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Research article

Development and Validity of a Scale of Perception of Velocity in Resistance Exercise

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Abstract
This aims of this study were twofold; 1) to development a new scale of perceived velocity in the bench press exercise and 2) to examine the scales concurrent validity. Twenty one physically active males with mean ±SD age, height and weights of: 27.5 ± 4.7 years, 1.77 ± 0.07 m, and 79.8 ± 10.3 kg respectively, took part in the study. The criterion variable used to test the validity of the new scale was the mean execution velocity (Vel_{real}) of the bench press exercise. Three intensities (light loads [< 40% 1RM], medium loads [40% -70% 1RM] and heavy loads [> 70% 1RM]) were measured randomly during 5 days of testing. Perceived velocity (Vel_{scale}) was measured immediately after each exercise set using the new scale. A positive linear correlation (r range = 0.69 to 0.81) was found in all three intensities, analyzed individually, between the Vel_{real} and Vel_{scale}. Pearson correlations showed a greater frequency of scale use resulted higher correlation values (range r = 0.88 to 0.96). This study provides evidence of the concurrent validity of a new scale of perceived velocity in the bench press exercise in trained adult males. These results suggest the exercise intensity of the bench press can be quantified quickly and effective using this new scale of perceived velocity, particularly when training for maximum power.

Key words: RPE, rating perceived velocity, strength training, weight lifting.

Introduction

Strength training has undergone a substantial advancement, in recent years thanks to advances in new technologies applied to training control (Randell et al., 2011). The use of tools such as linear positioning transducers (LPT) means that training variables such as velocity, force or power can be quantified for each repetition. Traditionally, in order to quantify the intensity of external resistance exercises, external indices have been used. These include one repetition maximum (1RM), a specified percentage of the 1RM, rest between sets (Miranda et al., 2009; Senna et al., 2008), the total number of sets and repetitions per exercise (Bird et al., 2005; Fleck, 1999). In the past decade, the execution velocity has come to occupy a central role in monitoring training, and has been shown to be a good indicator of the intensity of strength exercises (Kawamori and Haff, 2004; Kawamori and Newton., 2006; Pereira and Gomes, 2003; Sánchez–Medina et al., 2010). The importance of velocity can be seen in the production of power. Mechanical power is defined as force multiplied by the velocity of movement. Therefore, both components (force and velocity) are essential for strength and power training and its development (Baker et al., 2001).

Scales to measure subjective exertion, or the rating of perceived exertion (RPE), such as the Borg scale, are effective methods to quantify and monitor the intensity of aerobic exercise (Soriano–Maldonado et al., 2013). This is primarily because of the strong association between RPE and such physiological variables such as heart rate, lactate, VO_2max, ventilatory thresholds and respiratory rates (Chen et al., 2002; Groslambert et al., 2006; Irving et al., 2006; Robertson et al., 2005). The Borg scale has also been used to monitor the intensity of strength training exercises, either by the 15 (6–20) category scale (Gearhart et al., 2009; Lagally and Roberson, 2006; Row et al., 2012; Tiggemann et al., 2010) or the Borg category–ratio (CR-10) scale (Buckley and Borg, 2011; Day et al., 2004). Numerous studies involving resistance exercise (Buckley and Borg, 2011; Lagally et al., 2002; Lagally and Robertson, 2006) have demonstrated strong associations between the Borg scale RPE and intensity indices such as myoelectric activity, the total load and the percentages of the 1RM. These associations suggest an effective use of a perceived exertion scale in determining intensities of exercises using external resistance. Row et al. (2012) examined the use of RPE to predict an adequate intensity for power exercises in older people for leg press exercise. The authors concluded that because of the strong relation between the load and the RPE, load self–intensity is possible for power exercises.

