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Effects of Velocity Loss During Body Mass Prone-Grip Pull-up Training on Strength and Endurance Performance

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Abstract

Sánchez-Moreno, M, Cornejo-Daza, PJ, González-Badillo, JJ, and Pareja-Blanco, F. Effects of velocity loss during body mass prone-grip pull-up training on strength and endurance performance. *J Strength Cond Res* 34(4): 911–917, 2020—This study aimed to analyze the effects of 2 pull-up (PU) training programs that differed in the magnitude of repetition velocity loss allowed in each set (25% velocity loss "VL25" vs. 50% velocity loss "VL50") on PU performance. Twenty-nine strength-trained men (age = 26.1 ± 6.3 years, body mass [BM] = 74.2 ± 6.4 kg, and 15.9 ± 4.9 PU repetitions to failure) were randomly assigned to 2 groups: VL25 (n = 15) or VL50 (n = 14) and followed an 8-week (16 sessions) velocity-based BM prone-grip PU training program. Mean propulsive velocity (MPV) was monitored in all repetitions. Assessments performed at pre-training and post-training included estimated 1 repetition maximum; average MPV attained with all common external loads used during pre-training and post-training testing (AV_{inc}); peak MPV lifting one's own BM (MPV_{best}); maximum number of repetitions to failure lifting one's own BM (MNR); and average MPV corresponding to the same number of repetitions lifting one's own BM performed during pre-training testing (AV_{MNR}). VL25 attained significantly greater gains than VL50 in all analyzed variables except in MNR ($P < 0.05$). In addition, VL25 improved significantly ($P < 0.001$) in all the evaluated variables while VL50 remained unchanged. In conclusion, our results suggest that once a 25% velocity loss is achieved during PU training, further repetitions did not elicit additional gains and can even blunt the improvement in strength and endurance performance.

Key Words: training volume, movement velocity, athletic performance, strength training

Introduction

Controlling and monitoring the training load undertaken by athletes during resistance training (RT) is a complex process for strength and conditioning coaches. The interaction between training intensity and volume produces what is termed a "level of effort," which is defined as the relationship between the repetitions completed in a set and those that could potentially be performed (24). The indicators that have traditionally been used as references for quantifying the RT load (1 repetition maximum, "1RM," and maximum number of repetitions, "MNR," tests) present potential limitations, such as daily changes in the actual 1RM. Therefore, it cannot be guaranteed that the relative loads (%1RM) used in each particular training session truly represent the scheduled ones. Another limitation is that the MNR that can be performed with a given %1RM shows a great variability between individuals (9,23). Hence, a given MNR does not necessarily represent the same %1RM for every individual.

Velocity monitoring may provide a better quantification of the level of effort involved during RT, together with a better monitoring of training effects (8,20,24). The validity of the velocity-based training approach (VBT) is based on (a) the strong relationship observed between movement velocity and %1RM in different exercises (8,16,25,26,29) and (b) the relationship between the velocity loss induced in each set and the percentage of repetitions actually performed in each set with respect to those that could be completed (9,24). Hence, the velocity loss achieved in the set provides very accurate information about the level of effort incurred in a set, in terms of the percentage of repetitions actually performed with regard to the MNR (9).

The pull-up (PU) is a multijoint upper-body exercise, which is considered a valid measure of weight-relative muscular strength (22,28). This exercise is commonly used in sport disciplines that require upper-body pulling strength, such as canoeing (5), climbing (10), and kayaking (17). Furthermore, it has traditionally been used as a physical fitness testing tool to assess upper-body strength and endurance in a variety of populations including the military, firefighters, and police officers (2). The PU performance is generally scored by the MNR completed until muscular failure lifting subject's own body mass (BM) or by the value of 1RM.

