Original Article

The perception of effort is not a valid tool for establishing the strength-training zone

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ABSTRACT

The main purpose was to investigate whether the perception of effort during the two first repetitions of strength exercises could be an adequate strategy for estimating the strength-training zone. The sample comprised 11 women (18 to 35 years-old). In the first week, the volunteers performed a 1-RM test in seven exercises on strength machines, and the load was calculated to reach 50%, 70% and 90% of the 1-RM. Over the next three weeks, the volunteers were required to perform randomly the exercises at these three intensities. After the two first repetitions, the volunteers were questioned about how many repetitions they believed they could achieve until failure (self-estimated). Additionally, volunteers were asked to indicate their exertion according Borg scale. After volunteers performed every exercise until concentric failure to complete the repetition maximum test (RMs test). The data were analyzed using linear regression, Pearson correlation and paired t-test. The results showed that the self-estimated number of repetitions underestimated 44% and 30% of the mean values of repetition maximum obtained directly at intensities of 50% and 70% ($p < 0.05$), respectively. Although repetition maximum were correlated with Borg scale ($r = -0.23$ to -0.41; $p < 0.05$) and self-estimated number of repetitions ($r = 0.25$ to 0.41; $p < 0.05$), the standard errors of estimate obtained by linear regression were very high (40% to 49%), which prevented any estimation equations. In conclusion, the perception of effort during the two first repetitions is not a satisfactory strategy for estimating the strength-training zone. **Key words:** RESISTANCE TRAINING, PERCEPTION OF EFFORT, RATING OF PERCEIVED EFFORT, BORG SCALE.

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INTRODUCTION

Strength training (ST) is essential for some groups of people, including athletes at one extreme and the elderly or people in neuromuscular rehabilitation at the other. In fact, ST is a kind of "full body training" and has been associated with reducing blood pressure (Duncan, Birch, & Oxford, 2014), triglyceride levels and insulin resistance, improving some cognitive indicators and reversing some effects of fibromyalgia and rheumatoid arthritis (Hurley, Hanson, & Sheaff, 2011). However, accurate ST prescription is not simple, since there are many variables to be managed (American College of Sports Medicine [ACSM], 2009).

An important strategy for prescription of ST, although not the only one, takes into consideration the repetition maximum training zone (TZ). For example, the TZ aiming at maximal strength, muscle hypertrophy, or muscular endurance must be around 1-6 repetitions maximum (RM), 6-12 RM, or 15-30 RM, respectively (ACSM, 2009; Campos et al., 2002).

Despite TZ management being essential for prescription of ST, we have not yet found a simple, fast, accurate and low-risk strategy to achieve this goal. The load percentage of one-RM (1RM), as applied to ST prescription, has already been discarded in gyms. The main reasons for this are that the 1RM test is classically known for increasing muscle soreness and injuries in some groups (Pollock et al., 1991; Shaw, McCully, & Posner, 1995) and its complexity and low accuracy to establish the TZ (Ferreira et al., 2006; Moraes et al., 2014; Richens & Cleather, 2014; Shimano et al., 2006; Testa, Noakes, & Desgorces, 2012).

The 1RM could be estimated using equations obtained from submaximal loads (Kravitz, Akalan, Nowicki, & Kinzey, 2003; Mayhew, Ball, Arnold, & Bowen, 1992). However, even though the accuracy of several equations has been adequate for some exercises, such equations do not solve the problem regarding the precision required to reach TZ using percentage of 1RM. Moreover, equipment and machines from every training center are not equal and there are no equations for most exercises, such that estimation equations have been of little applicability for training prescription.

Another possible method of reaching the TZ is by directly doing RM tests targeting the pre-established TZ (e.g. 8 - 12 RM). In this case, the issue is the requirement for evaluator experience and the high strain felt during the final repetitions. This latter would be a problem mainly for those in rehabilitation or weakened by illness (Hampton, Armstrong, Ayyar, & Li, 2014). Thus, a more appropriate strategy for obtaining the desired TZ is lacking.

In gyms, it is common to use an empirical strategy to reach TZ, which presupposes the effort perceived by the person evaluated. Firstly, a submaximal load is established; secondly, the person being tested is required to perform two or three repetitions; thirdly, they are asked about how many repetitions they feel or believe that they could do after completion of the two or three repetitions. This empirical approach assumes that perceived exertion could be used in a context of exercise prescription. Nevertheless, this hypothesis has not been tested to date.

