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Abstract

Purpose: The objective of this study was to investigate the influence of the grip width on the power-force-velocity-profile, the maximal strength and performance during a repetition to failure test in the pull-up exercise (PU). **Method:** Fourteen trained males performed an incremental loading and repetitions to failure test with the PU exercise using biacromial and free grip widths. Power-force-velocity relationship, 1RM and repetitions completed were determined. **Results:** The mean grip width used by participants was 20.04% higher in the free grip width condition (p<0.001). There were similar results in the 1RM (p=0.954), repetitions to failure test (p=0.117) and power-force-velocity profile (p>0.05) in both grip width conditions. A stronger relationship was observed between 1RM and repetitions to failure test during the biacromial (R^2=0.720; p<0.001) with respect to the free grip width (R^2=0.607; p=0.002). **Conclusion:** Therefore, the choice of a free or a biacromial grip width does not affect the maximal strength, power-force-velocity relationship nor the repetitions to failure during the PU exercise. Data derived from studies using one type of grip width or the other can be used interchangeably.

Keywords: Conditioning; Physical Fitness; Resistance training; Testing

Main text purpose

The pull-up (PU) is an upper-limb resistance training exercise (Snarr, Hallmark, Casey, & Esco, 2017) commonly used as part of physical fitness tests in firefighters, police and military (Perez-Olea, Valenzuela, Aponte, & Izquierdo, 2018). There is a lack of studies about the impact of the exercise technique in the PU performance. However, even small differences in grip width or hand position can affect muscle activation and mechanical variables (Dickie, Faulkner, Barnes, & Lark, 2017; Leslie & Comfort, 2013). Up until now differences in PU muscle activation by change in hand orientation (supinated, pronated, neutral and rope grips) have been described (Dickie et al., 2017; Leslie & Comfort, 2013). The scapular kinematics and external forces in three PU techniques (supinated, narrow and wide pronated grips) have also been addressed (Prinold & Bull, 2016). The relationship between PU and lat pulldown (LPD) exercises, from the point of view of several anthropometric variables, is also frequently pointed out (K. A. Halet, J. L. Mayhew, C. Murphy, & J. Fanthorpe, 2009; Sanchez-Moreno, Pareja-Blanco, Diaz-Cueli, & Gonzalez-Badillo, 2016), since both exercises are usually considered interchangeable in training programs. In the case of the LPD, closed grip and medium grip widths (1 and 1.5 times the biacromial [BA] distance) allowed pulling 4% more load than a wide grip (2 times BA distance) (Andersen, Fimland, Wiik, Skoglund, & Saeterbakken, 2014). The lever arm from the shoulder joint could be increased as the grip gets wider, which increases the shoulder torque, probably reducing the load that could be lifted. Therefore, if the grip width could modify biomechanical properties and provide a mechanical advantage in the LPD, it could also be expected in the PU. For this reason, considering the mechanical tension as a key mechanism of resistance training-induced strength (Cormie, McGuigan, & Newton, 2011; McGuigan, Wright, &

Fleck, 2012) and muscle hypertrophy (Schoenfeld, 2010), grip width differences could become relevant in PU. Nevertheless, this variable has not been studied yet.