One of the most popular practices for PU exercise is to perform repetitions to failure using one's own BM. However, a recent meta-analysis demonstrated that similar increases in muscular strength can be achieved with failure and nonfailure RT (4). To the best of our knowledge, no study has analyzed the effect of different PU training programs on 1RM and MNR in this exercise. A recent article reported a close relationship ($r = -0.96$) between relative load and movement velocity in PU, together with a strong relationship ($R^2 = 0.88$) between the velocity loss induced in a set and the percentage of MNR performed (29). These findings allow us to estimate the percentage of MNR that has been completed as soon as a given percentage of velocity loss is detected during a PU set.

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A velocity loss of 25% in a PU set means that an individual has completed ~50% of the MNR, whereas a velocity loss of 50% corresponds to ~85% of the MNR, regardless of the total number of repetitions to failure that could be completed (29). Pareja-Blanco et al. (20) compared the effects of 2 squat training programs that differed in the velocity loss reached in each set: 20 vs. 40%. A velocity loss of 20% (which corresponded to performing approximately 50% of MNR in squat exercise) resulted in similar or even superior strength gains to a 40% velocity loss (close to muscle failure in this exercise). However, to the best of our knowledge, no previous study has analyzed the effect of different velocity loss magnitudes on upper-body exercises. Therefore, it is still unknown whether it is possible to extrapolate findings from VBT training studies performed in lower-body exercises to upper-body exercises. Thus, in an attempt to gain further insight into the adaptations brought about by different velocity losses during the set in upper-body exercises, we aimed to compare the effects of 2 PU training programs that differed in the magnitude of repetition velocity loss allowed in each set (25 vs. 50%).

Methods

Experimental Approach to the Problem

Subjects trained twice per week (72–96 hours apart) over an 8-week period for a total of 16 sessions. The training program used only the prone-grip PU exercise. The 2 groups trained with their own BM (without external loads) in each session but differed in the maximum percent velocity loss reached in each set (25 vs. 50%). As soon as the corresponding target velocity loss limit was exceeded, the set was terminated. Sessions were performed in a research laboratory under the direct supervision of the investigators, at the same time of day (±1 hour) for each subject and under controlled environmental conditions (20° C and 65% humidity). Both groups were assessed on 2 occasions: before and after the 8-week training intervention. Pre-training and post-training testing sessions took place in 1 session which comprised the PU loading tests up to 1RM and the maximum number of repetitions to failure (MNR test) without added weight (performed in that order, separated by a 5-minute rest, and described later in detail). Any upper-body pull exercises were removed from the usual strength training during the experimental period to avoid any additive effect caused by this type of exercise.

Subjects

Thirty-four strength-trained men (mean ± *SD*: age = 26.5 ± 6.3 years, range: 18.4–35.2 years, BM = 74.3 ± 6.1 kg, and height = 176.1 ± 5.3 cm) volunteered to take part in this study. Subjects had a training background in PU exercise ranging from 2 to 4 years (2–3 sessions per week; 15.9 ± 4.9 PU repetitions to failure with BM). Once informed about the purpose, testing procedures, and potential risks of the investigation, all subjects gave their voluntary written consent to participate. 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.

Subjects were randomly assigned to 1 of 2 groups, which differed only in the magnitude of repetition velocity loss allowed in each training set: 25% (VL25; n = 17) or 50% (VL50; n = 17). Only those subjects who complied with at least 95% of all training sessions were included in the statistical analyses. Five subjects withdrew from the study during the 8-week training period, one of them due to injury and the rest because they missed training sessions. Thus, of the 34 initially enrolled subjects, 29 subjects remained for statistical analysis (VL25, n = 15, age = 26.7 ± 5.5 years, BM = 74.1 ± 4.7 kg, height = 175.8 ± 6.0 cm vs. VL50, n = 14, age = 24.8 ± 6.1 years, BM = 74.3 ± 8.1 kg, height = 176.1 ± 5.0 cm).

