

Movement Velocity as Indicator of Relative Intensity and Level of Effort Attained During the Set in Pull-Up Exercise

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Purpose: To analyze the relationship between movement velocity and relative load (%1RM) in the pull-up exercise (PU) and to determine the pattern of repetition-velocity loss during a single set to failure in pulling one's own body mass. **Methods:** Fifty-two men (age = 26.5 ± 3.9 y, body mass = 74.3 ± 7.2 kg) performed a first evaluation (T1) consisting of an 1-repetition-maximum test (1RM) and a test of maximum number of repetitions to failure pulling one's own body mass (MNR) in the PU exercise. Thirty-nine subjects performed both tests on a second occasion (T2) following 12 wk of training. **Results:** The authors observed a strong relationship between mean propulsive velocity (MPV) and %1RM ($r = -.96$). Mean velocity attained with 1RM load (V_{1RM}) was 0.20 ± 0.05 m·s⁻¹, and it influenced the MPV attained with each %1RM. Although 1RM increased by 3.4% from T1 to T2, the relationship between MPV and %1RM, and V_{1RM} , remained stable. The authors also confirmed stability in the V_{1RM} regardless of individual relative strength. The authors found a strong relationship between percentage of velocity loss and percentage of performed repetitions ($R^2 = .88$), which remained stable despite a 15% increase in MNR. **Conclusions:** Monitoring repetition velocity allows estimation of the %1RM used as soon as the first repetition with a given load is performed, and the number of repetitions remaining in reserve when a given percentage of velocity loss is achieved during a PU exercise set.

Keywords: loading intensity, training volume, velocity loss, velocity-based resistance training, strength training

Exercise intensity is one of the most important variables to consider when designing resistance training (RT) aimed at improving strength levels.^{1,2} Traditionally, exercise intensity has been defined and prescribed as a percentage of 1-repetition maximum (%1RM), often called relative intensity.¹⁻³ Another commonly used method is to prescribe exercise intensity based on the maximal load that can be lifted with a given number of repetitions (XRM) in each set.¹ However, these methods have some potential limitations, which means neither 1RM nor XRM tests are entirely appropriate for precisely monitoring exercise intensity.^{4,5} Movement velocity has been introduced as a valid method for monitoring exercise intensity in real time.⁵ A very close relationship has been observed between movement velocity and %1RM in different resistance exercises,⁵⁻⁷ making it possible to: (1) evaluate an athlete's strength without the need to perform 1RM or XRM tests; (2) determine the %1RM that is being used as soon as the first repetition with a given load is performed with maximal voluntary velocity.⁵

Training volume is another important variable for configuring the training load in RT because it affects neuromuscular responses and subsequent adaptations.^{2,8} Typically, training volume is prescribed using a specific number of repetitions in each exercise set for all subjects. However, the maximal number of repetitions that can be completed against a given relative load (%1RM) shows a large interindividual variability.⁹ Therefore, if during a training session, all subjects perform the same number of repetitions per set against the same relative load, it is possible that they are exerting different levels of effort.⁹ Thus, rather than performing a fixed number of repetitions, it seems more appropriate to terminate each training set as soon as a certain level of neuromuscular fatigue is

detected.^{9,10} In this regard, recent studies have shown that (1) the velocity loss in the set shows very strong relationships with mechanical and metabolic measures of fatigue,¹⁰⁻¹² and (2) there is a very close relationship between the percentage of velocity loss incurred in a set and the percentage of performed repetitions.⁹ These results support the validity of using velocity loss as a variable to objectively quantify neuromuscular fatigue during RT in different exercises, including bench press and squat.^{9,10} However, whether the same results occur in other resistance exercises such as the pull-up (PU) remains unexplored.