The high correlation between intensity and perceived exertion (Day, McGuigan, Brice, & Foster, 2004; Tiggemann et al., 2010), even when only two submaximal repetitions are performed (Pincivero, Coelho, & Campy, 2003), lends support to this practical strategy and indicate the plausibility of using perception of exertion to estimate TZ. If perceived exertion proves to be an efficient strategy, certainly it will be more helpful for weaker people, such as those in rehabilitation (Hampton et al., 2014).

We hypothesized that perceived exertion during the first repetitions could be adequate to estimate the TZ. Consequently, we sought to investigate if TZ could be estimated using a self-estimated number of repetitions reported by the volunteer during the first two repetitions in a single set during seven different exercises. Furthermore, we used the Borg scales of perceived exertion ratings as a method to serve of positive control. In fact, Borg scale is the more common instrument used for perceived physical exertion (Berchicci, Menotti, Macaluso, & Di Russo, 2013; de Morree, Klein, & Marcora, 2012; Hampton et al., 2014; Pincivero et al., 2003) and has been used to identify the internal training load for resistance training (Charro, Aoki, Coutts, Araújo, & Bacurau, 2010).

MATERIAL AND METHODS

Participants

Participants were recruited by proximity; therefore, this study was based on convenience sampling. Posters were displayed around our University Center inviting volunteers to take part in a research study involving bodybuilding techniques. The exclusion criteria were: a) response "Yes" for any one question in the physical activity readiness questionnaire (PAR-Q); b) response "Yes" to questions regarding smoking, diabetes, anemia, or any injury that could interfere in physical performance and clinical family history of sudden death (1st-degree relatives). Following this process, we identified 11 female volunteers, aged 18 to 35. The study was approved by the… [*hidden to the review proceeding*] Ethical Committee (protocol 51494/2012) and all volunteers signed the free and clarified consent term.

Experimental protocols

The experiment lasted four weeks. In the first week anamnesis, PAR-Q, and the 1RM test were carried out. Over the second, third, and fourth weeks, a set of exercises was carried out at three different intensities (50%, 70%, and 90% of 1RM load) until concentric failure. Participants were instructed to avoid exercise and alcohol consumption and maintain their habitual diet for 24 hours, in addition to having an ideal night's sleep (around 8 hours) prior to each test.

One-repetition maximum (1 RM) test

1 RM tests were conducted on seven different strength exercise machines as follows: chest fly; seated leg extension; front pull-down pulley; lying leg curl; low-pulley biceps curl; triceps extension on a pulley machine and military press machine. In the first week, the 1RM test was carried out following the aforementioned sequence. The volunteer performed mild passive stretching for 20 seconds, then the 1RM load was estimated by evaluator's experience and the volunteer requested to complete as many repetitions as possible. Where more than one repetition was completed, 5 minutes were allowed to pass until the next attempt with a new load. The maximum number of attempts during the same day was five, with a minimum 48-hour wait before a further test.

Set of strength exercises and perceived effort reporting

One week following the 1RM test, 50%, 70%, and 90% of the 1RM load was calculated for each exercise. Such loads were then randomly selected for weekly application, with one set of each exercise at each load selected. Before each set of an exercise, each volunteer received a detailed explanation of the Borg scale. After that, it was conducted a 20-second passive stretching for the muscle groups active in each exercise. All exercises and tests were performed in the same sequence as the 1RM test. Volunteers were asked to perform just two repetitions and then asked how many repetitions they believed would be necessary before the failure (Self-estimated number of repetitions). Also, it was asked about the perceived effort using the Borg scale. Subsequently, to minimize memorization of the answers, each volunteer was directed to the next exercise to perform the same procedures. After completing two repetitions of all exercises, the volunteer was redirected to the first exercise. Now, all were then asked to complete maximum possible repetitions until concentric failure (Maximum number of repetitions test; RM test). Of note, the volunteers were verbally encouraged to reach concentric failure by the evaluators in both 1RM test and RMs Tests.

Borg scale of perceived exertion

The Borg scale was used, as modified by McGuigan and Foster (2004) and comprising an ascending numeric scale ranging from 0 to 10 (CR-10), in which 0 and 10 signify the lowest (no effort is perceived) and highest (maximum effort perceived) exertion, respectively. This scale includes the respective key words linked to the perception of effort: “no exertion”, “very, very easy”, “easy”, “moderate”, “somewhat hard”, “hard”, “very hard”, “maximum exertion”.