Procedures

All PU tests were performed on a standard stationary, horizontal bar (28 mm diameter). To be counted as a complete PU repetition, the subject lifted had to lift his body from a full-arm extension hanging position until his 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 this was recorded, so that it could be repeated in the subsequent testing sessions. During each repetition of both tests (progressive loading and MNR) and all training sessions, the subjects were required to perform the eccentric phase in a controlled manner and maintain a static position for ~1 second at the end of this phase before performing the concentric phase at maximal intended velocity on hearing the command. In addition, at the end of the eccentric phase, any possible horizontal movements caused by this phase were eliminated by the researchers holding the subjects by the ankles. All repetitions were recorded using a linear velocity transducer (T-Force System; Ergotech, Murcia, Spain). This device has been found to be reliable (24). All reported repetition velocities in this study corresponded to the mean propulsive velocity (MPV) (27). 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 1 set of 3 PU repetitions with no external load, was followed in all testing sessions. Strong verbal encouragement was provided during all tests to motivate subjects to give maximal effort.

Progressive Loading Test. Individual load-velocity relationships and 1RM strength were determined using a progressive loading test. The test-retest reliability of this relationship in the PU exercise has been previously established (29). Subjects started without additional weight, and the load was gradually increased, initially in 5-kg increments until the attained MPV was lower than 0.30 $m·s^{-1}$, which represents at least 95% 1RM, so that 1RM could be determined (29). Because subjects needed to lift their BM, 1RM was calculated as the sum of the maximum weight lifted and the subject's BM. Three repetitions were executed when the MPV was higher than 0.75 $m·s^{-1}$, 2 when the MPV was between 0.75 and 0.55 $m·s^{-1}$, and only one when the MPV was less than 0.55 $m·s^{-1}$. Interset rests were 3 minutes when the MPV was higher or equal than 0.55 $m·s^{-1}$ and 4 minutes when the MPV was less than 0.55 $m·s^{-1}$. This resulted in a total of 6.5 ± 2.7 increasing loads performed by each subject. 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 allowed weights to be attached using a chain. The cable from the linear velocity transducer was fixed to the back of the belt. The following variables derived from this progressive loading test were used for analysis: (a) estimated 1RM value, which was calculated from the MPV attained against the heaviest load of the test (>95% 1RM), as follows: %1RM = −53.472 MPV + 110.68 (R = −0.96; SEE = 3.2% 1RM) (29); (b) average MPV attained against all absolute loads common to pre-test and post-test (AV_{inc}); and (c) fastest MPV attained without additional weight (MPV_{best}). The AV_{inc} value was used in an attempt to analyze the extent to which the 2 training interventions affected the PU load-velocity relationship (21).

Maximum Number of Repetitions Test. 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 complete when the subject was not able to raise the chin above the bar or when the subjects paused more than 2–3 seconds in the extended position. Test-retest reliability has been previously reported elsewhere (30). The following variables derived from this test were used for analysis: (a) maximal number of repetitions to failure (MNR) and (b) average MPV attained against the same number of repetitions to pre-training and post-training (AV_{MNR}). For example, if 1 subject performed 15 repetitions at pre-training and 20 repetitions at post-training, we evaluated the average MPV over the first 15 repetitions in both tests. This enabled assessment of the changes in MPV corresponding to the MNR at pre-training.

Resistance Training Program. The descriptive characteristics of the training program are presented in Table 1. Both groups trained using only the BM prone-grip PU exercise (no external load). The technical execution was identical to that previously described in the Testing Procedures section. The number of sets (progressed from 2 to 4) and interset recovery periods (3 minutes) were kept identical for both groups in each training session. Instead of fixing a number of repetitions before beginning the program, we set a target fatigue level (velocity loss). Therefore, the groups differed in the degree of fatigue experienced during the exercise sets, which was objectively quantified by the magnitude of velocity loss attained in each set (25 vs. 50%) and, consequently, differed in the number of repetitions performed per set (Table 1) and the total number of repetitions completed during the training program (Figure 1). During training, subjects received immediate velocity feedback from the measurement system while being encouraged to perform each repetition at maximal intended velocity.