The PU exercise is a multi-joint upper-body exercise¹³ in which the individual grips a stationary bar overhead and pulls his/her body mass (BM) upward to the bar. The individual is typically limited to the use of BM as resistance, although external loads can be added via a weighted vest or belt to achieve greater resistance.^{14,15} This exercise is commonly used in sport disciplines that require upper-body pulling strength, such as canoeing,^{16,17} climbing,¹⁸ and kayaking.¹⁹ Furthermore, it has traditionally been used to assess upper-body strength and muscular endurance in different populations.^{13,20,21} Studies have analyzed the joint movement and work,²² surface electromyography activation patterns,^{20,23,24} similarities between PU and lat-pull exercises,²⁴⁻²⁸ and the influence of body composition on performance in the PU exercise.²⁶⁻²⁸ However, to our knowledge, the velocity-load relationship in the PU exercise has not yet received attention. In addition, because the PU exercise is often used to assess muscular endurance through the maximum number of repetitions that can be completed lifting one's own BM,²⁹ knowing the velocity decline occurring during a single set to failure can provide useful information to coaches and strength and conditioning professionals to individually prescribe training volumes during training sessions.

Therefore, the aims of the present study were (1) to analyze the relationship between movement velocity and relative load (%1RM) in the PU exercise to assess the use of velocity data to

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estimate loading intensity; and (2) to determine the velocity decline during a single set to failure lifting one's own BM to determine the percentage of performed repetitions (%Rep) with respect to the maximum number that can be completed for different magnitudes of velocity loss (%VL) within a set to failure.

Materials and Methods

Subjects

Fifty-two men (mean $\pm$ SD: age = 26.5 ± 3.9 y, body mass = 74.3 ± 7.2 kg, height = 176.7 ± 5.8 cm) volunteered to take part in this study. Subjects were firefighter candidates with a training background in PU exercise ranging from 2 to 4 years (2–3 sessions per week). None of the subjects was taking drugs, medications, or dietary supplements known to influence physical performance. All subjects provided written informed consent and were screened for medical contraindications prior to testing. The present investigation was approved by the Research Ethics Committee of Pablo de Olavide University, and was conducted in accordance with the Declaration of Helsinki.

Experimental Design

For each subject, testing was conducted over 3 sessions separated by 48 to 72 hours. The first session was used for anthropometric assessments, medical examination, and familiarization with PU testing protocols. During the familiarization, subjects carried out some practice sets with light and medium external loads (from 0–20 kg), while researchers emphasized proper technique. During the second session, all 52 subjects performed a strength test with increasing loads up to 1RM for individual determination of the full load–velocity relationship. Finally, in the third session, the subjects conducted a test to determine the maximum number of repetitions to failure (MNR test) without added weight. A subset of the total sample (39 subjects) performed the same experimental protocol on a second occasion (T2) after 12 weeks of RT. During this time, each subject trained following his usual routine (2–3 sessions per week), which included the PU exercise (3–5 sets, 50–80% of MNR, 2–4 min interset rests).

Testing Procedures

All PU tests were performed on a standard stationary, horizontal bar. To be counted as a complete PU repetition, it was required that the subject lifted his body from a full-arm extension hanging position until the chin was above the bar. A self-selected width with pronated grip (approximately 150% of the biacromial distance) was used throughout the first testing session and it was recorded in order to be repeated in the subsequent testing sessions. During each repetition of both tests (1RM and MNR test), the subjects were required to perform the eccentric phase in a controlled velocity (~ 0.65 – 0.75 m·s⁻¹) and maintain a static position for ~ 1 second at the end of this phase before performing the concentric phase at maximal intended velocity upon hearing the command. All repetitions were recorded with a linear velocity transducer (T-Force System; Ergotech, Murcia, Spain). The reliability of this system has been reported elsewhere.¹⁰ All reported repetition velocities in this study correspond to the mean propulsive velocity (MPV).³⁰ The same warm-up protocol, which consisted of 5 minutes of jogging at a self-selected easy pace, 5 minutes of joint mobilization exercises, and 2 sets of 3 to 5 PU repetitions with no

external load, was followed in all testing sessions. Testing sessions were performed at the same venue and time of day (± 1 h) for each subject, under the same environmental conditions. Strong verbal encouragement was provided during all tests to motivate subjects to give maximal effort.

