MONITORING TRAINING VOLUME THROUGH MAXIMAL NUMBER OF REPETITIONS OR VELOCITY-BASED APPROACH

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ABSTRACT

Purpose: This study aimed: i) to analyze the inter-individual variability in the maximal number of repetitions (MNR) performed against a given relative load (%1RM) and, ii) to examine the relationship between the velocity loss (VL) magnitude and the percentage of completed repetitions with regard to the MNR (%Rep), when the %1RM is adjusted on based on individual load-velocity relationships.

Methods: Following assessment of 1RM strength and individual load-velocity relationships, fourteen resistance-trained men completed 5 MNR tests against loads of 50, 60, 70, 80, and 90% 1RM, in the Smith machine Bench Press exercise. Relative loads were determined from the individual load-velocity relationship.

Results: Individual relationships between load and velocity displayed coefficients of determination (R^2) ranging from 0.986 to 0.998. The MNR showed an inter-individual coefficient of variation (CV) ranging from 8.6 to 33.1%, increasing as %1RM increased. The relationship between %Rep and magnitude of VL showed a general R^2 of 0.92-0.94 between 50 and 80% 1RM, which decreased to 0.80 for 90% 1RM. Mean individual R^2 values were between 0.97 and 0.99 for all loading conditions. The %Rep when a given percentage of VL was reached showed inter-individual CV values ranging from 5 to 20%, decreasing as %Rep increased in each load condition.

Conclusions: Setting a number of repetitions had acceptable inter-individual variability, with moderate relative loads being adjusted based on individual load-velocity relationship. However, in order to provide a more homogenous level of effort between athletes, the VL approach should be considered, mainly when using individual VL-%Rep relationships.

Keywords: velocity loss, velocity-based training, resistance training, repetitions in reserve, degree of fatigue

INTRODUCTION

Muscular strength is associated with health status[1] and improvements in sport skill performance.[2] The design of resistance training programs depends on the combination of several variables such as muscle action, exercise selection, loading and volume training, rest intervals, frequency and movement velocity.[3-5] In this regard, training volume is considered a critical factor in inducing neural and structural adaptations.[4,6] Training volume is traditionally determined by fixing beforehand the number of repetitions to be completed in each exercise set by all individuals.[2] However, the maximal number of repetitions (MNR) that can be completed against a given relative load (%1RM) exhibits large variability (coefficient of variation [CV]: ~ 20%) between individuals.[7-10] This may lead to different levels of effort (i.e. the relationship between the actual number of repetitions performed in a set in relation to the MNR that could be completed) among individuals performing the same number of repetitions per set, because the number of repetitions that remain undone (i.e. repetitions left in reserve) may considerably differ between them.[11,12]

As an alternative to the traditional approach, using the velocity loss (VL) incurred within each set has been suggested as a variable for monitoring and normalizing the resistance training volume between individuals.[7,11-13] During an exercise set, performing each repetition at maximal voluntary effort, movement velocity declines progressively as a consequence of the development of fatigue.[13,14] The magnitude of VL is calculated as the relative difference between the fastest (usually the first) and the last repetition performed. In an attempt to analyze whether VL can be used to quantify fatigue during resistance training, Sánchez-Medina and González-Badillo[13] observed high positive relationships (R^2 = 0.83 – 0.94) between the repetition VL and different mechanical and metabolic measures of fatigue. Likewise, a strong relationship (R^2 = 0.93 – 0.97) was observed between VL induced during the set and the percentage of repetitions completed with regard to MNR that could be completed up to concentric muscle failure (%Rep) for relative loads between 50-85% 1RM in Smith machine bench press (BP) and squat exercises.[7,12] There was also a low inter-individual variability (CV: 2.1 – 6.6%) for the %Rep completed to a given magnitude of VL.[7] Therefore, completing repetitions until a specific magnitude of VL is achieved seems to be an appropriate way to obtain accurate information about the degree of fatigue that occurs in the set and to achieve a more homogeneous level of effort across individuals, regardless of the number of repetitions completed by each individual.

The findings mentioned above are based on the load-velocity relationship observed for exercises such as BP and squat.[15-20] The load-velocity relationship describes a mean velocity value associated with a certain %1RM, which is very similar for every individual regardless of strength levels or changes in performance.[15] This velocity value can be obtained from both linear[21-24] and polynomial regression models.[15-20] As a potential drawback, these general equations assume that the velocity associated with each %1RM is the same for all individuals; however, recent studies have shown a significant inter-individual variability in the load-velocity relationship for BP and squat exercises.[25,26] It has subsequently been shown that individual load-velocity relationships may provide more accurate predictions of %1RM than general equations.[24,26]

The inter-individual variability in the MNR against a given %1RM and the relationship between the repetition VL and the %Rep have been studied in Smith machine BP and squat exercises assuming that all individuals lifted each %1RM at the same velocity.[7,12]

However, the existence of inter-individual variability in the load-velocity relationship has been recently proposed.[24,25] Therefore, the main aims of this study were: i) to analyze the inter-individual variability in the MNR performed against different %1RM and ii) to examine the relationship between the magnitude of VL and the %Rep, when the %1RM is adjusted based on individual load-velocity relationships.

METHODS

Subjects

Fourteen resistance-trained and physically active men (age: 26.6 ± 3.3 years; height: 1.75 ± 0.05 m; body mass: 76.8 ± 9.6 kg), with at least 2 years of resistance training experience in the BP exercise (range 2 to 10 years; 1RM strength for the BP exercise: 92.3 ± 16.0 kg, and 1.21 ± 0.18 normalized per kg of body mass), volunteered to participate in this study. All participants were injury-free and were fully informed about procedures, potential risks and benefits of the study and they all signed a written informed consent prior to the tests. Participants reported to be free from taking drugs, medications or dietary supplements known to influence physical performance. The study was conducted in accordance with the Declaration of Helsinki II and approved by the Local Research Ethics Committee.