Statistical Analyses

Values are reported as mean ± *SD*. The normality of distribution of the variables and the homogeneity of variance across groups were verified using the Shapiro-Wilk test and Levene's test, respectively. Data were analyzed using a repeated-measures analysis of covariance (with baseline values as covariate) analysis with a Bonferroni post hoc adjustment. In addition, effect sizes (ESs) were calculated using Hedge's *g* on the pooled *SD* (11). Probabilities were also calculated to establish whether the true (unknown) differences were lower, similar, or higher than the smallest worthwhile difference or change (0.2× between-subject *SD*) (3). Quantitative chances of better or worse effects were assessed qualitatively as follows: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; and >99%, almost certain. If the chances of obtaining beneficial/better or detrimental/worse were both >5%, the true difference was assessed as unclear (1,13). Inferential statistics based on the interpretation of magnitude of effects were calculated using a purpose-built spreadsheet for the analysis of controlled trials (12). The rest of the statistical analyses was performed using SPSS software version 18.0 (SPSS Inc., Chicago, IL).

Results

No significant differences between groups were found at pre-training for any of the variables analyzed. The %1RM that represented subjects' BM at pre-training did not differ between groups (69.2 ± 7.6 vs. 66.3 ± 10.5%1RM, for VL25 and VL50, respectively). No significant changes were observed in BM for any group. The repetitions performed in different velocity ranges by each group are shown in Figure 1. The VL25 group trained at a significantly faster mean velocity than the VL50 group (0.71 ± 0.11 vs. 0.56 ± 0.13 $m \cdot s^{-1}$, respectively; $P < 0.001$), whereas VL50 performed more repetitions ($P < 0.001$) than VL25 (556.3 ± 121.9 vs. 363.0 ± 84.6 repetitions). Furthermore, VL50 completed significantly ($P < 0.001$) more repetitions at slow and moderate velocities (<0.6 $m \cdot s^{-1}$) than VL25 (Figure 1). The actual mean velocity loss of the entire training program (i.e., for all sessions and all sets combined) was 26.3 ± 4.1% for VL25 vs. 50.5 ± 7.9% for VL50.

Progressive Loading Test

Significant "group" × "time" interactions were observed for 1RM, AV_{inc}, and MPV_{best} (Table 2). Significant differences

Table 1
Descriptive characteristics of the velocity-based pull-up training program performed by both experimental groups.*†

Scheduled	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8
Sets × VL (%)								
VL25	2 × 25%	2 × 25%	2 × 25%	3 × 25%	3 × 25%	3 × 25%	3 × 25%	3 × 25%
VL50	2 × 50%	2 × 50%	2 × 50%	3 × 50%	3 × 50%	3 × 50%	3 × 50%	3 × 50%
	Session 9	**Session 10**	**Session 11**	**Session 12**	**Session 13**	**Session 14**	**Session 15**	**Session 16**
Sets × VL (%)								
VL25	4 × 25%	4 × 25%	4 × 25%	4 × 25%	4 × 25%	4 × 25%	3 × 25%	2 × 25%
VL50	4 × 50%	4 × 50%	4 × 50%	4 × 50%	4 × 50%	4 × 50%	3 × 50%	2 × 50%

Actually Performed	Total rep	MPV all reps ($m \cdot s^{-1}$)	Mean velocity loss (%)	Fastest MPV ($m \cdot s^{-1}$)	Slowest MPV ($m \cdot s^{-1}$)	Rep per set	All sets
VL25	363.0 ± 84.6‡	0.71 ± 0.11‡	26.3 ± 4.1‡	0.84 ± 0.13	0.60 ± 0.09‡	7.3 ± 2.2‡	50
VL50	556.3 ± 121.9	0.56 ± 0.13	50.5 ± 7.9	0.82 ± 0.21	0.36 ± 0.08	11.3 ± 3.6	50