One-Repetition-Maximum Test

Individual load–velocity relationships and 1RM strength were determined using a progressive loading test. The test-retest reliability of 1RM test in the PU exercise has been previously established.¹⁴ Subjects started without additional weight and the load was gradually increased, initially in 5-kg increments and reducing down to 1-kg additions so that 1RM could be precisely determined. Because subjects needed to lift their BM, PU maximal strength (1RM) was calculated as the sum of the maximum weight lifted and the subject's BM. For example, if a subject weighing 90 kg was able to lift 20 kg during the loading test, his 1RM was 110 kg (90 kg + 20 kg = 110 kg). Three repetitions were executed when the MPV was higher than 0.75 m·s⁻¹, 2 when the MPV ranged from 0.75 m·s⁻¹ to 0.55 m·s⁻¹, and only 1 when the MPV was less than 0.55 m·s⁻¹. Inter-set rests were 3 minutes when the MPV was higher than 0.55 m·s⁻¹ and 4 minutes when the MPV was less than 0.55 m·s⁻¹. Only the best repetition (fastest and executed correctly) at each load was considered for subsequent analysis. To add additional weight, a specialized belt was used which could be adjusted around the waist and which allowed weights to be attached via chain. The cable from the linear velocity transducer was fixed to the back of the belt.

Tests of Maximum Number of Repetitions to Failure

During this test, subjects were required to complete the maximum number of repetitions until muscular failure, lifting their own BM from a full-arm extension hanging position (using the same width pronated grip and execution as in the progressive loading test) until the chin was above the bar. The test was considered as finished when the subject was not able to raise the chin above the bar or when the subjects paused more than 2 to 3 seconds in the full-arm extension hanging position. The test-retest reliability of this test has been previously reported elsewhere.¹⁵

Statistical Analyses

Standard statistical methods were used for the calculation of means, standard deviations (SD), standard error of the estimate (SEE), confidence intervals (CI), and Pearson product-moment correlation coefficients (r). The Kolmogorov-Smirnov test was applied to determine the nature of the data distribution for the velocity attained with the 1RM load (V_{1RM}). Load–velocity relationships were studied by fitting first-order linear equations to the data. The relationship between %VL and %Rep was studied by fitting second-order polynomials to the data. Test-retest absolute reliability was assessed using the coefficient of variation (CV), whereas relative reliability was calculated with the intraclass correlation coefficient (ICC) using the 1-way random effects model. A related-sample t -test was used to analyze intragroup changes between T1 and T2. One-way ANOVA with Scheffé post hoc comparisons was used to detect differences between subgroups of subjects (group 1: relative strength ratio ≤ 0.41 [RSR, defined as 1RM load value divided by body mass]; group 2: $0.41 < \text{RSR} \leq 0.52$; and group 3: $\text{RSR} > 0.52$). Significance was accepted at the $P \leq .05$ level.

All analyses were performed using SPSS software version 17.0 (SPSS, Chicago, IL, USA).

Results

Relationship Between Relative Load and Velocity

After plotting MPV against %1RM from T1, a strong relationship ($r = -.96$) was observed between these variables (Figure 1A). The average correlation value for each individual's curve fit was $r = -.97 \pm .03$ (95% CI = $-.96$ to $-.98$; CV = 3.7%). The MPV attained with each %1RM was obtained from these lineal fits, from 65% 1RM onwards, in 5% increments (Table 1). The lightest load was set at 65% of 1RM because the lowest weight used in this exercise was the subject's own BM, and the relative load this represented was $68.3 \pm 7.0\%$ (95% CI = 66.4–70.3% 1RM).

Predicting Load (%1RM) From Velocity Data

The resulting prediction equation for estimation of relative load (%1RM) from the MPV data ($\text{m}\cdot\text{s}^{-1}$) was: $\text{load} = -53.472 \text{ MPV} + 110.68$ ($r = -.96$; SEE = 3.15% of 1RM).