Design

A cross-sectional research design was used to examine the MNR completed during a single set to failure against 5 different loads in the BP exercise. Participants performed 7 sessions separated by a period of 4–7 days. Before these testing sessions, two preliminary sessions were devoted to familiarizing the participants with the BP execution technique (i.e. lifting at maximal velocity) and to recording the individual grip width in order to standardize the range of movement throughout the experiment. During the first and seventh testing sessions, progressive loading tests for the determination of 1RM strength and individual load-velocity relationships were conducted. During the remaining sessions (the second to the sixth), five tests of MNR, one per session, were performed against loads of 50, 60, 70, 80, and 90% 1RM, in random order for each participant. Relative loads were determined from the initial (first session) individual load-velocity relationship. Participants were asked to abstain from any strenuous physical activity for at least 2 days before each session. All sessions took place at a neuromuscular research laboratory under the direct supervision of a researcher. All sessions were performed in a Smith Machine with no counterweight mechanism (Matrix Fitness, G1-FW161, WI, USA), at the same time of the day for each subject and under similar environmental conditions (20ºC and 60% humidity, approximately).

Testing Procedures

Progressive loading test

Participants lay supine on a flat bench, with their feet resting on the floor, and their hands placed on the barbell in the positions individually recorded and marked during the familiarization session. The position on the bench was carefully adjusted, so that the vertical projection of the bar corresponded with each participant's intermammary line. The participants were required to perform the eccentric phase at a controlled velocity (~0.30–0.50 $m \cdot s^{-1}$), and maintain a static position for ~1.5 s at the end of this phase (i.e. ~1 cm above each participant's chest) with the aim of minimizing the contribution of the rebound effect and allowing for more reproducible measurements.[27] Then, the concentric phase was performed at maximal intended velocity upon hearing the command. Each participant was carefully instructed to always perform the concentric phase of each repetition in an explosive manner but throwing the bar at the end of the concentric phase was not allowed. A regulation system was used to adjust the height of the bar, allowing it to rest between the eccentric and concentric phases and standardize the range of movement throughout the sessions. The participants warmed up by performing 5 min of joint mobilization exercises and 2 sets of 8 repetitions with a 15 kg load. The initial load was set at 25 kg and was progressively increased in 10 kg increments until the mean propulsive velocity (MPV) was $\leq$0.40 $m \cdot s^{-1}$. Then, the load was increased with smaller increments (5 down to 1 kg), so that the 1RM value could be precisely determined. Three repetitions were executed for light loads (> 1.00 $m \cdot s^{-1}$), two for medium loads (1.00 – 0.50 $m \cdot s^{-1}$) and one for the heaviest loads (<0.50 $m \cdot s^{-1}$). Inter-set recoveries were 3, 4 and 5 min for light, medium and heavy loads, respectively. Only the best repetition (i.e. highest MPV) with each load was considered for subsequent analysis. The propulsive phase corresponds to the portion of the concentric action during which the measured acceleration is greater than the acceleration due to gravity (–9.81 $m \cdot s^{-2}$).[28] All repetitions were recorded at 1000 Hz with a linear velocity transducer (T-Force System Ergotech, Murcia, Spain), whose reliability has been reported elsewhere.[13] The 1RM strength and individualized load-velocity relationships were obtained from these tests. Therefore, individual second-order polynomial equations ($R^2 = 0.993 \pm 0.004$) were used to estimate the MPV corresponding to each %1RM employed during the MNR tests.

Tests of Maximum Number of Repetitions to Failure

Participants performed 5 MNR tests against loads of 50, 60, 70, 80, and 90% 1RM. The execution technique and devices used were those described for the progressive loading test. As mentioned above, the %1RM values were determined from the individual load-velocity relationships obtained during the initial progressive loading tests. The absolute loads (kg) were individually adjusted to ensure the corresponding MPV matched (± 0.03 $m \cdot s^{-1}$) the prescribed %1RM for each session. We used a range of 0.03 $m \cdot s^{-1}$ since it has recently been shown that the smallest detectable change in MPV when using T-Force System is 0.03 $m \cdot s^{-1}$ in BP exercise.[29] A standardized warm-up was performed, consisting of 5 min of joint mobilization exercises followed by two sets of 8 and 6 BP repetitions with 15 kg and 40% of 1RM, respectively. In addition, each MNR test (except the MNR test at 50%, which was only preceded by standardized warm-up) had a specific warm-up as follows: i) MNR test with 60% 1RM: 1x4 repetitions with 50% 1RM; ii) MNR test with 70% 1RM: 2x4-3 repetitions with 50% and 60% 1RM, respectively; iii) MNR test with 80% 1RM: 3x4-3-2 repetitions with 50%, 60% and 70% 1RM, respectively; iv) MNR test with 90% 1RM: 4x4-3-2-1 repetitions with 50%, 60%, 70% and 80% 1RM, respectively. Inter-set recovery periods were 3, 4 and 5 min for light, medium and heavy loads, respectively. The MNR completed was used for further analysis. In addition, several velocity parameters were examined: i) MPV of the fastest (usually first) repetition in the set (MPV_{BEST}); (ii) MPV of the last completed repetition in the set (MPV_{LAST}); and (iii) VL magnitude over each set, defined as: $100 \cdot (MPV_{LAST} - MPV_{BEST}) \cdot MPV_{BEST}^{-1}$.