Robertson et al. (2003) developed and validated the use of the OMNI-RES scale for adults (male and female) performing both lower and upper body exercises. To validate this scale, researchers used the total weight lifted (Wt_{tot}) and lactate [Hla] as criterion variables. The positive correlation of Wt_{tot} and Hla in resistance exercises demonstrated the validity of this scale for use by both male and female recreational athletes. Robertson et al. (2005) validated the use of the OMNI-RES scale in children (10–14 years old) performing resistance exercise. The strong association (biceps curl [BC] = 0.87 and knee extension [KE] = 0.80) between Wt_{tot} and BC and KE exercises demonstrated the validity of this scale for use in a population of schoolchildren in performing resistance exercises. Lagally et al. (2002) compared the OMNI-RES scale with the Borg scale (6–20) using the latter as a crite-

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rion variable. There was a strong positive correlation (r range = 0.94 to 0.97) between RPE derived from the OMNI-RES scale and the Borg scale for knee extension exercise. Thus, the authors demonstrated that, like the Borg Scale, the OMNI-RES scale is valid and accurate for exercises employing external resistance.

The velocity with which repetitions are performed affects the specific training adaptations at neural, metabolic (Buitrago et al., 2012) and hypertrophic levels (Housh et al., 1992). Recent research by Buitrago et al. (2012) showed that for a given load, execution velocity determines the total number of repetitions that can be performed. However, these authors concluded that more research is needed on the mechanisms involving velocity control with certain loads. One of the most interesting debates regarding execution velocity focuses on *explosive* load displacement vs. *controlled* load displacement. Fielding et al. (2002) compared two groups of subjects who lifted the same external percentage (70% RM), but differed in rates of bar displacement. One group was asked to move the bar with comparatively fast acceleration involving an explosive movement. The other group performed the repetitions at a controlled rate. After 12 weeks of training using leg press and leg extension workouts three days per week, the authors concluded that increases in the 1RM were similar in both groups. However, the group employing explosive movement significantly improved power performance in the leg press exercise over a wide range of loads (from 40% to 90% of the 1RM).

Based on the previous research, it is clear that execution velocity is a significant indicator of exercise intensity. However, a subjective scale to control velocity of resistance exercise does not exist. Therefore, the main purpose of the present research was to develop and validate a new scale of perception of velocity for upper body strength training, i.e. bench press exercise.

Methods

Experimental design

The experimental model in this study consisted of three stages: informational, instructional and load assessment using the new scale of velocity perception.

Informational stage: During the first session the experimental procedure was explained, informed consents were signed. Prior to the instructional stage, the subjects' height and body mass were measured, and the handgrip for the bench press exercise was standardized. In order to standardize the handgrip, subjects lay horizontally in a supine position with the elbow joint flexed at a 90º angle. The bar was positioned 5 cm above the jugular notch.

Instructional stage: All subjects performed an incremental load protocol up to 1RM. The protocol started with an initial load of 20 kg. Loads progressively increased by 10 kg (when execution velocity was increased to 0.5 $m \cdot s^{-1}$) and increased by 5 kg (when execution velocity was less than 0.5 $m \cdot s^{-1}$). A LPT (T-Force System, Ergotech, Murcia, Spain) was used to measure the mean velocity of each repetition. Verbal encouragement was provided to all the subjects to lift the barbell as fast as possible (i.e. explosively) during the concentric phase. There were 3–5 minutes rests between sets in the incremental protocol to avoid the effect of neural fatigue on 1RM assessment. All subjects performed a total of 1–4 repetitions. Following the completion of each series, the maximum and minimum execution mean velocity of the repetitions in that series were given as feedback. Subjects then had to identify and mark the corresponding velocity value in the new scale of perception of velocity (Figure 1).