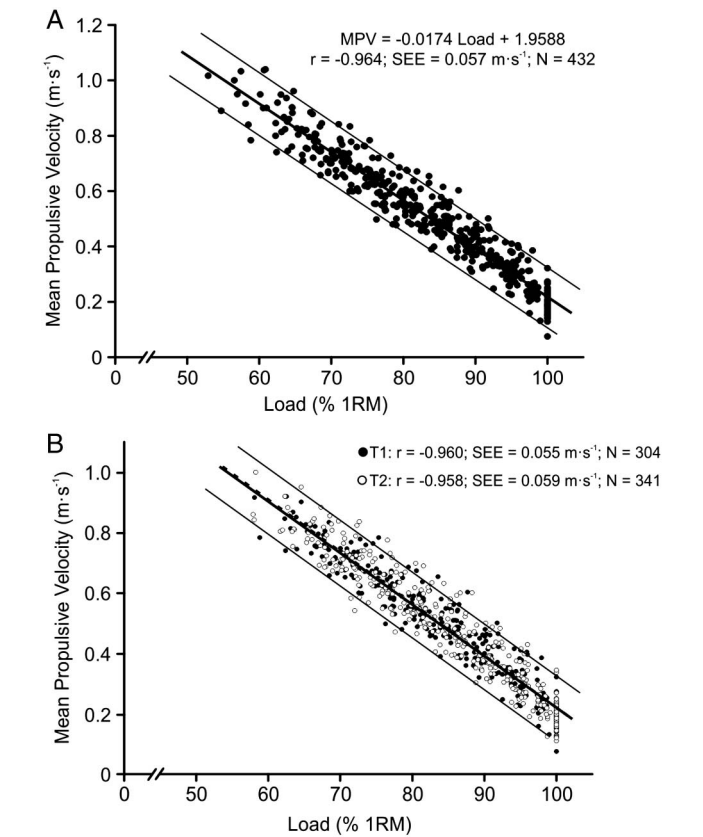


Figure 1 — Relationship between relative load (%1RM) and mean propulsive velocity (MPV) obtained from 432 items of raw data derived from the 52 incremental tests performed in T1 (A), and from 304 and 341 items of raw data from the subset of 39 subjects who performed the incremental tests in T1 and T2 (B). The thick line shows the fitted curve for the data, and the thin lines indicate limits within which 95% of predictions will fall. SEE, standard error of the estimate.

Table 1 Changes in Mean Propulsive Velocity ($\text{m}\cdot\text{s}^{-1}$) Attained with Each Relative Load

Load (%1RM)	MPV (T1)	MPV (T2)	Difference (T1–T2)	CV (%)
65%	0.84 ± 0.08	0.83 ± 0.08	0.01	5.2
70%	0.75 ± 0.07	0.74 ± 0.07	0.00	5.1
75%	0.66 ± 0.06	0.66 ± 0.06	0.00	5.4
80%	0.57 ± 0.06	0.57 ± 0.06	0.00	5.5
85%	0.48 ± 0.05	0.48 ± 0.05	0.00	5.9
90%	0.39 ± 0.05	0.39 ± 0.05	0.00	6.9
95%	0.30 ± 0.05	0.30 ± 0.05	0.00	9.4

Abbreviations: 1RM, 1-repetition maximum; CV, coefficient of variation; MPV, mean propulsive velocity; T1, pretest; T2, posttest.
Note. Values are mean $\pm$ SD (N = 39). Changes are from initial test (T1) to retest (T2), after 12 weeks of training, in the pull-up exercise.

Stability in the Load–Velocity Relationship After Modifying the 1RM

From T1 to T2, the 1RM value improved from 106.0 ± 13.1 kg to 109.4 ± 12.5 kg ($P < .001$). However, the difference in mean test velocity (defined as the mean of the velocity values, calculated each 5% from 65–95% 1RM for each test) was 0.00 ± 0.04 $\text{m}\cdot\text{s}^{-1}$ or, when expressed as absolute values, 0.03 ± 0.03 $\text{m}\cdot\text{s}^{-1}$, thus remaining practically unchanged (0.57 ± 0.06 $\text{m}\cdot\text{s}^{-1}$ and 0.57 ± 0.06 $\text{m}\cdot\text{s}^{-1}$ for T1 and T2, respectively; see Table 1). Additionally, the relationship between MPV and %1RM remained stable in both tests ($r = -.96$, Figure 1B). Furthermore, the MPV attained with each %1RM showed a good relative (mean ICC: .82 [95% CI = .78–.83]) and absolute (mean CV = 6.1%) reliability.