From a different point of view, the effect of grip width could also be reflected in the power-force-velocity-profile, which is based on force-velocity (F-V) and power-velocity (P-V) relationships. These relationships may reveal interesting information about the upper-limb muscle function (Samozino, Rejc, Di Prampero, Belli, & Morin, 2012). In this regard, recent studies have used parameters derived from the F-V relationship as a way to monitoring the training status and the level of effort in PU (Munoz-Lopez, Marchante, Cano-Ruiz, Chicharro, & Balsalobre-Fernandez, 2017; Sanchez-Moreno, Rodriguez-Rosell, Pareja-Blanco, Mora-Custodio, & Gonzalez-Badillo, 2017). These studies showed that there is an almost perfect relationship between the load (%1RM) and the mean propulsive velocity (MPV) in the pronated PU exercise, allowing the estimation of the training intensity (by measuring movement velocity) and the F-V profile (Munoz-Lopez et al., 2017). In addition, monitoring velocity in a repetitions to failure set (RF) has been considered a valid tool to estimate the number of repetitions in reserve when a given percentage of velocity loss is achieved during a PU exercise set (Sanchez-Moreno et al., 2017). Despite this, research has shown that load-velocity (L-V), F-V and P-V relationships are sensitive to inter-individual differences, movement patterns and muscle groups used (Jaric, 2015; Soriano, Suchomel, & Marin, 2017). Consequently, considering that slight biomechanical differences in the same exercise could produce variations in the F-V profile or EMG (Dickie et al., 2017), it is reasonable to expect that the width of the grip will also produce them during the PU exercise. In the available literature most of the studies conducted in PU have used a free grip (FREE) without anatomical references (Dinunzio, Porter, Van Scoy, Cordice, & McCulloch, 2018; Kristin A Halet, Jerry L

Mayhew, Colleen Murphy, & Joe Fanthorpe, 2009; Perez-Olea et al., 2018; Thomas et al., 2018), one has used BA grip width (Youdas et al., 2010) and others described an imprecise approach, such us "slightly wider than shoulder width or approximately 150% of the BA distance" (Munoz-Lopez et al., 2017; Sánchez-Moreno, Cornejo-Daza, González-Badillo, & Pareja-Blanco, 2020; Sanchez-Moreno et al., 2017). These variations among studies cast doubts on the transference of the results and the establishment of clear recommendations about the influence of the grip on performance, velocity and maximal strength capacity, making the study of the effect of grip width in PU of great interest.

Therefore, the main aim of this study was to analyze the influence of the PU grip width on 1) the maximal strength, 2) force-velocity-power relationship and 3) performance in a test of RF. According to previous studies (Andersen et al., 2014), it is hypothesized that the use of a narrow grip width would provide better performance during a PU than a wider or a FREE grip width.

Methods

Study Design

A within-participant repeated-measures design was used to compare the F-V relationship and the performance in a RF test using pronated BA or FREE grip widths during the PU. In a randomized and counterbalanced order, each subject performed four tests: an incremental loading test and a RF test with each type of grip width. Assessments were separated by 48 h of rest and they were performed at the same hour of the day. Before each trial, participants undertook 15 minutes of a standard warm-up (cardiovascular activity, joint mobility & stretching and 3 sets of 5 repetitions [the first with 50% of the body weight (BW), the second at 100% BW and 70% of the selfperceived maximal velocity, the third at 100% BW and 100% of the maximal velocity; 2-min rest] of pronated FREE or BA PU exercise in function of the corresponding test). On the first testing day, the wingspan-width and the BA distance were taken by a certified expert following the International Society of Advancement of Kinanthropometry (ISAK) recommendations. To improve the testing accuracy, participants BW was measured before each testing session (Tanita BC-418 MA, Tanita Corporation, Tokyo, Japan). All participants were instructed to maintain their normal diet, hydration and sleeping habits during the experiment.

Participants

Fourteen healthy voluntary males (age: 24 ± 3 years; height: 176.16 ± 5.35 cm; body weight (BW): 76.23 ± 5.94 kg and body fat: 12.22 ± 2.73%) participated in this study. None of them had any cardiorespiratory or musculoskeletal disorders. Inclusion criteria to participate in the study were that 1) participants were experienced lifters and consistently trained a minimum of 3 times per week for at least the last 12 months; 2) they were all able to perform more than 10 PU consecutive repetitions. All participants gave their informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the local University Ethic Committee.

