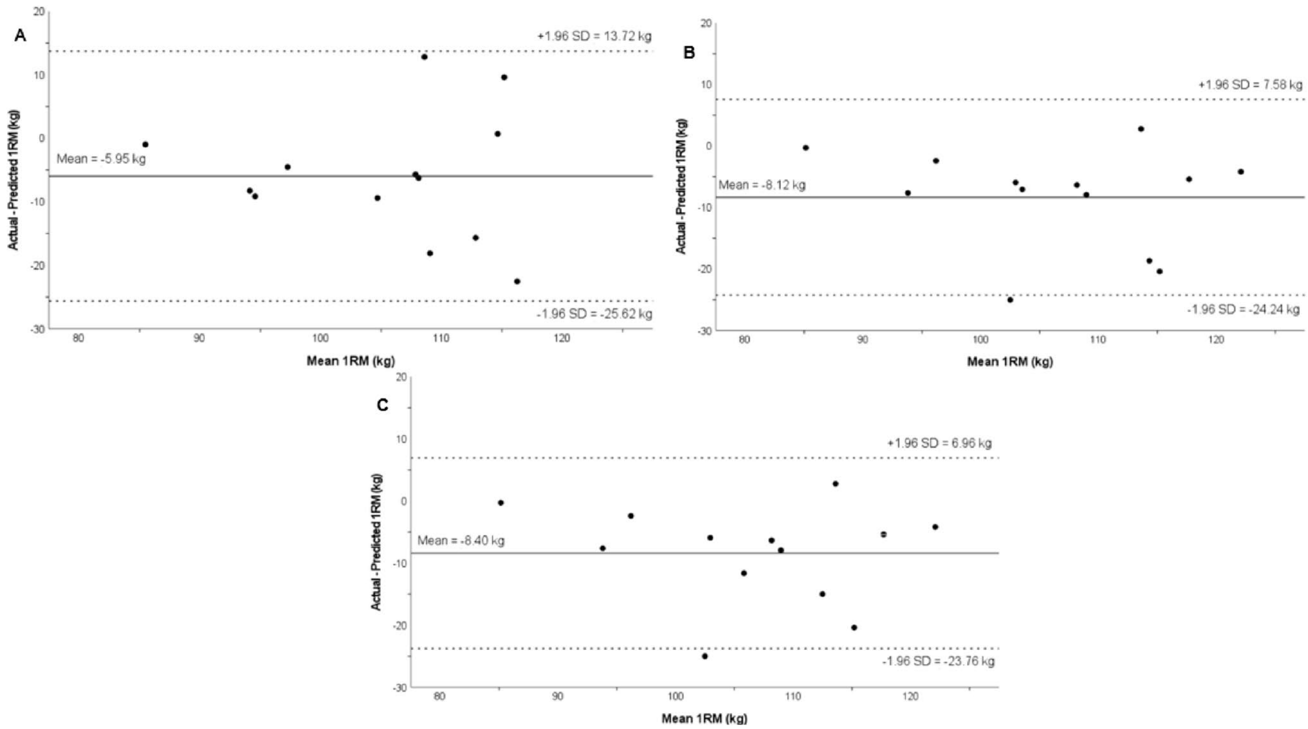

Fig. 2 Bland–Altman plots of the difference between actual and estimated 1RM through a reference MVT value in the Free Weight Eccentric-Concentric Squat ($n=13$) for the different load–velocity profiling approaches. (**A**) Conventional multipoint; (**B**) Conventional 2-point; (**C**) Practical 2-point. Solid and dashed lines represent mean difference and 95% limits of agreement (mean value ± 1.96 SDs), respectively

was homoscedastic for both movements in all profiling methods. This is supported by the lack of significance of the Pearson's correlation coefficients obtained between the absolute difference and mean values of each variable.

Discussion

In this study, we explored if modeling the load–velocity relationship using a practical 2-point approach (not involving the direct pre-determination of 1RM) provided similar results compared to that seen when using more conventional approaches (multipoint or 2-point approach involving the direct pre-determination of 1RM) for the back-squat exercise. We found that the slope and y intercept of the load–velocity relationship did not differ between the three profiling approaches. Ultimately, in line with that shown in three previous reports focusing on the bench-press and half-squat exercise [21–23], this indicates that the practical approach enables the characterization of the back-squat load–velocity relationship without requiring the direct pre-determination of 1RM. In addition, our data also show that all profiling approaches fail to provide accurate individual estimates of 1RM for the SMCS and the FWECS. Thus, the direct determination of the back-squat 1RM should not be neglected based on the premise that the individualized load–velocity profile allows its accurate estimation.