*VL25 = group that trained with a mean velocity loss of 25% in each set (*n* = 15); VL50 = group that trained with a mean velocity loss of 50% in each set (*n* = 14); VL = magnitude of velocity loss expressed as percent loss in mean repetition velocity from the fastest (usually first) to the slowest (last one) repetition of each set; MPV = mean propulsive velocity; Total rep = total number of repetitions performed during the training program; MPV all reps = average MPV attained during the entire training program; Mean velocity loss = Average velocity loss attained during the entire training program; Fastest MPV = average of the fastest repetitions measured in each session (this value represents the average intensity, %1RM, achieved during the training program); Slowest MPV = average of the slowest repetitions measured in each session; Rep per set: average number of repetitions performed in each set; All sets = total number of sets performed during the entire training program.
†Data are mean ± *SD*. Only 1 exercise (pull-up) was used in training.
‡Significant differences between VL25 and VL50 groups in mean overall values: $P < 0.001$.

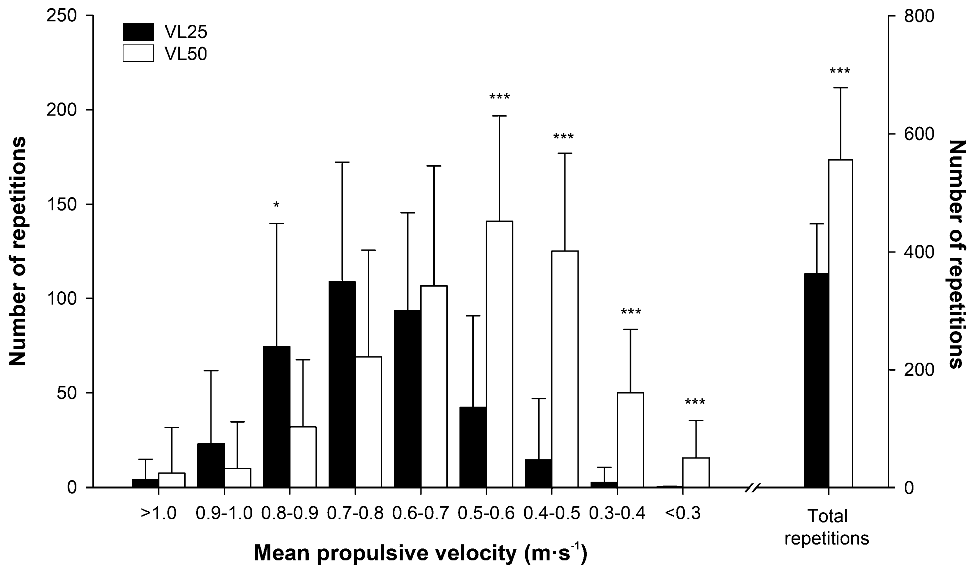

Figure 1. Number of repetitions in the pull-up exercise performed in each velocity range and total number of repetitions completed by both training groups. Data are mean ± *SD*. Statistically significant differences between groups: **P* < 0.05, ****P* < 0.001. VL25 = group that trained with a mean velocity loss of 25% in each set (*n* = 15); VL50 = group that trained with a mean velocity loss of 50% in each set (*n* = 14).

between groups were observed in these 3 variables at post-training (Table 2). The VL50 group did not attain significant improvements in any of these variables, whereas VL25 improved ($P < 0.001$) in 1RM, AV_{inc}, and MPV_{best} (Table 2). In addition, the VL25 group showed greater ESs for 1RM, AV_{inc}, and MPV_{best} than VL50 (Figure 2).

Test of Maximum Number of Repetitions to Failure

A significant "group" × "time" interaction was observed for AV_{MNR} (Table 2). Only the VL25 group attained significant increases both in MNR and AV_{MNR}, whereas the VL50 group did not show significant improvements in any of these variables (Table 2). In addition, VL25 showed greater ES compared with the VL50 group on MNR and AV_{MNR} (Figure 2).

Discussion

The main finding of this study was that training with a velocity loss of 25% (VL25) in each set induced greater gains in strength (1RM as well as the velocity attained against all loads) and muscular endurance performance (MNR as well as the velocity attained against the same number of repetitions) than training with a velocity loss of 50% (VL50). These results were observed despite the fact that the VL50 group performed significantly more repetitions than VL25 (556 vs. 363 repetitions) during the training program.