Statistical Analysis

Standard statistical methods were used for the calculation of means, standard deviations (SD), confidence intervals (CI) and coefficients of determination (R^2). Relationships between MPV and load were studied by fitting second-order polynomials to data. The reliability of 1RM strength and individual load-velocity relationships (assessed in sessions 1 and 7) was examined. Absolute reliability was assessed using the standard error of measurement (SEM), which was calculated from the root mean square of the intra-subject total mean square,[30] expressed in relative terms as an intra-subject CV, which was calculated as $100 \cdot SEM \cdot mean^{-1}$. Relative reliability was calculated with the intraclass correlation coefficient (ICC) using the one-way random effects model with 95%CI. According to Stokes,[31] CV values of ≤15% can be classified as "satisfactory", whereas ICC values were classified according to Fleiss[32] as "excellent" (ICC ≥ 0.75), "moderate to good" (0.40 < ICC < 0.75) or "worse" (ICC ≤ 0.40) correlations. A related-sample t-test was used to compare the changes in the MPV corresponding to the different %1RM between both progressive loading tests and 1RM value (sessions 1 and 7). In order to examine the dispersion of the mean percentage of VL attained at each %1RM, the inter-individual CV was calculated (inter-individual CV = $100 \cdot SD \cdot mean^{-1}$). One-way repeated measures analysis of variance (ANOVA) was used to detect differences between loading conditions (50 vs. 60 vs. 70 vs. 80 vs. 90% 1RM) for all variables (MPV_{BEST}, MPV_{LAST}, VL, and MNR). Bonferroni´s post hoc adjustments were performed when appropriated. Significance was accepted at $p \leq 0.05$. All statistical analyses were performed using SPSS software version 20.0 (SPSS Inc., Chicago, IL). Figures were designed using SigmaPlot 12.0 (Systat Software Inc, San Jose, California, USA).

RESULTS

Progressive loading test and 1RM load

The relationship obtained between MPV and %1RM for the data from the whole sample was almost perfect (**Figure 1**), showing R^2 values of 0.976 and 0.975 in the first and second measurements, respectively. In addition, the mean individual R^2 values were 0.993 ± 0.004 (range: 0.986 – 0.998) and 0.993 ± 0.005 (range: 0.980 – 0.999) for both evaluations. Good stability criteria were met for 1RM, with similar values for the first and the second measurement (92.3 ± 16.0 kg and, 93.6 ± 16.6 kg, respectively), showing an ICC of 0.984 (95% CI: 0.951 to 0.995). In addition, no significant differences were found for the MPV corresponding to each %1RM between both measurements (**Table 1**). A high absolute reliability was observed for the MPV attained at the different %1RM, except for the velocity at 1RM (intra-subject CV: 15.7%). The ICCs for the mean velocity attained at the different %1RM showed values ranging from 0.70 to 0.84, which decreased as the %1RM increased (**Table 1**).

Tests of Maximum Number of Repetitions to Failure

Table 2 summarizes the characteristics of each set to failure performed against the 5 loads under study in terms of MNR and actual repetition velocities. Relative loads actually performed matched the scheduled %1RM. MPV_{BEST}, which is representative of the relative load, showed statistically significant differences ($P < 0.001$) between all loading conditions with inter-individual CV values ranging from 5.0 to 7.3%. Conversely, MPV_{LAST} was very similar ($P > 0.05$) for all loading conditions with inter-subject CV ranging from 21.9 to 30.5%. In addition, no significant differences were observed between MPV_{LAST} for all load conditions and MPV_{LAST} for both progressive loading tests ($P > 0.05$). As expected, the VL progressively decreased as %1RM increased. The MNR completed against each load decreased as %1RM increased ($P < 0.001$). MNR showed an inter-individual CV ranging from 8.6 to 33.1%, increasing as %1RM increased. In addition, the relationship between the %Rep and the magnitude of VL showed a general R^2 of 0.92-0.94 between 50 to 80% 1RM, which decreased to 0.80 for 90% 1RM. Mean individual R^2 values were between 0.97 and 0.99 for all loading conditions (**Figure 2**). The %Rep with respect to the MNR to failure when a given magnitude of VL was reached against the different loading conditions is reported in **Table 3**. The %Rep when a given percentage of VL was reached showed inter-individual CV values ranging from 2.9 to 21.4%, which decreased as %Rep increased in each load condition (**Table 4**).

DISCUSSION

This study was designed to evaluate the accuracy of two methods (traditional "MNR" vs. a velocity-based training approach) to prescribe resistance training volume during BP exercise performed on a Smith machine, when the %1RM was adjusted based on individual load-velocity relationships instead of using general equations, and avoiding a direct measure of the 1RM value in every training session. One of the main findings was that the inter-individual variability in the MNR completed against each load (50%, 60%, 70%, 80% and 90% 1RM) increased as the relative load increased, showing acceptable variability values (CV < 15%) for relative loads up to 80% 1RM. A second finding was that the pattern of repetition velocity decline showed an acceptable inter-individual variability (CV < 15%) when the magnitude of VL was equal to or greater than 20% against all relative loads under study. Moreover, individual %Rep-VL magnitude relationships provided better adjustments than general %Rep-VL relationships. Therefore, individual %Rep-VL relationships should be considered in order to provide more accurate predictions of the percentage of repetitions left in reserve from the VL magnitude.