Incremental Loading Test

After the standardized warm-up protocol participants completed an incremental PU test, with five or six loading conditions. The grip position in the bar was individually set for each participant, who had to place the index fingers on the marks. The participants chose whether or not to wrap the bar with the thumb, keeping this position through all the tests. From this position, after 2 seconds of full complete extension, participants were instructed to pull vertically at the maximum velocity until the chin is clearly above the bar, leaving the bar at the level the lower third of the neck. Body swinging and abrupt movements of the hips were forbidden. Two attempts were performed at each loading condition. Resting time between repetitions and loads was set at 1 and 3 minutes, respectively. The first load was the individual BW and it was increased by 10 or 5 kg by set considering the MPV during the up-phase (above or below the 0.5 $m \cdot s^{-1}$ of the MPV, respectively). Only 1 repetition per set was performed when the MPV did not reach 0.4 $m \cdot s^{-1}$. The test finished when the MPV got below 0.3 $m \cdot s^{-1}$. The selection criterion for the best repetition was the highest MPV. The MPV displayed a strong within-participant reliability at each loaded and grip width condition (mean CV: 7.69 ± 2.96 and 8.10 ± 1.44; mean ICC: 0.82 ± 0.30 and 0.79 ± 0.36, respectively for BA and F grip).

Repetitions to Failure Test

In this test, the participants executed the maximum number of RF with the corresponding grip width. They were instructed to perform strict PU repetitions with special emphasis on the concentric phase of the movement. Participants had to stay in a fully extended position between one repetition and the next to avoid taking advantage of the stretch-shortening cycle. The test finished when the participant was not able to raise the chin above the bar or when he paused for more than 2 seconds in the full-arm extension hanging position (Sanchez-Moreno et al., 2017). No additional load was used, and participants selected an individual free cadence. The number of repetitions performed and the MPV were monitored during the test. The test-retest reliability of this test has been previously reported (Sanchez-Moreno et al., 2017; Vanderburgh & Edmonds, 1997)

Measurement Equipment and Data Analysis

Kinematic variables were recorded by a linear velocity transducer (T-Force System, Ergotech, Murcia) with a sampling rate of 1000 Hz. The MPV, mean propulsive force (MPF) and mean propulsive power (MPP) within the propulsive phase were determined (Sanchez-Medina, Perez, & Gonzalez-Badillo, 2010). The dynamic system was attached to the back of the weight vest in the middle area between the lower edges of the scapulae. The cable of the transducer moved vertically from the ground and the participants' legs were slightly separated to prevent touching the cable. The overloads (weighted vest, sandbag and discs) were weighted with a precision scale (Seca 709, Seca Ltd., Hamburg, Germany). Maximum repetition (1RM) was estimated by fitting first-order linear equation load-MPV and taking 0.25 $m \cdot s^{-1}$ as 1RM velocity (Munoz-Lopez et al., 2017; Sanchez-Moreno et al., 2017). The absolute loads (kg; calculated as BW plus any additional load) were expressed as relative loads (%1RM) and another linear regression was conducted to establish the relationship between %1RM and MPV, MPF and MPP. Force and velocity of each load were modeled by a least-squares linear regressions model to calculate the F-V profile variables. The intercepts of the F-V relationship with force and velocity axes were assessed to calculate the theoretical maximal force (F_0) and velocity (V_0), respectively. The slope of the relationship ($-F_0/V_0$) and maximal power (P_0) (calculated as $[F_0 \cdot V_0]/4$) were also determined.

A video camera (Handycam® HDR-CX240E) was used to record the testing sessions at a 250 Hz sampling rate to determine if the chin surpassed the bar in cases where there was doubt.

Statistical Analyses

Data are expressed as means and standard deviations (mean ± SD). Normal distributions of the data were confirmed using a Shapiro-Wilk test. Within-participant reliability of MPV at each loaded condition and grip width was assessed by calculating the ICC, CV and the corresponding 95% confidence intervals. An acceptable variability was defined as a CV < 15% and an ICC > 0.70 (Haff, Ruben, Lider, Twine, & Cormie, 2015). The Chi-square test was used for the frequency analysis of grip width for the best 1RM result or better performance in the RF test. The relationship between %1RM and velocity was established by fitting first-order-polynomials to the data. The goodness of fit of the linear regressions was assessed by the coefficient of determination (R^2) and the standard error of the estimate (SEE). A mean comparison test for paired data was used to compare the MPV, MPF and MPP at each %1RM and the F-V profile variables between BA and FREE grip widths. The magnitude of differences was expressed as standardized mean differences (Cohen's d effect size, ES thresholds: > 0.2 [*small*], > 0.6 [*moderate*], > 1.2 [*large*] and >2 [*very large*] [Hopkins et al., 2009]). The individualized regression equations were plotted in an Excel spreadsheet (Excel Microsoft Software Corporation, Seattle, WA, USA). The reliability analysis was performed by means of a custom spreadsheet (Hopkins, 2000), while SPSS software version 24.0 (IBM SPSS, Chicago, IL, USA) was used for all other analyses. Statistical significance was set at an alpha level of 0.05.