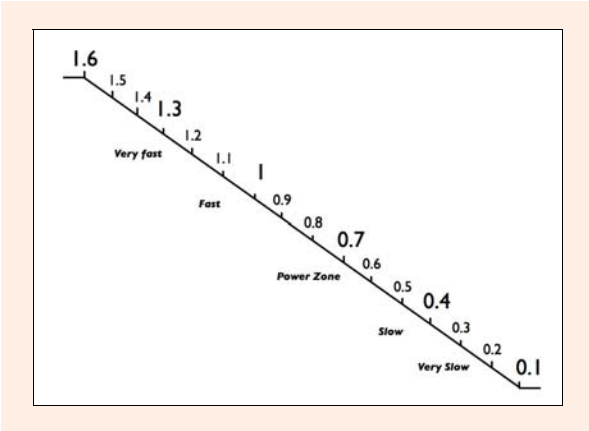

Figure 1. New scale of perception of velocity.

Load evaluation stage according to individual power curves: A total of 5 assessments were carried out on different days. There were 24–72 hours between testing days. Three intensities (low, medium and high) were used to assess each subject. The weight of the loads was determined by the power curve criteria for each of the subjects (Figure 2). The light intensity corresponded to a bar velocity exceeding 1 $m \cdot s^{-1}$. The medium intensity corresponded to bar velocities between 0.6 to 0.7 $m \cdot s^{-1}$, while for the heavy loads the velocity of the bar was less than 0.4 $m \cdot s^{-1}$. Thus, although the external resistance (load [kg]) was different for each subject, the intensity (measured by the velocity [$m \cdot s^{-1}$]) was the same.

Each of the three series was executed in random order. Each subject performed three sets of 2–4 repetitions with 5 minutes of rest between each set. During the series, the subject did not know the weight of the load. Therefore, each subject left the room while the load was placed on the bench for the next evaluation. After the load was in place, the subject was blindfolded and accompanied to the bench for proper positioning. Partial occlusion pads were used to obstruct the peripheral view during the exercise so that subjects could not see the load during the repetitions. Following each series, the subject selected the perceived value on the new velocity scale, based on subjective perception. While performing random series each subject was provided with the minimum and maximum velocity reached during the incremental protocol performed at the instructional stage, according to the memory–anchoring procedure (Lagally and Costigan, 2004). A LPT was used to assess each repetition performed in the different intensities (LL, MPL and HL). The average of the mean velocity in the concentric phase of each repetition for every trial was used to calculate the final variable.

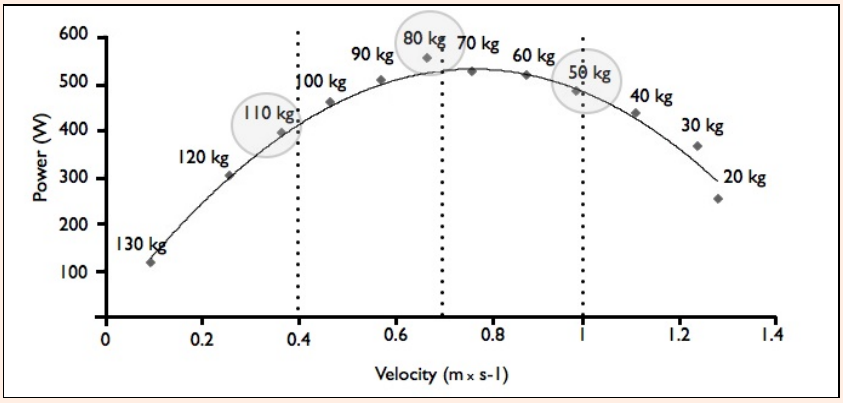

Figure 2. Power curve used to determine the intensity of the different loads in random series.