In agreement with previous studies,[24,26] our data suggest that individual load-velocity relationships provide more accurate predictions of %1RM than general equations (mean individual $R^2 = 0.993 \pm 0.004$ vs. general equation $R^2 = 0.976$). The greater accuracy of individual load-velocity relationships may be explained by the fact that general equations do not take into account inter-individual differences, which could induce slight differences in the individual load-velocity relationships. On the other hand, the large inter-individual variability (CV: ~ 20%) in the MNR performed against different relative loads has been widely documented.[7,9,10,12,33] The findings obtained in the present study partly support these results, showing inter-individual variability values lower than 15% for relative loads up to 80% 1RM (**Table 2**). The lower inter-individual CV values observed in the present study may be partially explained by the load adjustment based on individual load-velocity relationships performed in the present study. Only two of the studies that analyzed the inter-individual variability in the MNR used the velocity-based approach to determine the relative load.[7,12] These studies used the mean velocity associated with each %1RM, estimated from a general equation developed for the BP exercise,[15] which means that all participants performed the first repetition of each %1RM at the same velocity ($\pm$ 0.02 $m \cdot s^{-1}$). However, since individual load-velocity relationships were used in the present study, MPV_{BEST} (i.e. velocity corresponding to a given %1RM) showed inter-individual CV values ranging from 5.0 to 7.3%, which means maximum differences between participants of up to 0.2 m per second for 50 and 60% 1RM (**Table 2**). When the general equation for the BP exercise is applied, a difference in the mean velocity attained with a given absolute load of 0.07 to 0.09 m per second means a difference of 5% in the relative load.[15] Therefore, if the general equation had been applied in the present study, the same velocity value would represent a difference of 10% of 1RM employed by the two extreme participants (i.e. the fastest and the slowest). This fact could have influenced the MNR completed against each load by each participant. However, the absolute between-participant differences in mean velocity were progressively reduced as the %1RM increased, with maximal differences of 0.05-0.07 $m \cdot s^{-1}$ when loads heavier than 80% 1RM were used. Likewise, the heavier the load, the higher the inter-individual CV for MNR. Because of the acceptable CV values reported for MNR completed with moderate loads (i.e. 50-60 %1RM, CV ~ 10.0%), fixing a given number of repetitions to perform during a training session, which will depend on the specific purpose of the training session, may be a choice. However, when heavier relative loads are used (≥ 70% 1RM), setting a specific number of repetitions to be performed seems not to be the best method to determine the resistance training volume and equalize the degree of fatigue between subjects. It should be noted that the wide range observed in MNR against each %1RM indicates that performing the same number of repetitions against a given %1RM would mean a different level of effort for different athletes. For instance, 8 repetitions at 70% 1RM for the two extreme athletes would mean 8 repetitions over 11 MNR or 17 MNR, and consequently, the repetitions left in reserve would meaningfully differ between them (3 and 9 repetitions in reserve, respectively).

The minimum velocity threshold (MVT) is associated with the mean concentric velocity produced on the last successful repetition of a set to failure performed with maximal lifting effort.[34] Knowing this velocity is an important practical application for coaches since it allows estimating the value of the 1RM through the load-velocity relationship. In this regard, Izquierdo et al.[14] observed no significant differences between MVT in the sub-maximal sets to failure across the 4 load conditions (60%, 65%, 70 and 75% 1RM) and velocity at 1RM in the Smith machine BP exercise. The findings obtained in the present study support these results, showing no significant differences between MVT at a range of sub-maximal loads from 50% to 90% 1RM. However, previous research has observed reliability values for MVT in sets to failure at sub-maximal loads below the threshold of acceptable reliability (intra-subject CV = 18.3%).[35] Likewise, comparable reliability values (intra-subject CV: 13.9%) were reported to mean concentric velocity associated to 1RM load.[24] In our study, the test-retest intra-subject CV was 15.7% for the MVT attained during the different load conditions and 1RM attempts (Table 1). Therefore, our results also seem to support that a general velocity of 1RM could be more appropriate to estimate the 1RM during the BP exercise performed on a Smith machine.

The magnitude of VL attained during the set has been proposed as an accurate variable for prescribing resistance training volume.[13] This statement is based on several findings: firstly, the high relationship (R^2 ~ 0.93-0.95) between the %Rep completed and the percentage of VL reached in the set for loads ranging from 50 to 85 %1RM.[7,12] The present findings confirm those previously published, showing a high correlation (R^2 = 0.92-0.94) between these two parameters for loads ranging from 50 to 80 %1RM (**Figure 2**). However, this relationship dropped considerably for the 90% 1RM (R^2 = 0.80). To our knowledge, this relationship has not been analyzed to this extreme relative load (i.e. 90% 1RM). The relevant drops in velocity from one repetition to another with 90% 1RM may indicate that the VL approach is not be sensitive enough to quantify resistance training volume with these loads. However, individual %Rep-VL relationships showed higher coefficients of determination (mean R^2 = 0.97-0.99) compared to general equations (R^2 = 0.80-0.94). On the other hand, a low inter-individual variability (<15% CV) was previously observed for the %Rep completed for magnitudes of VL ranging from 15 to 75%.[7] The findings obtained in the present study partly support these results, showing acceptable inter-individual variability values (≤15% CV) for magnitudes of VL greater than 20% against each relative load under study (**Table 4**). The slightly higher CV values observed in the present study could be attributable to the different strategies used to adjust the relative load. Previous studies[7,12] analyzing CV values of VL magnitude prescribed the relative intensities using a general load-velocity equation;[15] thus, all individuals performed the first repetition (MPV_{BEST}) at a very similar velocity (± 0.02 m·s^{-1}), whereas in the present study the individual load-velocity relationships were calculated for each participant. Therefore, the MPV_{BEST} for each %1RM was not exactly the same for each participant (inter-individual CV values ranged from 5.0 to 7.3%). Despite these slight differences observed in the CV values and the different strategies carried out to determine the %1RM during resistance training compared to the previous studies,[7,12] similar %Rep for a given magnitude of VL were observed compared to these studies (**Table 3**). Therefore, our findings suggest that, when the %1RM is adjusted based on individual load-velocity relationships, the VL magnitude can be used as an accurate strategy for prescribing resistance training volume. However, this VL magnitude may not be an appropriate method to prescribe resistance training volume with relative loads of 90% 1RM. Moreover, similar to the way in which individual load-velocity relationships provide more accurate predictions of %1RM than general equations,[24,26] individual relationships between VL magnitude and %Rep may result in a more homogeneous level of effort across individuals, regardless of the number of repetitions completed by each individual. As a limitation of this study, we must note that within-subject test-retest reliability of MNR for each load was not studied. Future research should consider this analysis to provide more confidence for prescribing resistance training volume according to our results. In addition, caution should be taken when using our findings with other exercises, populations or athletes with significantly different relative strength values.