Influence of the Velocity Attained With 1RM

The $V_{1\text{RM}}$ attained in T1 was 0.20 ± 0.05 $\text{m}\cdot\text{s}^{-1}$ (range: 0.08–0.32 $\text{m}\cdot\text{s}^{-1}$) and followed a normal distribution. A significant correlation ($r = .57$, $P < .001$; Figure 2A) was found between $V_{1\text{RM}}$ and mean test velocity during T1. The $V_{1\text{RM}}$ (0.20 ± 0.05 $\text{m}\cdot\text{s}^{-1}$) and the relationship between mean test velocity and $V_{1\text{RM}}$ remained very similar ($r = .58$; and $r = .51$, $P < .001$; Figure 2B) when only the 39 subjects who performed both tests (T1 and T2) were used in the analysis. Despite the influence of RSR on MNR completed ($r = .87$, $P < .001$), no significant differences in $V_{1\text{RM}}$ and mean test velocity were found for the different relative strength groups (Table 2).

Relationship Between Velocity Loss During the Set and the Percentage of Repetitions Performed

A strong relationship ($R^2 = .88$) was observed between the %VL and %Rep during T1 (Figure 3A). The average correlation value for each individual curve fit was $R^2 = .97 \pm .03$ (95% CI = .96–.98; CV = 3.5%).

Stability in the Relationship Between Velocity Loss During the Set and the Percentage of Repetitions Performed After Modifying the MNR

From T1 to T2, the MNR value increased from 15.1 ± 4.2 repetitions to 17.0 ± 4.1 repetitions ($P < .001$). However, the relationship between %VL and %Rep observed in both tests remained stable ($R^2 = .89$ and $R^2 = .87$ for T1 and T2, respectively, Figure 3B).

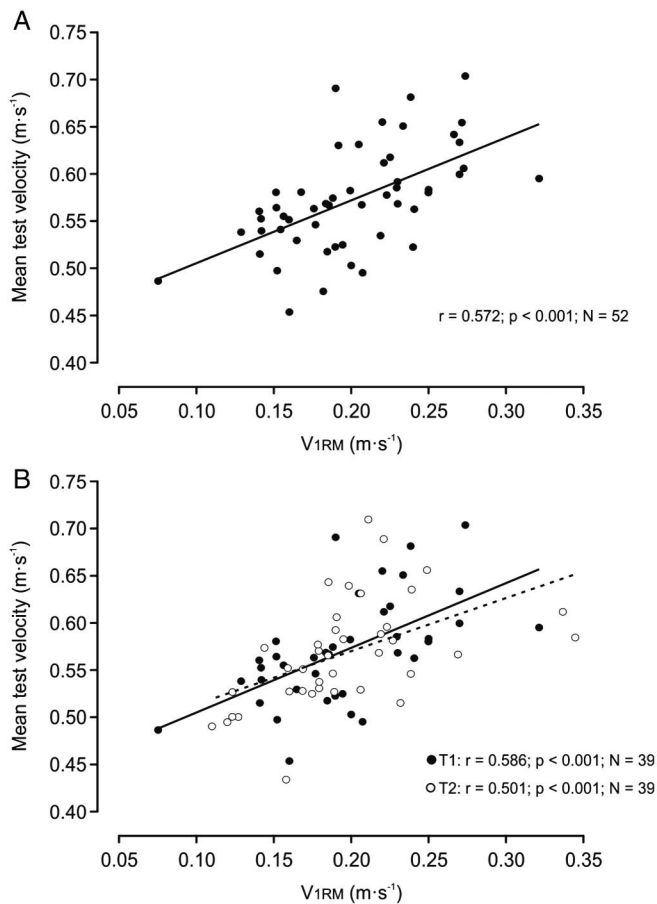


Figure 2 — Correlation between mean velocities attained with the 1RM load (V_{1RM}) and mean test velocity from T1 ($N=52$; A) and from T2 ($N=39$; B).