Subjects

Twenty–one (n = 21) male subjects participated voluntarily in this research. The subjects' ages, weights, and heights (expressed as mean ± SD) were: 27.5 ± 4.7 years, 79.8 ± 10.3 kg and 1.77 ± 0.07 m, respectively. The participants were members of the Spanish Army Intelligence Service. All subjects had performed exercises with external resistance, at least 3 times a week, in the year prior to the research. To be included in the study, subjects had to have a ratio of Maximum Repetition / Body Weight > 1 (RM/BW > 1). During the period of the study, the research subjects were instructed not to: (a) do exercise with external resistance or to do aerobic exercise (b) take caffeine or any doping substance. All series were carried out at the same daily time with 48–72 hours between series. The risks and benefits of the research were explained. All participants signed an informed consent to participate in the study. This study was approved by the institution's ethics committee.

New scale of the perception of velocity

The research design focused on the development and validation a new scale of perceived velocity of resistance exercise. The main purpose of this scale is to subjectively identify the rate at which an individual raises the bar in the bench press exercise. This scale has the following characteristics:

Range of numeric values: The numerical range of the new scale is from 1.6 to 0.1 $m \cdot s^{-1}$. These values correspond to the maximum average found during the exploratory screening tests in the bench press exercise. The intervals between the numerical values were set at 0.15 $m \cdot s^{-1}$ because when loads were increased by 10 kg during the incremental protocol, the differences in velocity between loads was approximately 0.1 ± 0.05 $m \cdot s^{-1}$.

Qualitative values: In addition to numeric values, the scale has five qualitative values, which are: very fast, fast, medium, slow and very slow. The procedure used to determine the location of these qualitative values within a numerical category range was determined by instructing subjects to verbally qualify a load after lifting it. The mean and the typical deviation of the mean velocity of 10 evaluations were used to locate a particular point for each of the qualitative values (Figure 1).

Procedure for rating of perceived velocity

The rating of perceived velocity was recorded for each of the loads using the new scale of perceived velocity. Standard instructions for the new scale of perceived velocity were read before each series. These instructions were adapted from instructions for the OMNI-RES scale (Robertson et al., 2003). The instructions include: (a) a definition of subjective perception of velocity, (b) the meaning of the values in the new scale of perception of velocity, and (c) identification of the maximum and minimum values attained by each subject in the incremental protocol loads. The following instructions were read to the participants:

Instructions

Definition of subjective perception of velocity: This is defined as the estimated amount of time used to move a load in a specific range of movement.

The meaning of the scale values: The scale values correspond to the mean velocity (in $m \cdot s^{-1}$) that you will reach over the course of the entire test.

Identification of maximum and minimum values: You will see a scale in which the values represent mean velocity. We would like you to notice the maximum and minimum value that you reached during the incremental protocol. Following each set, you must point to and say the value on the scale that you just reached, based on the velocity you think you reached.

Statistical analyses

Descriptive data for perceptual and velocity variables were expressed as mean ± SD. The validation of the scale was determined by a correlation analysis and simple linear regression between the perceived velocity (perceived in the new scale) and mean velocity of each execution (criterion variable). Normality distribution of the variables was assessed using a Kolmogorov–Smirnov test. Heteroscedasticity was examined by plotting the absolute differences against the individual means (Atkinson and Neville, 1988). No presence of heteroscedasticity was detected. Pearson correlation coefficients were use to determine the interrelationships between variables. The strength of correlations were defined as, r = 0–0.1

Table 1. Actual (Vel_{real}) and perceived velocity (Vel_{scale}) values for the three load categories from the five assessment days (n = 21). Values are means (± standard deviations).

Day	Light Load		Medium Load		Heavy Load	
	Vel_{real}	Vel_{scale}	Vel_{real}	Vel_{scale}	Vel_{real}	Vel_{scale}
1	1.02 (.18)	1.16 (.25)	.70 (.11)	.82 (.24)	.48 (.12)	.47 (.19)
2	1.04 (.15)	1.04 (.21)	.69 (.10)	.65 (.19)	.51 (.15)	.45 (.14)
3	1.00 (.15)	1.01 (.19)	.68 (.09)	.63 (.16)	.48 (.11)	.39 (.11)
4	1.00 (.14)	1.09 (.17)	.71 (.13)	.71 (.18)	.48 (.11)	.42 (.14)
5	.99 (.11)	1.06 (.16)	.69 (.11)	.65 (.15)	.45 (.10)	.42 (.12)