The absolute percent error, as well as the differences between actual and predicted 1RM here obtained are smaller than those reported in a previous study [20] in which the authors observed inaccurate predictions derived from the general MVT applied to the Smith Machine back squat. However, it is important to note that, for safety reasons, 1RM was determined indirectly in that study and that the reference value of MVT was set at 0.37 ms^{-1}. Most likely, these factors exerted a negative impact on the overall findings of that experimental design. For instance, in our study (particularly for the SMCS), we unraveled that the use of a reference MVT value of 0.3 ms^{-1} enables 1RM estimations that do not differ from actual 1RM, regardless of the profiling approach (multipoint, conventional 2-point or practical 2-point). On the other hand, for the FWECS, there were larger overestimations of 1RM values (reaching significance with both 2-point methods) and a seemingly greater absolute error with all approaches. These results support the contention that motor tasks involving three-dimensional displacements (e.g., free-weight exercise) decrease the accuracy of 1RM predictions based on the load–velocity relationship [11, 12]. In addition, the present findings also support the use of a greater MVT value together with the load–velocity relationship to reduce the magnitude of 1RM overestimation in the FWECS. This observation is well aligned with past findings showing that a MVT of 0.3 ms^{-1} consistently overestimates the 1RM in response to this specific squat variation [13, 25]. Alternatively, other aspects may have affected the accuracy of 1RM prediction during the FWECS. For instance, in the SMCS, the concentric movement began from the bottom-paused position. Thus, it was possible to ensure that the involvement of the stretch–shortening cycle in the performance of each lift was virtually dissipated [11]. On the contrary, during the FWECS, the time window of transition between the eccentric and concentric phase of each lift may have been different between participants and this may have contributed to added variability in concentric strength performance [32].

According to the findings of this study, 1RM prediction for the SMCS exhibited similar accuracy between all profiling methods. In specific, the mean misestimate of 1RM was small for the conventional multipoint, conventional 2-point and practical 2-point approach (0.25, 0.02 and 1.83 kg, respectively). In contrast, for the FWECS, there was a consistent overestimation of actual 1RM and this was particularly evident when examining the outcomes derived from the two-point approaches (conventional and practical 2-point: ~ 8.0 vs. multipoint: 6.0 kg). However, the multipoint method displayed wider limits of agreement. These results agree with those of previous studies showing that the estimation of the 1RM is less accurate when assessing the free-weight back squat [13, 25]. Moreover, the present data also suggest that the multipoint may be slightly more accurate than the 2-point approaches for 1RM estimation with the FWECS. As recently reported, the inclusion of heavier loads in the linear regression may allow for a better accuracy in 1RM estimation [33]. We contend that this does not offer a likely explanation for our observations because the heaviest relative load was similar between all examined approaches. However, and as recent report suggests, the optimal velocity separation between the heaviest and lightest experimental point should be of 0.6 ms^{-1} [34]. In our study, the difference between the lightest and heaviest experimental points was never superior to 0.5 ms^{-1}, regardless of profiling approach and movement performed. In addition, the lightest load entered into the multipoint model was significantly different from the loads used in two-point approaches. Thus, it can be concluded that the slightly better accuracy of 1RM estimation with the multipoint method is most likely related with the distance between experimental points and with discrepancies at the lighter (not the heavier) end of the FWECS load–velocity relationship. Yet, it is important to note that the absolute percent error was significantly different from zero for both the SMCS and FWECS. Ultimately, this limits the practical relevance of these predictions, especially for the FWECS because larger absolute percent errors were obtained when computing data from either two-point approaches applied to this specific exercise (with both the conventional and practical approach).

As depicted in the Bland–Altman analysis, data dispersion exhibited homoscedasticity. This indicates that individual strength levels do not affect the magnitude of 1RM misestimate. Finally, it should be noted that the limits of agreement between the actual and estimated 1RM were considerably high for both back-squat variations (~ 12 kg for the SMCS and between 15 and 20 kg for the FWECS). Therefore, such estimations should not be used for defining 1RM values on an individual basis (as they would likely represent a misestimate > 10% of the 1RM). A possible method for increasing the accuracy of these predictions would be to measure the optimal MVT (i.e., the velocity that minimizes the differences between actual predicted 1RM obtained in a preliminary testing session), instead of using a general value of 0.3 ms^{-1} [22]. However, unless such variable proves reliable and unchanged for long periods, it still would require the a priori determination of the 1RM, thus limiting the practicality of the predictive approach.

Limitations

This study has, at least, three important limitations. First, we did not use a crossover design (i.e., same group of participants performing both the SMCS and the FWECS) and this limits the comparisons of the performance of each approach between exercise variations. Second, our findings may not have translational value to other back-squat conditions (i.e., such as those involving the stretch–shortening cycle in the Smith machine back squat). This concept is further substantiated by past data showing that the velocities associated with each load are higher for the eccentric-concentric half-squat technique than for the concentric-only technique [11]. Third, due to the different techniques, concentric-only and eccentric-concentric, it is difficult to separate the effect of the type of implement used (both variants differed in the implement and execution technique).

Conclusions

It can be concluded that, for the back-squat exercise (SMCS and FWECS), the direct determination of actual 1RM is not required to parametrize (i.e., slope and y intercept) the load–velocity relationship via the two-point method. In addition, despite the fact that the use of a reference MVT value of 0.3 ms^{-1} allows attaining good accuracy in predicting 1RM at a group level (particularly for the SMCS), this is not the case for individual estimations as confirmed by the wide limits of agreement. Taken together, these findings indicate that none of these prediction methods should be used for estimating 1RM values on an individual basis and that, for the free-weight squat variation, the use of a MVT superior to 0.3 ms^{-1} (like the individual optimal MVT) might increase the accuracy of estimations and reduce random errors.

Author contributions AF, PS and MG performed data collection. AF, PPC, CVC and GVM computed data analyses. AF, PS, MG, PPC, CVC and GVM wrote and edited the manuscript.

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Data availability The datasets generated and analyzed during the current study are not publicly available due to their confidentiality but are available from the corresponding author on reasonable request.

Declarations

Conflict of interests The authors declare no competing interests.

Ethical approval and informed consent This study was approved by the Faculty's Ethics Committee (CEFMH No 16/2021) and all participants signed an informed consent.

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