PRACTICAL APPLICATIONS

The present findings suggest that strength and conditioning professionals may consider using the traditional method to determine training volumes (i.e. fixing a specific number of repetitions) with moderate relative intensity when these loads are determined based on individual load-velocity relationships. However, in order to provide a more homogenous level of effort between athletes, the VL approach should be considered, regardless the MNR that could be completed, mainly when using individual VL-%Rep relationships. This approach allows coaches and athletes to better adjust the training loads and autoregulate exercise volume during resistance training. The VL threshold should be scheduled beforehand depending on the training goal being pursued, as well as the individual characteristics.

CONCLUSIONS

Strong relationships were observed between %Rep and magnitude of VL (R^2 = 0.92-0.94) for relative loads from 50 to 80% of 1RM. Moreover, individual %Rep-VL magnitude relationships provided even better adjustments than general %Rep-VL relationships. However, setting a specific number of repetitions had acceptable inter-individual variability (CV < 15%) with moderate relative loads adjusted based on individual load-velocity relationships.

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FIGURE CAPTIONS

Figure 1. Relationships between relative load (%1RM) and bar velocity for the bench press exercise. Data obtained from raw load-velocity values derived from the progressive loading tests performed in the first (upper panel) and the second (lower panel) measurement. MPV: mean propulsive velocity; SEE: standard error of estimate.

Figure 2. Relationship between the magnitude of velocity loss incurred in a set and the percentage of completed repetitions with respect to the maximum number of repetitions that could be completed to failure against the 5 different loading conditions (50, 60, 70, 80 and 90 %1RM) under study. General and individual coefficients of determination (R^2) are shown. SEE: standard error of estimate. Individual R^2 are expressed as mean ± standard deviation (range). Loss of mean propulsive velocity: mean percent loss in velocity from the fastest to the last repetition over the set.

Table 1. Descriptive characteristics of the load-velocity relationship and 1RM value during the first and second measurements.

%1RM	**First**			**Second**			**ICC (CI 95%)**	**Intra-subject CV**	**dif**	**p-value**
	Mean	**CI 95%**	**Min-Max**	**Mean**	**CI 95%**	**Min-Max**				
20%	1.36 ± 0.10	1.31-1.42	1.14 -1.53	1.40 ± 0.11	1.33-1.46	1.23 -1.54	0.84 (0.51-0.95)	4.0	-0.03 ± 0.07	0.12
30%	1.18 ± 0.08	1.13-1.22	1.02-1.31	1.20 ± 0.09	1.15-1.25	1.06-1.33	0.83 (0.48-0.94)	3.8	-0.02 ± 0.06	0.23
40%	1.00 ± 0.06	0.96-1.04	0.89-1.12	1.01 ± 0.08	0.97-1.06	0.90-1.14	0.82 (0.47-0.94)	3.9	-0.01 ± 0.06	0.35
50%	0.83 ± 0.06	0.80-0.86	0.75-0.95	0.84 ± 0.06	0.80-0.88	0.75-0.96	0.80 (0.40-0.94)	4.1	-0.01 ± 0.05	0.64
60%	0.68 ± 0.05	0.65-0.71	0.61-0.78	0.68 ± 0.05	0.65-0.71	0.60-0.78	0.79 (0.35-0.93)	4.4	0.00 ± 0.04	0.95
70%	0.54 ± 0.04	0.51-0.56	0.48-0.61	0.53 ± 0.04	0.51-0.55	0.46-0.61	0.78 (0.35-0.93)	4.3	0.01 ± 0.03	0.59
80%	0.40 ± 0.03	0.38-0.42	0.35-0.45	0.39 ± 0.03	0.38-0.41	0.34-0.44	0.73 (0.18-0.91)	4.9	0.01 ± 0.03	0.26
90%	0.28 ± 0.03	0.27-0.30	0.21-0.31	0.27 ± 0.03	0.25-0.29	0.21-0.31	0.73 (0.20-0.91)	6.5	0.01 ± 0.02	0.07
100%	0.17 ± 0.04	0.15-0.19	0.08-0.22	0.16 ± 0.04	0.13-0.18	0.08-0.23	0.70 (0.11-0.90)	15.7	0.02 ± 0.03	0.11
1RM (kg)	92.3 ± 16.0	83.1-101.6	62.5-115.0	93.6 ± 16.6	84.0-103.2	62.5-115.0	0.98 (0.95-0.99)	3.1	-1.29 ± 4.05	0.84

Data are expressed as mean ± standard deviation. 1RM: one-repetition maximum; %1RM: relative load; First: data obtained from the first progressive loading test (first session); Second: data obtained from the second progressive loading test (seventh session); CI 95%: 95% of confidence interval; Min: Minimal value; Max: Maximal value; ICC: intraclass correlation coefficient; Intra-subject CV: intra-subject test-retest coefficient of variation; dif: absolute difference between values from First and Second progressive loading test; p-value: p-value obtained from the comparison between First and Second measurements.

Table 2. Descriptive characteristics of each loading magnitude under study.