Results

The mean grip width used by the participants was a 20.04% higher in the FREE grip (51.74 ± 5.78 cm) with respect to the BA grip (40.86 ± 0.43 cm; $p < 0.001$). This difference was maintained when it was expressed as the corresponding wingspan-grip width ratio (3.51 ± 0.47 *vs*. 4.39 ± 0.21 cm; $p < 0.001$ for FREE and BA calculated ratio, respectively). No association between the wingspan and the grip width was observed (R^2= -0.463, p = 0.095 *vs*. R^2= 0.157, p = 0.593 for FREE and BA grip width, respectively).

Trivial and not significant PU-1RM changes were observed between both grip width regardless of whether they were expressed as absolute or relative to BW values (mean, p [95% CI] and ES; 119.07 ± 9.66 *vs*. 117.21 ± 9.17 kg; p = 0.094 [-4.079; 0.364]; ES = -0.20; 1.545 ± 0.125 *vs*. 1.546 ± 0.180 $kg \cdot kg^{-1}$ BW; p = 0.954 [-0.065; 0.061]; ES = 0.01 for BA and FREE grip width, respectively).

The results of the RF test with both grip widths are presented in Table 1. The frequency analysis of the grip linked to the best 1RM showed the highest performance to be with a BA grip width (p = 0.033). There was no predominance of a grip type in the test of RF (p = 0.232). The association between 1RM and RF results displayed a strong lineal correlation with both grip widths (R^2 from 0.720 to 0.607) (Figure 1).

[Table 1 about here]

[Figure 1 about here]

No differences in MPV were detected at each %1RM between BA and FREE grip widths (p = 0.691 [-0.03, 0.08]). Moreover, characteristics of individual L-V relationships of this study sample showed an almost perfect relationship in both conditions (mean R^2 [lowest, higher value] BA = 0.962 [0.88, 0.99] and FREE = 0.968 [0.84, 1.00]). The regression equations between each percentage of the estimated 1RM and the MPV also displayed a good fit, so MPV was able to explain more than 85% of the %1RM variance with both widths grip (%1RM-BA = -50.976 MPV + 111.57; R^2 = 0.884; SEE = 3.99% of 1RM *vs*. %1RM-FREE = -46.888 MPV + 110.41; R^2 = 0.843; SEE = 4.80% of 1RM).

MPF and MPP data at each %1RM did not show differences between BA and FREE grip widths either ($p = 0.41$ and $p = 0.47$ for MPF and MPP). The results of the F-V and P-V relationships are shown in Table 2. No differences in F_0, V_0, P_0 and Sfv were detected when both types of grip width were compared. Figure 2 shows the mean force-power-velocity profile obtained from all participants in BA (Fig 2A) and FREE (Fig 2B) grip width. The raw value of maximal output reached during the incremental test was 10.18 ± 1.45 and 10.44 ± 2.16 $W \cdot kg^{-1}$ for BA and FREE grip width, respectively ($p = 0.633$). This value corresponded to the unloaded condition (or BW) during PU in all cases (65.96 ± 6.48 and 66.84 ± 6.16% of 1RM for BA and FREE grip width). The estimated P_0 was 13.85 and 13.99 $W \cdot kg^{-1}$ which corresponded to 41.15 ± 15.96 and 40.69 ± 12.47% of 1RM for BA and FREE grip width.