Table 2

Changes in selected performance variables from pre-training to post-training for each group.*†

	Pre	Post	ES (90% CI)	Percent changes of better/trivial/worse effect	
BM-VL25 (kg)	74.1 ± 4.7	74.1 ± 5.2	0.00 (−0.10 to 0.10)	0/100/0	Most likely trivial
BM-VL50 (kg)	74.3 ± 8.1	73.8 ± 8.0	−0.05 (−0.11 to 0.01)	0/100/0	Most likely trivial
1RM-VL25 (kg)‡	108.4 ± 10.4	114.3 ± 8.9§‖	0.54 (0.33 to 0.75)	99/1/0	Very likely+
1RM-VL50 (kg)	114.4 ± 20.8	115.2 ± 19.8	0.04 (−0.07 to 0.15)	1/99/0	Very likely trivial
AV_{inc}-VL25 ($m \cdot s^{-1}$)‡	0.54 ± 0.07	0.63 ± 0.08§‖	1.24 (0.79 to 1.69)	100/0/0	Most likely+
AV_{inc}-VL50 ($m \cdot s^{-1}$)	0.57 ± 0.10	0.59 ± 0.08	0.20 (−0.12 to 0.51)	50/48/2	Possibly+
MPV_{best}-VL25 ($m \cdot s^{-1}$)‡	0.78 ± 0.14	0.89 ± 0.14§‖	0.77 (0.52 to 1.02)	100/0/0	Most likely+
MPV_{best}-VL50 ($m \cdot s^{-1}$)	0.83 ± 0.20	0.84 ± 0.16	−0.05 (−0.23 to 0.33)	19/75/6	Unclear
MNR-VL25 (rep)	15.6 ± 5.0	17.9 ± 3.9‖	0.43 (0.23 to 0.64)	97/3/0	Very likely+
MNR-VL50 (rep)	16.1 ± 5.0	17.1 ± 4.4	0.18 (−0.01 to 0.36)	41/59/0	Possibly trivial
AV_{MNR}-VL25 ($m \cdot s^{-1}$)‡	0.52 ± 0.08	0.63 ± 0.11‖	1.17 (0.59 to 1.76)	99/1/0	Very likely+
AV_{MNR}-VL50 ($m \cdot s^{-1}$)	0.57 ± 0.11	0.58 ± 0.09	0.10 (−0.25 to 0.45)	31/61/8	Unclear

*ES = effect size within-group; CI = confidence interval. VL25 = group that trained with a mean velocity loss of 25% in each set (*n* = 15); VL50 = group that trained with a mean velocity loss of 50% in each set (*n* = 14); BM = body mass; 1RM = estimated 1 repetition maximum pull-up strength; AV_{inc} = average MPV attained against absolute loads common to pre-test and post-test in the pull-up progressive loading test; MPV_{best} = fastest MPV attained without additional weight in the pull-up progressive loading test; MNR = maximal number of repetitions to failure in the pull-up exercise without additional weight; AV_{MNR} = average MPV attained against the same number of repetitions to pre-test and post-test in the pull-up maximal number of repetitions test.

†Data are mean ± *SD*.

‡Significant group × time interaction: $P < 0.05$.

§Between-group significant differences at post-training: $P < 0.05$.

‖Intragroup significant differences from pre-training to post-training: $P < 0.001$.