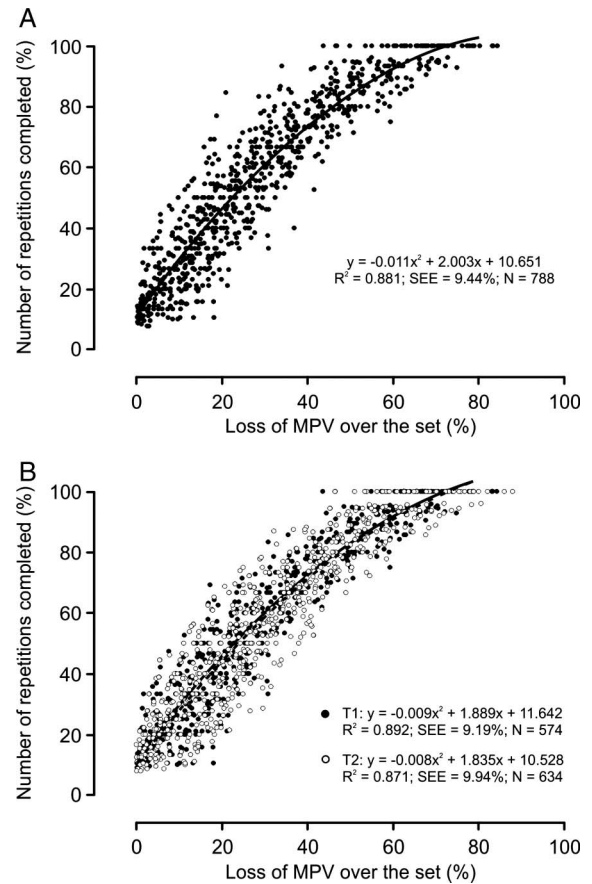


Figure 3 — Relationship between velocity loss during the set (%VL) and the percentage of repetitions performed (%Rep) directly obtained from 788 items of raw data derived from the 52 maximum number of repetitions to failure (MNR) test performed in T1 (A), and from 574 and 634 items of raw data from the subset of 39 subjects who performed the MNR tests in T1 and T2 (B). SEE, standard error of the estimate.

Table 2 Comparison of Mean Test Velocity, Mean Velocity Attained With the 1RM Load (V_{1RM}), and Maximal Number of Repetitions to Failure Between Subgroups of Different Relative Strength Ratio

Subgroup	RSR	Mean test velocity ($\text{m}\cdot\text{s}^{-1}$)	V_{1RM} ($\text{m}\cdot\text{s}^{-1}$)	MNR (repetitions)
G1 ($n=17$)	$0.32 \pm 0.06^{\dagger}$	0.59 ± 0.08	0.20 ± 0.05	$11.4 \pm 2.6^{\dagger}$
G2 ($n=18$)	$0.47 \pm 0.05^{\dagger}$	0.57 ± 0.03	0.20 ± 0.05	$16.6 \pm 2.4^{\dagger}$
G3 ($n=17$)	$0.65 \pm 0.10^{\dagger}$	0.56 ± 0.05	0.20 ± 0.04	$19.8 \pm 3.5^{\dagger}$

Abbreviations: MNR, maximal number of repetitions to failure in the pull-up exercise; RSR, relative strength ratio, defined as 1-repetition maximum value divided by body mass.

Note. Values are mean $\pm$ SD.

† All groups significantly different from each other ($P<.001$).

Table 3 shows the %Rep when a given %VL was reached in a set to failure during T1 and T2, and the differences between both tests.