[Table 2 about here]

[Figure 2 about here]

Finally, a strong relationship was observed between normalized 1RM ($kg \cdot kg^{-1}$ BW) and F_0 at both BA and FREE grip width (BA-$R^2 = 0.836$ [CI 95%: 0.170-0.772]; $p < 0.001$ & FREE-$R^2 = 0.955$ [CI 95%: -0.147-0.286]; $p < 0.001$).

Discussion

The PU with pronated grip is a popular pull exercise, but the grip width impact on mechanical variables and performance needs to be addressed. The main findings of this study suggest that despite the difference of ~20% between the FREE and BA grip width in the PU exercise this variance did not affect the estimated 1RM, F-V relationship nor the performance in a RF test. The moderate to strong relationship between the 1RM and the number of PU achieved during the RF test with both grips indicates that high levels of strength are needed to improve the performance regardless of the grip width employed. Participants displayed a preference to use a BA grip width when heavy loads were lifted, probably because of the increase of the lever arm from the shoulder joint as the grip gets wider (Andersen et al., 2014).

Contrary to what was expected, the results of this research did not reveal a predominance of a grip type during the RF test. Moreover, in this test, participants self-selected an individual cadence. To our knowledge, only one previous study has used the movement velocity as an indicator of the relative intensity and level of effort attained during the set in PU (Sanchez-Moreno et al., 2017). The authors concluded that the repetition velocity allowed an estimation of the number of repetitions remaining in reserve when a given percentage of velocity loss was achieved during a PU set (Sanchez-Moreno et al., 2017). This velocity monitoring is a very useful reference during training, if the practitioner applies a maximal intended velocity during the movement (Conceicao, Fernandes, Lewis, Gonzalez-Badillo, & Jimenez-Reyes, 2016; Gonzalez-Badillo & Sanchez-Medina, 2010; Sánchez-Moreno et al., 2020; Sanchez-Moreno et al., 2017). In contrast, when a self-selected cadence is used, the results of this study did not indicate an obvious pattern of velocity loss despite the large percentage of change between the MPV of the first and last repetition (43 and 44% for BA and FREE grip widths, respectively). Accordingly, monitoring movement velocity during a self-selected pacing RF test does not seem to be useful to determine the level of effort. Consequently, despite the validity of the F-V relationship to estimate training intensity by measuring movement velocity in several exercises (Conceicao et al., 2016; Gonzalez-Badillo & Sanchez-Medina, 2010; Sanchez-Moreno et al., 2017), this relationship is not applicable when movement velocity is not maximal, as clearly revealed the RF test results. Although it is not well documented, the cadence selected during a RF test in PU could have a significant influence. La Chance & Hortobagyi (1994) observed larges differences among self-paced, 2:2 and 2:4 cadences in RF during

PU and push-up exercises, the self-paced cadence being the best option (LaChance & Hortobagyi, 1994). Therefore, the use of a self-selected cadence in this study, instead of a maximal one, provides an ecological validity and transference to the physical fitness PU tests.

The L-V relationship and F-V profile are frequently used to evaluate the neuromuscular capacities. In this study, the 1RM was estimated from a linear relationship load *vs.* MPV, considering 0.25 $m\cdot s^{-1}$ as the velocity linked to the 1RM (Munoz-Lopez et al., 2017; Sanchez-Moreno et al., 2017). The F_0 and normalized 1RM ($kg\cdot kg^{-1}$ BW) displayed a strong relationship at both BA and FREE grip width (R^2 = 0.836 and 0.955, respectively), which confirms that an increment in the maximal force capabilities will develop the 1RM in PU exercise. As expected, the maximal power output reached during the incremental test (mean of 10.181 and 10.445 $W\cdot kg^{-1}$ for BA and FREE grip width, respectively) was about 66% of 1RM (unloaded PU in all cases), a higher value compared with the ~40% of 1RM estimated from the F-V profile (P_0: mean of 13.846 and 13.985 $W\cdot kg^{-1}$ for BA and FREE grip widths, respectively). These results are consistent with Muñoz-Lopez findings (Munoz-Lopez et al., 2017) and corroborate that an assistance device is needed to get an "*optimal load*" to maximize power capabilities in PU. Then, it could therefore be considered that the "*optimal load*" is linked to the maximal power (Cormie et al., 2011; McBride, Triplett-McBride, Davie, & Newton, 2002), which is of great interest in muscle power development, especially in ballistic exercises.