	50% 1RM	60% 1RM	70% 1RM	80% 1RM	90% 1RM
Actual %1RM #	49.2 ± 1.4 (46.2 - 51.2) CV = 2.9	60.6 ± 2.9 (57.3 - 68.1) CV = 4.7	70.8 ± 2.0 (68.0 - 75.0) CV = 2.9	82.0 ± 3.0 (78.0 - 86.4) CV = 3.6	90.7 ± 3.6 (86.5 - 97.6) CV = 3.9
MPV_{BEST} ($m \cdot s^{-1}$) #	0.82 ± 0.06 (0.71 - 0.91) CV = 7.3	0.68 ± 0.05 (0.59 - 0.79) CV = 6.9	0.54 ± 0.03 (0.49 - 0.63) CV = 6.3	0.41 ± 0.02 (0.38 - 0.45) CV = 5.0	0.28 ± 0.02 (0.26 - 0.31) CV = 7.2
MPV_{LAST} ($m \cdot s^{-1}$)	0.14 ± 0.04 (0.07 - 0.19) CV = 25.9	0.13 ± 0.04 (0.05 - 0.19) CV = 30.2	0.13 ± 0.04 (0.05 - 0.18) CV = 29.1	0.12 ± 0.04 (0.06 - 0.18) CV = 30.5	0.14 ± 0.03 (0.10 - 0.19) CV = 21.9
Velocity Loss (%)	83.1 ± 4.4¶ǁ (77.0 - 91.0) CV = 5.3	81.4 ± 5.6¶ǁ (73.0 - 92.3) CV = 6.9	76.4 ± 7.0ǁ (64.9 - 91.6) CV = 9.1	70.0 ± 9.5ǁ (55.7 - 86.3) CV = 13.5	49.5 ± 10.7 (29.6 - 65.0) CV = 21.5
MNR #	28.1 ± 2.4 (24 - 32) CV = 8.6	20.0 ± 2.2 (17 - 25) CV = 10.9	13.5 ± 1.8 (11 - 17) CV = 13.2	7.9 ± 1.1 (6 - 10) CV = 14.0	3.8 ± 1.3 (2 - 5) CV = 33.1

Data are mean ± standard deviation (range). Velocity values correspond to the mean concentric propulsive velocity of each repetition; %1RM: percentage of one-repetition maximum; Actual %1RM: percentage of 1RM actually performed; MPV_{BEST}: velocity of the fastest (usually first) repetition in the set; MPV_{LAST}: velocity of the last repetition in the set. Velocity Loss: mean percent loss in velocity from the fastest to the last repetition over the set; MNR: maximal number of repetitions completed in the set; CV: inter-subject coefficient of variation, calculated as 100 standard deviation$\cdot$mean^{-1}.

¶Statistically significant differences with respect to 80% 1RM.

ǁStatistically significant differences with respect to 90% 1RM.

#Statistically significant differences between all loads.

Table 3. Percentage of completed repetitions with respect to the maximum number of repetitions to failure when a given magnitude of velocity loss is reached.

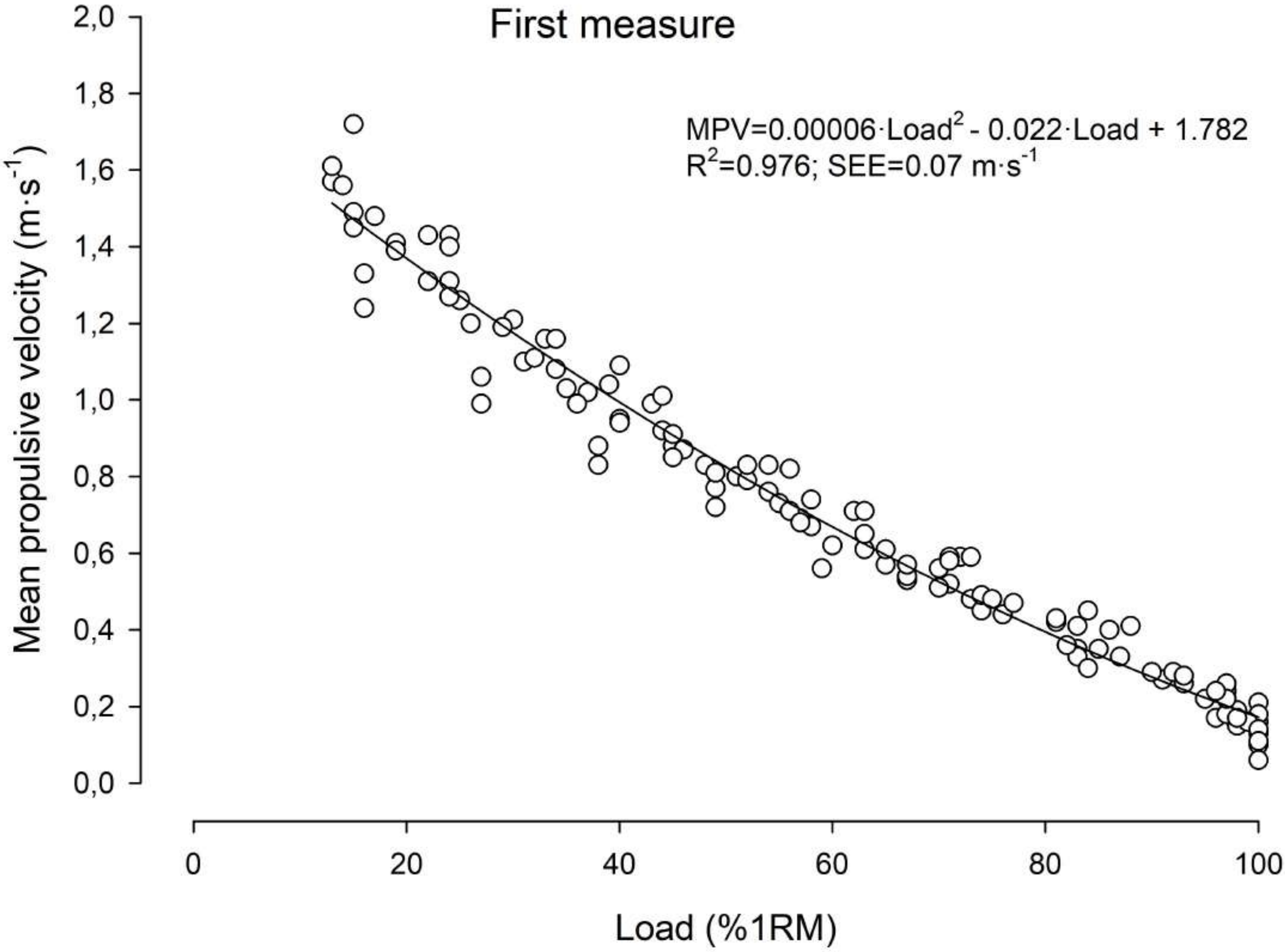
	Velocity Loss														
	15%	**20%**	**25%**	**30%**	**35%**	**40%**	**45%**	**50%**	**55%**	**60%**	**65%**	**70%**	**75%**	**80%**	**85%**
50% 1RM	31.6	39.2	46.3	53.0	59.4	65.3	70.7	75.8	80.4	84.6	88.4	91.7	94.7	97.2	99.3
60% 1RM	31.3	39.3	46.9	54.1	60.8	67.0	72.7	78.0	82.9	87.2	91.1	94.5	97.5		
70% 1RM	32.6	39.8	46.8	53.4	59.8	65.8	71.5	77.0	82.1	87.0	91.5	95.8	99.7		
80% 1RM	39.2	45.9	52.5	58.8	64.8	70.7	76.3	81.7	86.8	91.7	96.4				
90% 1RM	54.0	60.1	66.3	72.6	78.8	85.2	91.6	98.0							