(trivial), r = 0.1–0.3 (small), r = 0.3–0.5 (moderate), r = 0.5–0.7 (large), r = 0.7–0.9 (very large) and r = 0.9–1.0 (nearly) (Hopkins, 2003). The Intraclass Correlation Coefficients model 2.1 ($ICC_{2.1}$) and Standard Error of Measurement (SEM) were used to assess the variables' reliability. The SEM was calculated using the equation: SEM = √MSe, where MSe is the Mean Square subjects error derived from the 2-way analysis of variance (ANOVA) (Weir, 2005). A repeated measure ANOVA (Day × Intensity) of the differences (differences = Vel_{scale}–Vel_{real}) was conducted. The Bonferroni post Hoc method was used to analyze the significant differences. Effect size was evaluated with η^2_p (partial Eta squared) where, according to Cohen (1988), $0.01<\eta^2<0.06$ constitutes a small effect, and a medium effect when $0.06<\eta^2<0.14$ and a large effect when $\eta^2>0.14$. Significant differences were set at $p < 0.05$. All analyses were performed in SPSS v.20 (SPSS inc. Chicago, IL, USA).

Results

Table 1 lists the descriptive data expressed as mean (SD) of the actual velocity (Vel_{real}) and perceived velocity values on the scale (Vel_{scale}) for each intensity analyzed (light loads [LL], maximum power load [MPL] and heavy loads [HL]).

Table 2 summarized the $ICC_{2.1}$ and SEM of the Vel_{real} and Vel_{scale} for each intensity analyzed in all testing occasions. The results of the $ICC_{2.1}$ in all intensities analyzed together were for day 1 0.91 and 0.13 $m{\cdot}s^{-1}$, for day 2, 0.94 and 0.09 $m{\cdot}s^{-1}$ for day 3, 0.95 and 0.08 $m{\cdot}s^{-1}$, for day 4, 0.96 and 0.08 $m{\cdot}s^{-1}$, 0.97 and 0.07 $m{\cdot}s^{-1}$, respectively.

The results of the Pearson correlation between Vel_{real} and Vel_{scale}, in the three intensities analyzed (LL, MPL and HL) and all the intensities analyzed together are summarized in Table 3.

The simple linear regression analysis between Vel_{real} and Vel_{scale} corresponding to the last measurement is shown in Figure 3.

The repeated measures ANOVA showed significant differences in the *Day* factor (5 levels) ($p = 0.0001$; $\eta^2 = 0.26$) and *Intensity* (3 levels) ($p = 0.0001$; $\eta^2 = 0.61$), showing no significant differences in the interaction *Day × Intensity* ($p = 0.132$; $\eta^2 = 0.074$). The Bonferroni post hoc showed significant differences for the results of day 1 compared to day 3 ($p = 0.017$). No significant differences were found for the results of day 1 compared to days 2, 4 and 5 ($p = 0.079$, $p = 0.237$ and $p = 0.063$, respectively). The Bonferroni post hoc showed significant differences in the intensity factor ($p = 0.0001$, $p = 0.0001$ y $p = 0.0001$) in the pair compared (Vel_{real} vs Vel_{scale}) with the all intensities analyzed (LL, MPL and HL, respectively). Figure 4 shows the differences between the Vel_{real} - Vel_{scale} for the 5 evaluation days.

Discussion

The main objective of this research was to develop and validate a new scale of perceived velocity. Concurrent validity was examined as the basis of scientific support for the new scale, which measured the intensity of the bench press exercise. The Vel_{real} was used as criterion variable and was measured with a LPT. In general it was expected that the Vel_{scale} would be distributed as a positive linear function in all three intensities measured as

Table 2. Intraclass Correlation Coefficient ($ICC_{2.1}$) and Standard Error of Measurement (SEM for the three load categories from the five assessment days.