Despite no differences in performance, heaviest loads were lifted with a BA grip width. According to recommendations in the LPD exercise (Andersen et al., 2014), the results obtained indicate that the use of a narrow (or BA) grip could be a better option when the objective is to train with heavy loads and get higher mechanical stress. Furthermore, given the relationship between scapula kinematics and injuries, particularly concerning the shoulder impingement in overhead activities (Ludewig & Reynolds, 2009), a narrow grip seems to be safer than a wide one due to the joint position. Moreover, it should be noted that a narrow grip could involve a greater range of motion, adding work that may have an impact on the likely adaptations. Conversely, a wide grip width in PU has shown several kinematic patterns that are linked with increased shoulder injury risk since it reduces the range of pro/retraction in the same humerothoracic plane of elevation (Prinold & Bull, 2016). Consequently, the wide grip could limit the intensity of the training, which is an important variable to produce the desired adaptations in resistance trained athletes (Schoenfeld, Wilson, Lowery, & Krieger, 2016).

The current study had some limitations that need to be addressed. First, to avoid technical problems and potential injuries at the highest load that could be moved during the incremental PU test, the 1RM was estimated by fitting a first-order linear equation to the load-MPV relationship and taking 0.25 $m \cdot s^{-1}$ as 1RM velocity. Although it is a validated procedure in the literature (Munoz-Lopez et al., 2017; Sanchez-Moreno et al., 2017) the indirect determination may involve some small variation in the 1RM of a participant. Second, participants were free to choose their preferred cadence which could affect the results. Nonetheless, the self-selected cadence brings an ecological validity and a realistic application of the study to the actual physical fitness PU tests used by firefighters, police and the military.

Conclusions

In conclusion, the width selected by the participants in the FREE grip differs ~20% from the biacromial distance. This difference does not lead to significant changes in the estimated 1RM nor in the P-V and F-V relationship. Regardless of the type of grip width used, high levels of strength are needed to increase the number of repetitions during a RF test. Further comparative studies including greater grip widths in PU are needed to accurately clarify the grip width influence on performance, muscle activation and shoulder mechanical stress.

What does this article add?

The grip width selection does not seem to be crucial when the purpose is to accumulate as many repetitions as possible. However, based on the additional mechanical stress placed on the shoulder by the wider grip, the authors recommend the use of the narrow grip for training and testing. The absence of a significant performance benefit in using a wider compared to a narrow grip in this study suggests that available results derived from other studies with both grips can be used interchangeably. However, large differences between self-selected grip-widths have been detected among studies (ranged from 120 to 150% of the BA distance) so that wider grip-widths above the 20% of the BA distance could produce different effects to those described in this study.

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Figure Captions

Figure 1. Relationship between repetitions to failure and 1RM normalized per kg of body mass by using A) BA; and B) FREE grip width. Sample size = 13. One participant was eliminated from this test because he included rebounds in some repetitions.

Figure 2. Force-velocity profile (F_0 and V_0) and power-velocity quadratic regression (P_0) of entire sample with BA grip width (A) and FREE grip width (B).

Table 1. Performance attained during repetitions test to failure with both grip widths.