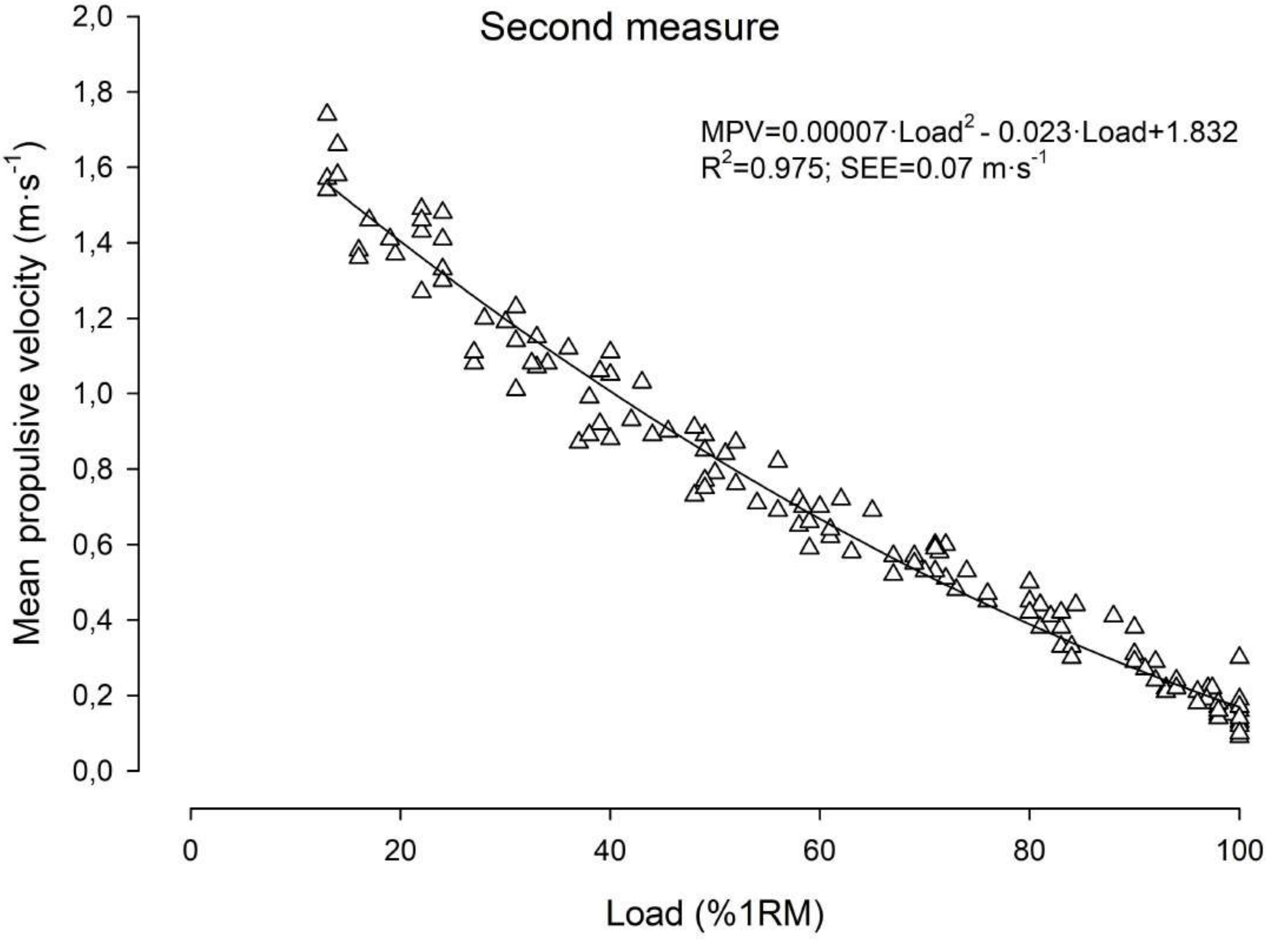
%1RM: percentage of one-repetition maximum; Velocity Loss: mean percent loss in velocity from the fastest to the last repetition over the set