Discussion

To our knowledge, this is the first study analyzing (1) the relationships between relative load and mean velocity, and (2) the relationship between %VL and the percentage of repetitions performed with regard to the maximal number of repetitions that can be

completed in the PU exercise. One of the main findings of this study was the close relationship ($r=-.96$) observed between relative load and MPV (Figure 1A), and the stability of this relationship despite the notable change in maximal dynamic strength (Figure 1B). Another important finding was the strong relationship ($R^2=.88$) observed between %VL and %Rep (Figure 3A), and the stability of this relationship despite the improvement in MNR (Figure 3B). These findings allow us (1) to determine the real intensity of effort being incurred by an

Table 3 Percentage of Repetitions Performed With Respect to the Maximal Number of Repetitions and Absolute Reliability for Each Magnitude of MPV Loss Reached in a Set to Failure

Loss of MPV (%)	% repetition performed (T1)	% repetition performed (T2)	Difference (T1–T2)	CV (%)
20%	45.6 ± 8.9	43.2 ± 10.2	2.4	14.0
25%	53.7 ± 8.8	51.7 ± 10.0	2.0	10.9
30%	61.2 ± 8.6	59.5 ± 9.8	1.7	9.1
35%	68.1 ± 8.2	66.7 ± 9.4	1.4	7.9
40%	74.4 ± 7.7	73.3 ± 8.8	1.1	6.9
45%	80.2 ± 7.1	79.3 ± 8.0	0.9	6.0
50%	85.3 ± 6.5	84.6 ± 7.1	0.8	5.2
55%	89.9 ± 6.1	89.2 ± 6.1	0.7	4.6
60%	93.9 ± 6.2	93.3 ± 5.7	0.6	4.2
65%	97.3 ± 7.0	96.7 ± 6.3	0.6	4.3

Abbreviations: CV, coefficient of variation; MPV, mean propulsive velocity.

Note. Values are mean ± SD (N = 39). Loss of MPV defined as: $100 \cdot (\text{MPV of the last repetition} - \text{MPV of the fastest repetitions [usually the first]}) / \text{MPV of the fastest}$. %Repetitions performed defined as: $100 \cdot (\text{submaximal number of repetitions} - \text{maximal number of repetitions}) / \text{maximal number of repetitions}$.

athlete when using any load from 65% to 95% of 1RM, and (2) to estimate how many repetitions are left in reserve when a given %VL is achieved during a PU exercise set.

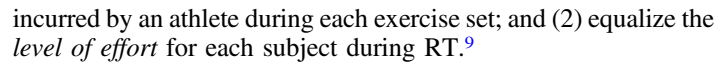
A very strong relationship between relative load and mean velocity has been observed in other exercises such as the bench press ($R^2 = .98$), prone bench pull ($R^2 = .94$), and full squat ($R^2 = .97$).^{5–7} The current research has extended that understanding to the PU exercise ($r = -.96$). An important difference between the aforementioned exercises and the PU was that, for the previously studied exercises, the best fit between relative load and mean velocity was a curvilinear-type fit (second-order polynomial), whereas for the PU exercise it was a linear fit. This may be because the lowest weight used in this exercise is the subject's own BM, which, in our study, represented approximately 65% 1RM. Therefore, the portion of the load–velocity curve analyzed in the present study was from 65% to 95% 1RM, which seems to confirm to a linear fit. Conversely, in other resistance exercises such as the bench press and bench pull, where the BM is not lifted, the portion of the curve analyzed was from 30% to 100% 1RM, which seems to follow a curvilinear fit.^{5,7}

In agreement with a previous study,⁵ our results showed that the MPV attained with each %1RM is not modified by 1RM value changes (9.8%) after a training period (Table 1). In addition, the ICC and CV values obtained for movement velocity in test–retest comparisons indicated a good reliability of this parameter, suggesting its use for strength assessment follow-up in the PU exercise. A similar reliability score (ICC = .87) has been observed in the load–velocity relationship for the bench press exercise.⁵ As consequence, the strong relationship observed in our study might be used to predict or adjust the relative intensity during a training session simply by monitoring the movement velocity in PU exercise. Thus, as an example, if a subject performs a repetition at $0.75 \text{ m} \cdot \text{s}^{-1}$ with a given load (kg), this means that such load represents approximately 70% of 1RM.