Statistical data analysis

Self-estimated number of repetitions and perceived exertion from the Borg scale were compared using a paired t-test. Linear regression and Pearson product-moment correlation were used to determine the extent of the relationship between Maximum Number of Repetitions obtained directly and results from the Borg scale, the Self-Estimated Number of Repetitions and the 1RM load. The same procedures were repeated with the Borg scale versus Self-estimated number of repetitions. The standard error of estimate (SEE) was obtained for every linear regression performed. The SEE was presented as a percentage of the mean of maximum repetitions at each intensity. The descriptive data were shown as mean ± standard error. The significance level was fixed at 5% ($p = 0.05$). The statistical packages SigmaPlot Version 11 and OriginPro8.1 were used.

RESULTS

The sample age, body weight, and height were, respectively, 22 ± 0.8 years old, 62 ± 0.4 kg, and 1.64 ± 0.02 m. Negative coefficients of correlation were identified between the Borg scale vs. Maximum number of repetitions obtained directly at all intensities (50%, r = -0.23; 70%, r = -0.37 and 90%, r = -0.41; df = 10; $p < 0.05$; r^2 = 0.05, 0.14, and 0.17, respectively). Similarly, significant correlation was also found between Self-estimated number of repetitions vs. Maximum number of repetitions obtained directly for all intensities (50%, r = 0.25; 70%, r = 0.38 and 90%, r = 0.41; df = 10; p < 0.05; r2 = 0.06, 0.14, and 0.17, respectively).

Despite the statistical significance and linear tendency found using either the Borg scale or Self-estimated number of repetitions vs. Maximum number of repetitions, the standard error of estimate (SEE) found during the linear regression, aimed at producing equations of prediction, were very high for both (Borg and Self-estimated repetitions) at all intensities (SEE = 49%, 40%, and 47% in relation the intensities 50%, 70%, and 90%, respectively). The Figures 1, 2, and 3 (Double-Y figures) depicts the correlations for Maximal number of repetitions vs. Self-estimated number of repetitions and Borg scale at three different intensities.

However, these SEE values were not higher than those found over linear regression performed between Maximum number of repetitions vs. 1RM load at the three different intensities (Table 1).

Significant coefficients of correlations were found between the Borg scale versus Self-estimated number of repetitions for all intensities (50%, r = - 0.57; 70%, r = -0.68; 90%, r = -0.61; df = 10; $p < .05$; r^2 = 0.32, 0.46, and 0.37, respectively).