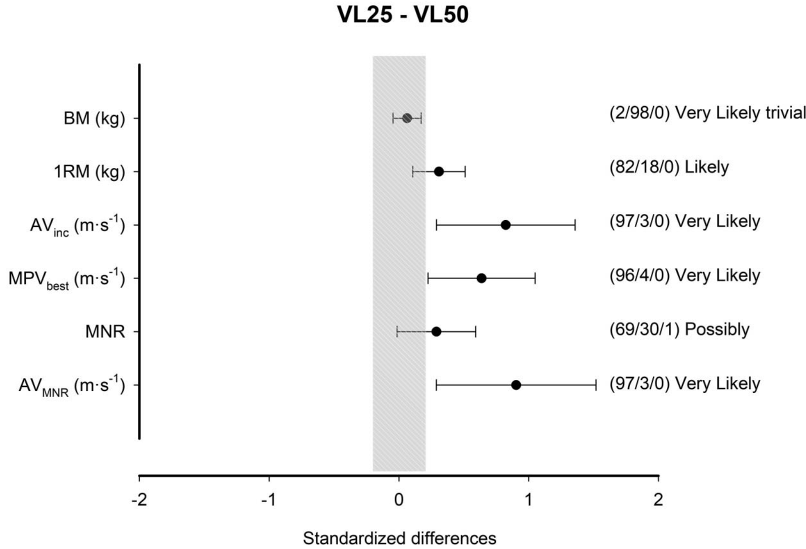

Figure 2. Difference scores (90% confidence intervals) for changes from pre-test to post-test in body mass (BM); estimated 1 repetition maximum pull-up strength (1RM); average MPV attained against absolute loads common to pre-test and post-test in the pull-up progressive loading test (AV_{inc}); fastest MPV attained without additional weight in the pull-up progressive loading test (MPV_{best}); maximal number of repetitions to failure in the pull-up exercise without additional weight (MNR); and average MPV attained against the same number of repetitions in the pre-test and post-test in the pull-up maximal number of repetitions test (AV_{MNR}) when comparing between groups. VL25 = group that trained with a mean velocity loss of 25% in each set (n = 15); VL50 = group that trained with a mean velocity loss of 50% in each set (n = 14). Gray areas represent trivial differences. The probability of the effect being practically relevant in favor of VL25 compared with VL50 is provided in the boxes. MPV = mean propulsive velocity.

Although both groups performed a similar number of repetitions at very high (>0.9 $m\cdot s^{-1}$) and moderate velocities (0.6–0.7 $m\cdot s^{-1}$), VL25 completed significantly more repetitions at high velocities (from 0.7 to 0.9 $m\cdot s^{-1}$), whereas VL50 completed significantly more repetitions at slow velocities (0.6–0.3 $m\cdot s^{-1}$) (Figure 1). These training programs resulted in better strength and endurance adaptations in VL25 compared with VL50 over the 8-week program. Therefore, setting a certain percentage of velocity loss during the training program seems a plausible way to avoid performing unnecessarily slow and fatiguing repetitions that may not contribute to the desired PU training effect.

The present findings also support previous studies that suggested the existence of an inverted U-shaped relationship between training volume and performance increase (6,7,15). In this regard, Pareja-Blanco et al. (20) observed that 8 weeks of RT in squat exercise with a velocity loss of 20% (which corresponded to performing approximately 50% of MNR) resulted in similar gains in performance compared with a velocity loss of 40% (close to muscle failure in this exercise) and even greater gains in high velocity actions such as vertical jumps. In another previous study, a professional soccer team was divided into 2 groups: one trained at a velocity loss of 15% and the other trained at a 30% loss (VL15 vs. VL30) (21). The results of this study, in which the subjects also trained using only the squat exercise, indicated that VL15 obtained results that were similar to or even better than VL30 in all physical variables by performing a considerably lower number of repetitions (60% of the repetitions completed by the VL30 group) (21). The results of this study seem to be in accordance with those observed in these previous studies (20,21) because the VL25 group attained greater gains in PU strength (1RM, AV_{inc}, and MPV_{best}) than the VL50 group. However, in this study, the VL50 group showed no positive effects on PU performance (Table 2). The mechanisms behind this lack of a positive effect on PU performance are unknown. Izquierdo et al. (14) observed a reduction in resting insulin-like growth factor-1 (IGF-1) concentration after 11 weeks of RT to failure, whereas the nonfailure group experienced a reduction in resting cortisol concentration and an increase in resting testosterone concentration. These authors concluded that subjects who trained to failure were likely in an overtrained state, as suggested the reduction in resting IGF-1 concentration (14). On the other hand, it could be hypothesized that the different muscle groups involved and manipulation of training intensity could explain the discrepancies with previous VBT studies analyzing the effect of different velocity loss magnitudes (20,21). In this study, the training program was performed using a prone-grip PU exercise without external load. This implies that the relative intensity did not increase during the training program, contrary to previous studies (20,21). Moreover, VL50 performed a high number of slow repetitions (MPV <0.6 $m\cdot s^{-1}$, Figure 1). It has been proposed that performing slow and fatiguing repetitions, as occurs in typical, to-failure training, may evoke a reduction in the IIX fiber type (20) and a physiological environment that does not provide optimal conditions for improving neuromuscular performance (18,19). Therefore, in accordance with previous studies suggesting that moderate volumes produce more favorable strength gains than high volumes during a training cycle (6,15), performing a training program based solely on performing repetitions to failure with one's own BM seems to be an inadequate stimulus to maximize strength performance in PU.