	BA	FREE	Difference (%)	ES	*p* value [IC 95%]
BW1RM (%)	65.9 ± 6.47	66.8 ± 6.16	1.34	0.14	0.26 [-0.76; 2.53]
RF (nº)	17.3 ± 3.40	18.0 ± 3.70	4.44	0.11	0.11 [-0.22; 1.76]
MPV (m/s)	0.61 ± 0.09	0.63 ± 0.06	3.43	0.25	0.50 [-0.01; 0.05]
LR (m/s)	0.36 ± 0.14	0.35 ± 0.14	-2.72	-0.05	0.73 [-0.05; 0.07]
FR (m/s)	0.64 ± 0.07	0.65 ± 0.06	1.09	0.09	0.86 [-0.05; 0.07]
FR–LR (m/s)	0.27 ± 0.15	0.29 ± 0.03	5.04	0.10	0.71 [-0.09; -0.06]

Abbreviations: BW1RM: percentage of BW with respect to the maximum repetition; RF: repetitions to failure; MPV: mean propulsive velocity throughout the test; LR: mean of propulsive velocity of last repetition; FR: mean of propulsive velocity of first repetition; FR-LR: mean of propulsive velocity of difference between FR and LR; BA: biacromial grip width ; FREE: free grip width; ES: effect size calculated as standardized mean differences divided by a standard deviation for the data (Cohen's *d*: [F-BA]/pooled SD); *p* value [IC 95%]: statistical significance [95% of confidence interval].

Table 2. Power-Force-Velocity profile.

	BA	FREE	Difference (%)	ES	*p* value [IC 95%]
F_0 (N·kg)	16.25 ± 1.60	16.36 ± 1.81	0.86	0.07	0.58 [-0.53; 0.68]
V_0 (m/s)	3.514 ± 0.87	3.43 ± 0.67	-2.27	-0.02	0.87 [-0.60; 0.51]
Sfv	-5.11 ± 1.69	-4.95 ± 1.16	-3.03	0.11	0.69 [-0.68; 0.99]
P_0 ($W \cdot kg^{-1}$)	13.846 ± 2.59	13.98 ± 2.81	1.00	0.11	0.75 [-1.78; 2.39]

Abbreviations: F_0: theorical maximal force; V_0: theoretical maximal velocity; Sfv: slope of the linear F-V relationship, calculated as Sfv = $F_0/V_{0;}$ P_0: theorical maximal mechanical power output, calculated as $P_0 = F_0 \times V_0/4$.