Day	Light Load		Medium Load		Heavy Load	
	ICC (95%IC)	SEM	ICC (95%IC)	SEM	ICC (95%IC)	SEM
1	.77 (.44-.91)	.13	.67 (.20-.87)	.13	.81 (.54-.92)	.09
2	.79 (.48-.84)	.10	.71 (.48-.84)	.10	.85 (.63-.89)	.08
3	.75 (.38-.90)	.11	.76 (.42-.90)	.07	.88 (.70-.95)	.05
4	.86 (.65-.94)	.08	.87 (.69-.95)	.07	.85 (.64-.94)	.06
5	.88 (.72-.95)	.06	.85 (.64-.94)	.07	.85 (.64-.94)	.05

Table 3. Pearson correlation coefficient and coefficient of determination between mean actual velocity vs. mean perceived velocity for each of the three load categories and all load categories together (n = 21).

	Light Load		Power Load		Heavy Load		All Loads	
Day	*r*	R^2	*r*	R^2	*r*	R^2	*r*	R^2
1	.66*	.44	.78*	.61	.72*	.52	.88*	.77
2	.66*	.44	.68*	.46	.73*	.53	.90*	.81
3	.62*	.38	.74*	.55	.73*	.53	.92*	.85
4	.77*	.59	.81*	.66	.78*	.61	.95*	.90
5	.85*	.72	.78*	.61	.75*	.56	.96*	.92

* p < 0.01

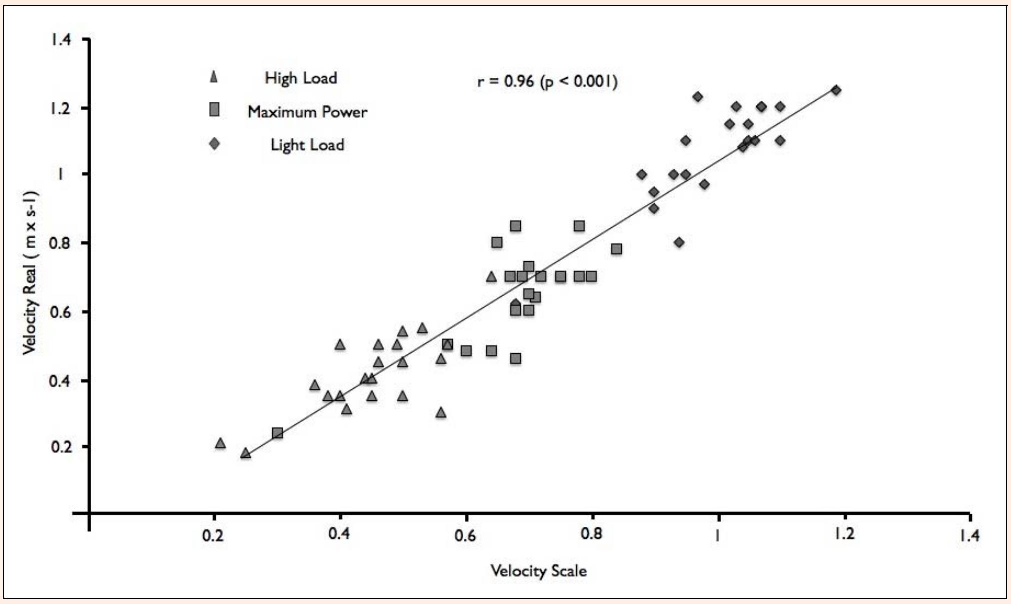

Figure 3. **Simple linear regression analysis between the actual velocity and the perceived velocity in the three intensities analyzed.**

compared to Vel_{real}, with each intensity individually distinguishable.