On the other hand, PU performance is generally scored on the basis of the MNR completed until muscular failure, lifting only one's own BM. For this reason, we included different variables (MNR and AV_{MNR}) to assess the effect of the training program on endurance performance in PU. In line with the findings in the strength test, only the VL25 group attained increases both in MNR and AV_{MNR}, whereas the VL50 group showed no improvements in endurance performance (Table 2). This phenomenon can be explained by the greater increase in MPV_{best} experienced by the VL25 group (from 0.78 ± 0.14 to 0.89 ± 0.14; Table 2). This means that the relative intensity representing the BM in PU for this group was reduced by approximately 7% (from 70 to 63% of 1RM). It is logical to assume that the lower the relative intensity (%1RM), the higher the MNR that can be performed. Therefore, the greater increase experienced in MNR by the VL25 group can be explained in part by the decrease in the relative intensity that represented their BM. In addition, a significant relationship ($R^2 = 0.84$) has recently been reported between the maximum number of PU and the mean velocity of a single PU repetition (2). Thus, it is likely that the relative increase in muscle strength is partly responsible for the improvement in local muscular endurance, assessed in this case by MNR and AV_{MNR}. Few studies have examined changes in muscular endurance following protocols with different training volume. Izquierdo et al. (14) observed greater bench press muscular endurance in subjects who trained to failure without differences in the squat exercise. Furthermore, it has been shown that higher volume loads (32) and eccentric intensity (31) led to improved repetition-to-failure performance. The discrepancy between these results and ours may be explained by the differences in the loads used to assess muscular endurance. Although in the cited studies (14,31,32) a relative intensity (75% 1RM) was used, in this study, this test was performed with the subjects' own BM, which did not change throughout the experimental period (Table 2). As we mentioned above, the reduction in the relative intensity that represented the BM experienced by the VL25 group may be the responsible for the greater endurance improvements achieved in this group.

One limitation of this study was the variability in the loading magnitude (%1RM) used during the training. However, this phenomenon is a characteristic of the PU exercise and is inevitable when the training is performed using only the BM. Future studies should use a belt to add external load added with a belt to equalize the relative intensity represented by the BM in all subjects to confirm these results.

In summary, a training program characterized by a low degree of fatigue (25% velocity loss) resulted in greater gains in PU strength and endurance than a training program with a greater level of fatigue (50% velocity loss), despite the fact that the VL50 group performed considerably more repetitions per set than the VL25 group (11.3 ± 3.6 vs. 7.3 ± 2.2 rep).

Practical Applications

This study provides important information for coaches and practitioners about training to improve performance in PU exercise. A velocity loss of about 25% during each training set, which represents completion of ~50% of the MNR, seems to be more appropriate for improving performance (both strength and endurance) in this exercise than a velocity loss of 50% (close to failure). These results suggest that improvements in strength and endurance PU performance may be compromised by excessive repetition volume.

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