Different studies have paid attention to the V_{IRM} in a range of upper-body pressing and pulling exercises.^{5,7,31} The mean V_{IRM} observed in the bench press was $\sim 0.16 \text{ m} \cdot \text{s}^{-1}$,^{5,31} while in the bench pull it was $\sim 0.52 \text{ m} \cdot \text{s}^{-1}$.⁷ Surprisingly, although the PU is an upper-body pulling exercise, the mean V_{IRM} observed ($\sim 0.20 \text{ m} \cdot \text{s}^{-1}$) was similar to that observed in an upper-body pressing exercise such as

the bench press. However, in contrast with previous results reported in bench press exercise,⁵ the present study suggests that neither the mean test velocity nor the V_{IRM} were influenced by the relative strength of the subjects (Table 2). However, an important finding to take into account is that the individual values of V_{IRM} had an influence on the mean test velocity (Figure 2), such that as the V_{IRM} increased, there was a tendency toward higher MPV with each %1RM. Figure 4 provides examples illustrating this tendency. Figure 4A shows 1 subject who improved his 1RM value by 9.8%. The V_{IRM} value in T1 and T2 were identical ($0.14 \text{ m} \cdot \text{s}^{-1}$), and MPV with each %1RM and mean test velocity remained stable (0.56 and $0.57 \text{ m} \cdot \text{s}^{-1}$, respectively). Figure 4B shows a case in which the subject showed a similar change in 1RM from T1 to T2 as the first case (10.1%), but the V_{IRM} decreased (from 0.27 – $0.21 \text{ m} \cdot \text{s}^{-1}$). Consequently, the MPVs attained with each %1RM and mean test velocity ($0.63 \text{ m} \cdot \text{s}^{-1}$ and $0.53 \text{ m} \cdot \text{s}^{-1}$) were lower in T2 than in T1. Finally, the subject whose curves are shown in Figure 4C did not improve his maximal strength. For this subject, V_{IRM} in T1 ($0.14 \text{ m} \cdot \text{s}^{-1}$) and T2 ($0.17 \text{ m} \cdot \text{s}^{-1}$) were very similar, and the MPVs attained with each relative load and mean test velocity were the same in both tests ($0.55 \text{ m} \cdot \text{s}^{-1}$). These results suggest that a maximum value for V_{IRM} should be established in order for 1RM to be considered true and valid in the PU exercise. If V_{IRM} exceeds this value, the mean velocities attained with each %1RM and relative loads will deviate from their true values.

Finally, a strong relationship ($R^2 = .88$) was observed between %VL and %Rep (Figure 3A). In addition, the %Rep during the set to failure when a given magnitude %VL was reached were very similar in both tests (Table 3). These results are in agreement with a recent study that also showed a very close relationship between %VL and %Rep ($R^2 = .96$ – $.97$) against 8 different submaximal loads in the bench press exercise.⁹ This result makes it possible to determine the percentage of repetitions that has been completed as soon as a given percentage of velocity loss is detected.⁹ For example, our results indicate that when an individual reaches a 25% loss of MPV in a PU set without added weight, he will have completed $\sim 50\%$ of the possible repetitions (Table 3), regardless of the total number of repetitions to failure that could be completed. Thus, monitoring movement velocity during RT in the PU exercise allows us to: (1) determine the actual degree or *level of effort* being



These results have important practical applications for the prescription and monitoring of training loads in the PU exercise. The close relationship between MPV and %1RM allows us to determine what %1RM is being used as soon as the first repetition with a given load is performed with maximal voluntary velocity (from 65% to 95% 1RM). In addition, the strong relationship between %VL and %Rep allows us to know and match the *level of effort* for each subject during PU training. Using this approach, rather than prescribing a fixed number of repetitions to perform, which shows a high interindividual variability, training volume during PU should be monitored using the magnitude of velocity loss attained in each exercise set, because it is closely linked to the actual level of effort being incurred.^{9,10}

The main findings of the present study were that: (1) there is a strong relationship between relative load and mean velocity in PU exercise that allows us to use one to estimate the other with great precision; (2) there is a strong relationship between velocity loss and the percentage of repetitions performed with regard to the maximal number of repetitions, which allows us to estimate the *level of effort* attained during the set.

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