Concurrent validity

Vel_{real} at different intensities: In this study, the Vel_{real} was used as criterion variable to quantify exercise intensity. Different authors (Row et al., 2012; Sánchez–Medina et al., 2010) have proposed velocity as an effective measure to quantify exercise intensity. The results obtained in this study show that there was a positive correlation between the perceived velocity measured by the scale and actual velocity with a range of r = 0.62 to 0.85 (large to very large). The correlation analysis (Table 3) showed that the intensities of maximum power load and high loads had the highest Pearson correlations. The lowest correlations were found in light loads. A possible explanation for the lower correlation coefficients at the light loads can be due to the homogeneity of the sample used to evaluate scale. However, all coefficients derived from the correlation analysis showed significant differences. Lagally et al. (2006) analyzed the RPE in different strength exercises (including the bench press) at two different intensities (30 and 90% of 1RM). The results of the study showed that the RPE increased with increased exercise intensity. The repeated measures ANOVA showed significant differences ($p < 0.001$) between the different intensities

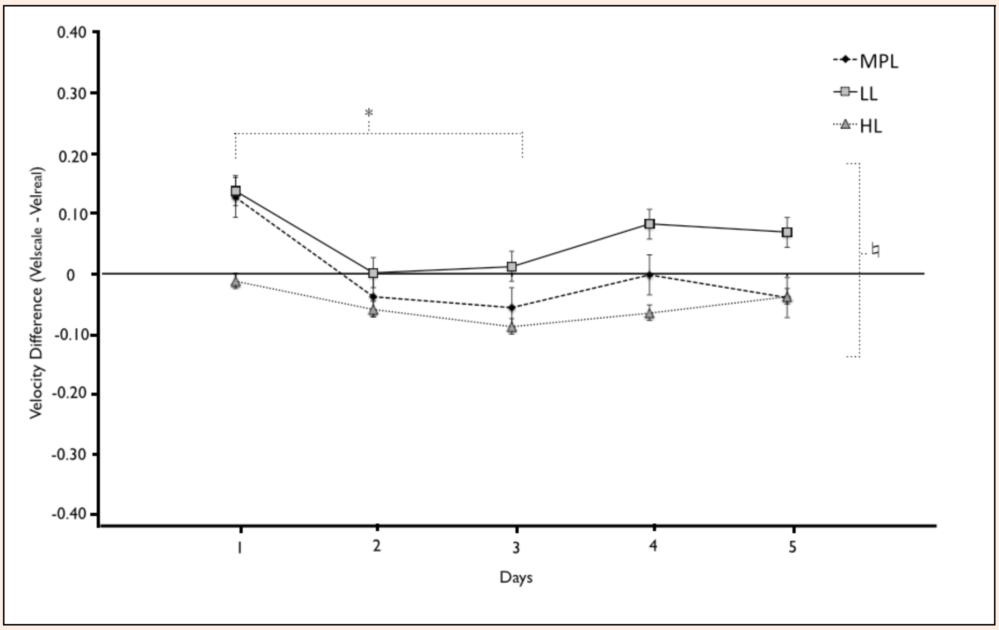

Figure 4. **Differences between Vel_{scale} and Vel_{real} in the five evaluation days in all three intensities analyzed.** * Significant differences in Day 1 vs Day 3 ($p < 0.05$) ♮ Significant differences in intensities (LL, MPL and HL) ($p < 0.01$).

analyzed presently (Figure 4). This demonstrates that the new scale of perception of velocity is sensitive to changes in resistance exercise intensity. Concurrent validity of otherscales like the OMNI-RES developed by Robertson et al. (2003) was conducted using two criterion variables (Wt_{tot} and Hla). The Pearson correlation coefficients (r range = 0.71 to 0.91 and r = 0.87) showed a strong correlation between the Wt_{tot} displaced, Hla and RPE, respectively. However, the comparison between this and other studies is complicated, since no study has used Vel_{real} as the criterion variable to measure exercise intensity.