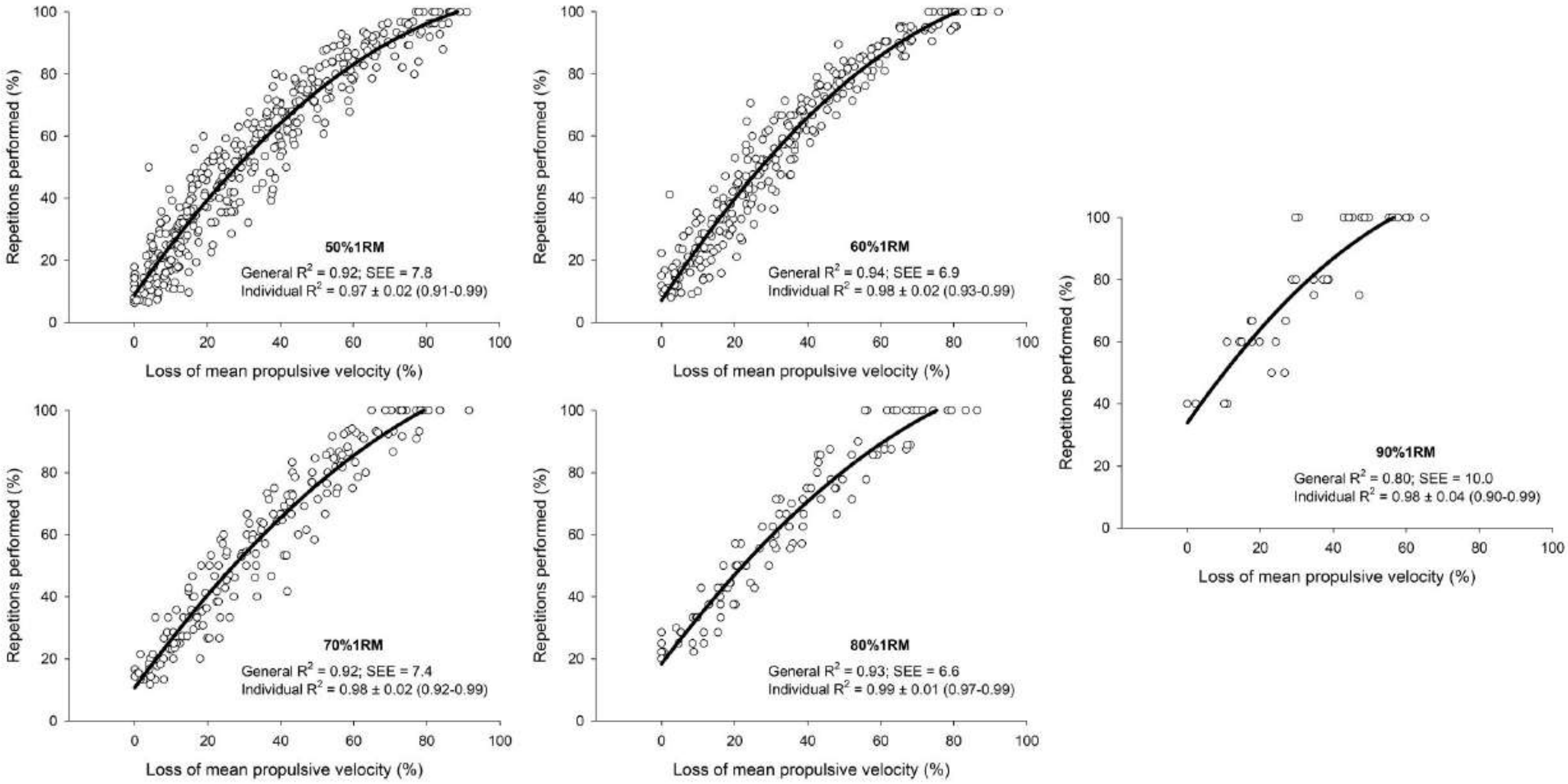
Table 4. Inter-subject coefficient of variation for the percentage of completed repetitions with respect to the maximum number of repetitions to failure when a given percentage of velocity loss is reached.

	Inter-subject CV for each percent of Velocity Loss														
	15%	**20%**	**25%**	**30%**	**35%**	**40%**	**45%**	**50%**	**55%**	**60%**	**65%**	**70%**	**75%**	**80%**	**85%**
50% 1RM	20.9	17.7	15.7	14.1	12.8	11.6	10.4	9.2	8.0	6.8	5.7	4.7	4.2	4.3	5.2
60% 1RM	21.4	16.7	13.7	11.6	9.9	8.5	7.3	6.2	5.1	4.2	3.4	2.9	3.0	3.6	
70% 1RM	19.2	16.8	15.2	13.8	12.6	11.4	10.2	9.1	7.9	6.8	5.8	5.1	4.9		
80% 1RM	13.0	12.1	11.6	11.3	10.9	10.4	9.9	9.3	8.9	8.6	8.6	8.9			
90% 1RM	19.2	14.5	13.0	12.5	12.0	11.2	10.2	9.5							

%1RM: percentage of one-repetition maximum; Velocity Loss: mean percent loss in velocity from the fastest to the last repetition over the set; Inter-subject CV: inter-subject coefficient of variation, calculated as 100 standard deviation·mean^{-1}.


First measure
MPV=0.00006·Load2 - 0.022·Load + 1.782
R2=0.976; SEE=0.07 m·s-1
Mean propulsive velocity (m·s-1)
2,0
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0
20
40
60
80
100
Load (%1RM)


Second measure
MPV=0.00007·Load2 - 0.023·Load+1.832
R2=0.975; SEE=0.07 m·s-1
Mean propulsive velocity (m·s-1)
2,0
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0
20
40
60
80
100
Load (%1RM)



Repetitons performed (%)
Loss of mean propulsive velocity (%)
50%1RM
General R2 = 0.92; SEE = 7.8
Individual R2 = 0.97 ± 0.02 (0.91-0.99)
60%1RM
General R2 = 0.94; SEE = 6.9
Individual R2 = 0.98 ± 0.02 (0.93-0.99)
70%1RM
General R2 = 0.92; SEE = 7.4
Individual R2 = 0.98 ± 0.02 (0.92-0.99)
80%1RM
General R2 = 0.93; SEE = 6.6
Individual R2 = 0.99 ± 0.01 (0.97-0.99)
90%1RM
General R2 = 0.80; SEE = 10.0
Individual R2 = 0.98 ± 0.04 (0.90-0.99)