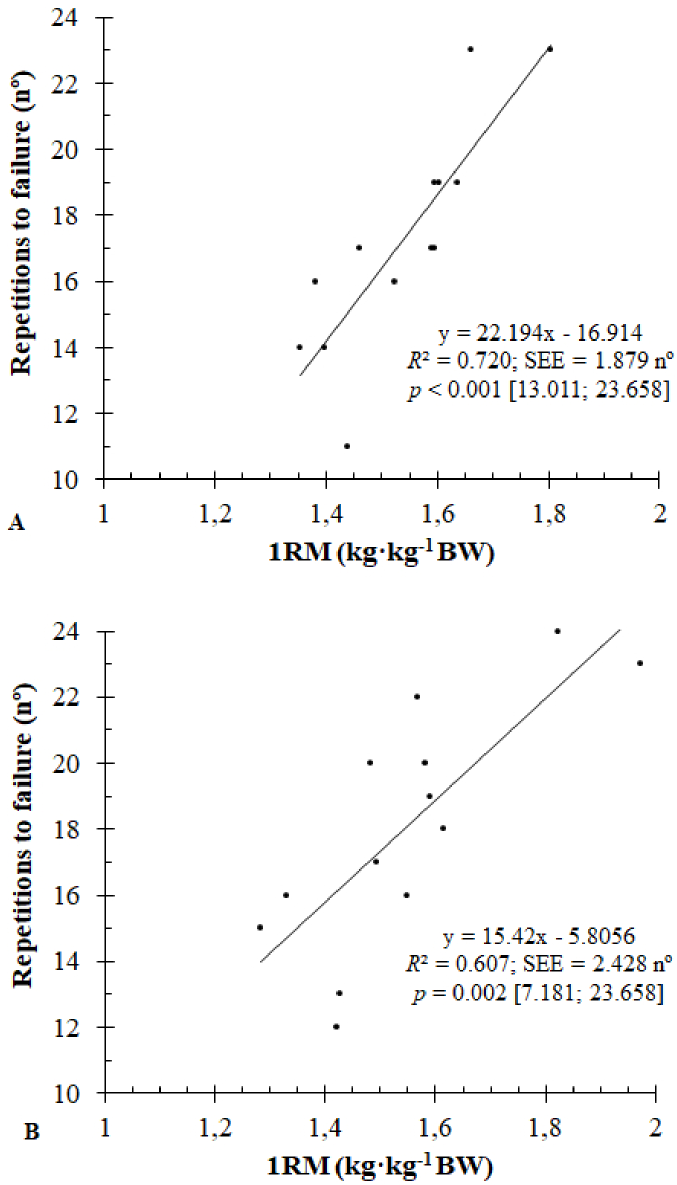

Figure 1. Relationship between repetitions to failure and 1RM normalized per kg of body mass by using A) BA; and B) FREE grip width. Sample size = 13. One participant was eliminated of this test because he included rebound in some repetitions.

28x39mm (500 x 500 DPI)

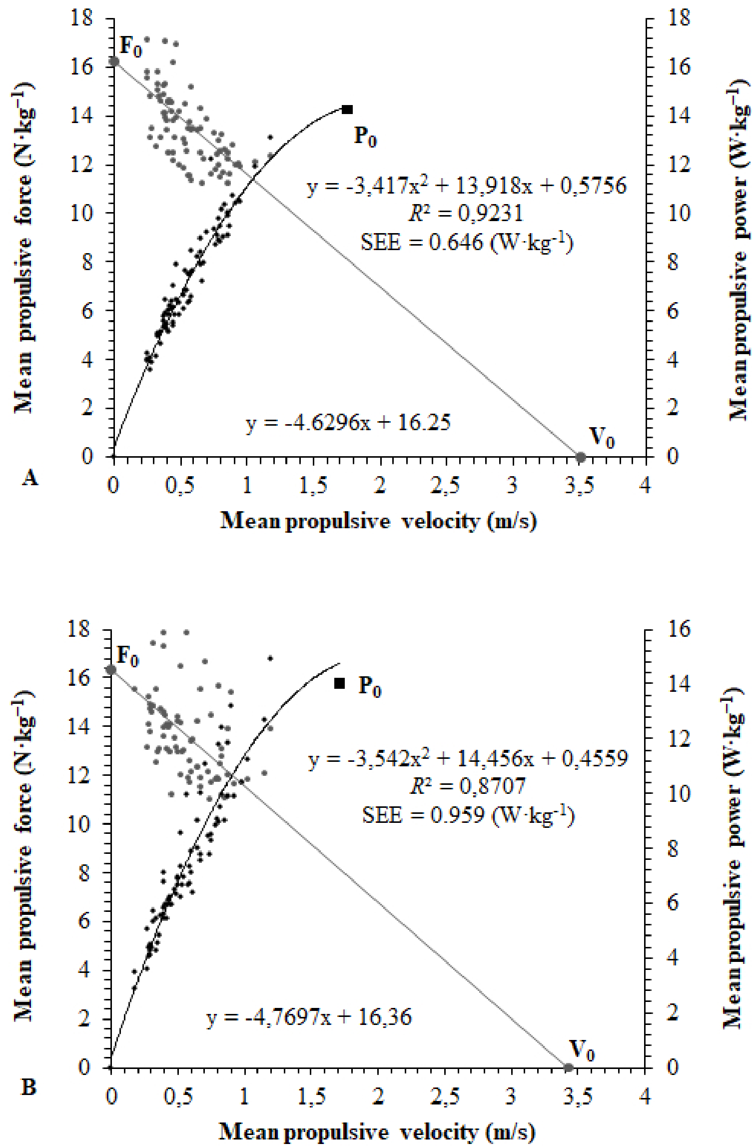

Figure 2. Force-velocity profile (F_0 and V_0) and power-velocity quadratic regression (P_0) of entire sample with BA grip width (A) and FREE grip width (B).

28x39mm (500 x 500 DPI)