Vel_{real} on a global level: The positive linear correlation between Vel_{scale} and Vel_{real} when global data are analyzed (Table 3) suggest that the measurement perception of velocity level is an effective method to approximate actual mean velocity in the bench press exercise. Moreover, this fact is confirmed in the repeated measures ANOVA, since no significant differences in Day × Intensity interaction were found. Table 3 demonstrates that, using the new scale, perception of velocity ratios increased based on the Pearson correlation r = 0.88 to r = 0.96. Figure 4 shows the difference between the Vel_{scale} and Vel_{real}. The points which are farthest away from 0 indicate a poor fit between perceived and real velocity, while some values are closer to 0, indicating that perception and actual measurement closely agree. In general, the perceived and actual measures of the three intensities tend to converge on values close to 0. On a specific level, the new scale was most acute in estimating velocity at the maximum power intensity (i.e. 60% 1RM). The intensities in heavy and light loads tend to be underestimated and overestimated, respectively. The study by Pincivero et al. (2001) revealed that the RPE is underestimated in sub-maximal exercise. However, this study was conducted using isokinetic procedures for assessing leg extension exercises.

It is important to note the difficulty of comparing the results of our research to other studies validating the OMNI-RES scale since the criterion variables used to test the validity of those studies were Hla and Wt_{tot} (Robertson and Noble, 1997; Robertson et al., 2003) or the Borg CR10 scale itself (Lagally et al., 2002). Atkinson and Neville (1998) defined the validity term as the ability if the measurement tool to reflect what is designed to measure. The criterion variable used to test the validity of this research was the actual velocity (i.e. mean velocity) of each of the repetitions and sets as measured on a LPT. Since the new scale is designed to measure the mean velocity of execution of the bar, it is proposed that this be the "gold standard" possible for assessing validity. As the new scale of velocity perception was shown to be valid, it can be used to monitor intensity during bench press exercises in trained adults. Coaches and athletes can train based on the concept of velocity as a variable to quantify resistance exercise intensity without the need for a linear displacement device. Thus, the measurement of perception of velocity can be a complement to other scales of perception such as the 15 category Borg scale or the OMNI-RES. Regular use of the new scale of perceived velocity in external resistance training provides athletes with continuous feedback of execution velocity in each repetition and set, especially with high power loads, which is a fundamental objective of sports training. In our research, reliability measurements ($ICC_{2.1}$ and SEM) support this idea. These statistical values decreased throughout the trial. For example, the SEM for days 1, 2, 3 and 4 were 0.13 $m \cdot s^{-1}$, 0.09 $m \cdot s^{-1}$, 0.08 $m \cdot s^{-1}$, 0.08 $m \cdot s^{-1}$ and 0.07 $m \cdot s^{-1}$, respectively. The lower statistical reliability ($ICC_{2.1}$ and SEM) found on different days and in the three loads analyzed (Table 3) support the idea that with continuous use of the velocity perception scale, the level of velocity perception improves. Future research needs to be conducted in order to assess, once the athletes know how the perception velocity scale works, if they are able to train without a LPT.

Conclusion

Ratings of subjective perception of velocity using a new scale were distributed linearly and positively compared to the actual velocity during the three intensities analyzed. Overall, high correlations were found between Vel_{real} and Vel_{scale}. These correlation coefficients increased as the number of sessions increased. The results obtained in this research provide concurrent validity of the new scale of perception of velocity for resistance exercise and demonstrate that it can be used as a means to quantify the intensity of the bench press exercise in a population of trained adults.

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Key points

- Measurement of perception of velocity can complement other scales of perception such as the 15 category Borg scale or the OMNI-RES.
- The results obtained in this study show that there was a positive correlation between the perceived velocity measured by the scale and actual velocity
- Regular use of the new scale of perceived velocity in external resistance training provides athletes with continuous feedback of execution velocity in each repetition and set, especially with high power loads

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