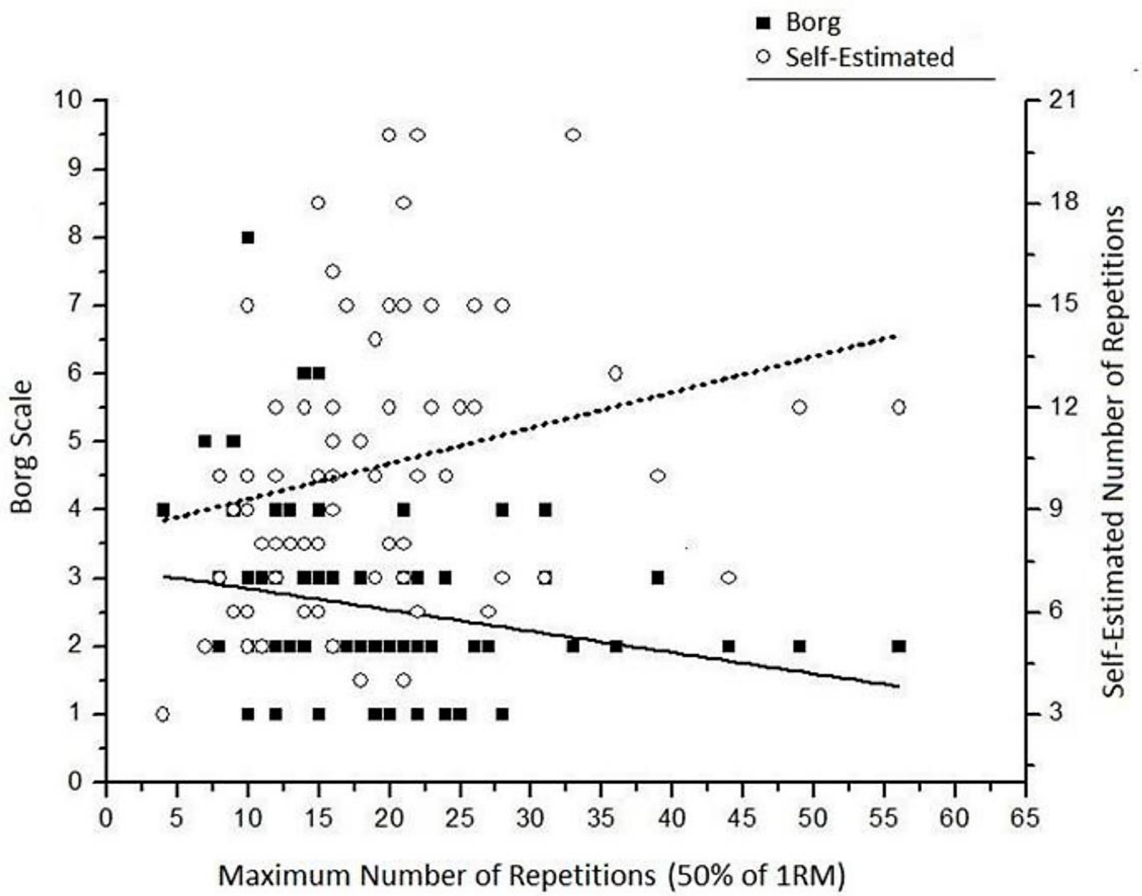

Figure 1. Correlations for maximal number of repetitions vs. self-estimated number of repetitions and Borg scale depicted by Double-Y scatter plot at 50% of 1RM. The dashed line trend is Borg scale.

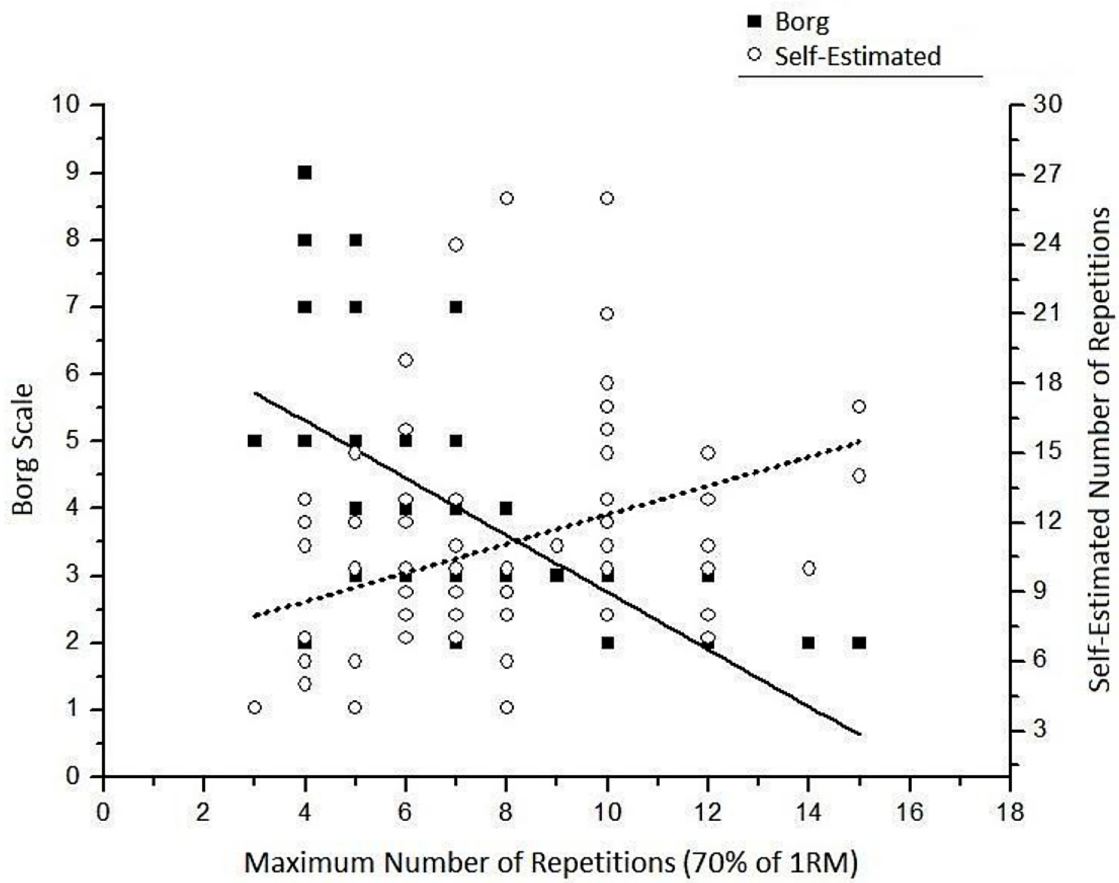

Figure 2. Correlations for maximal number of repetitions vs. self-estimated number of repetitions and Borg scale depicted by Double-Y scatter plot at 70% of 1RM. The dashed line trend is Borg scale.

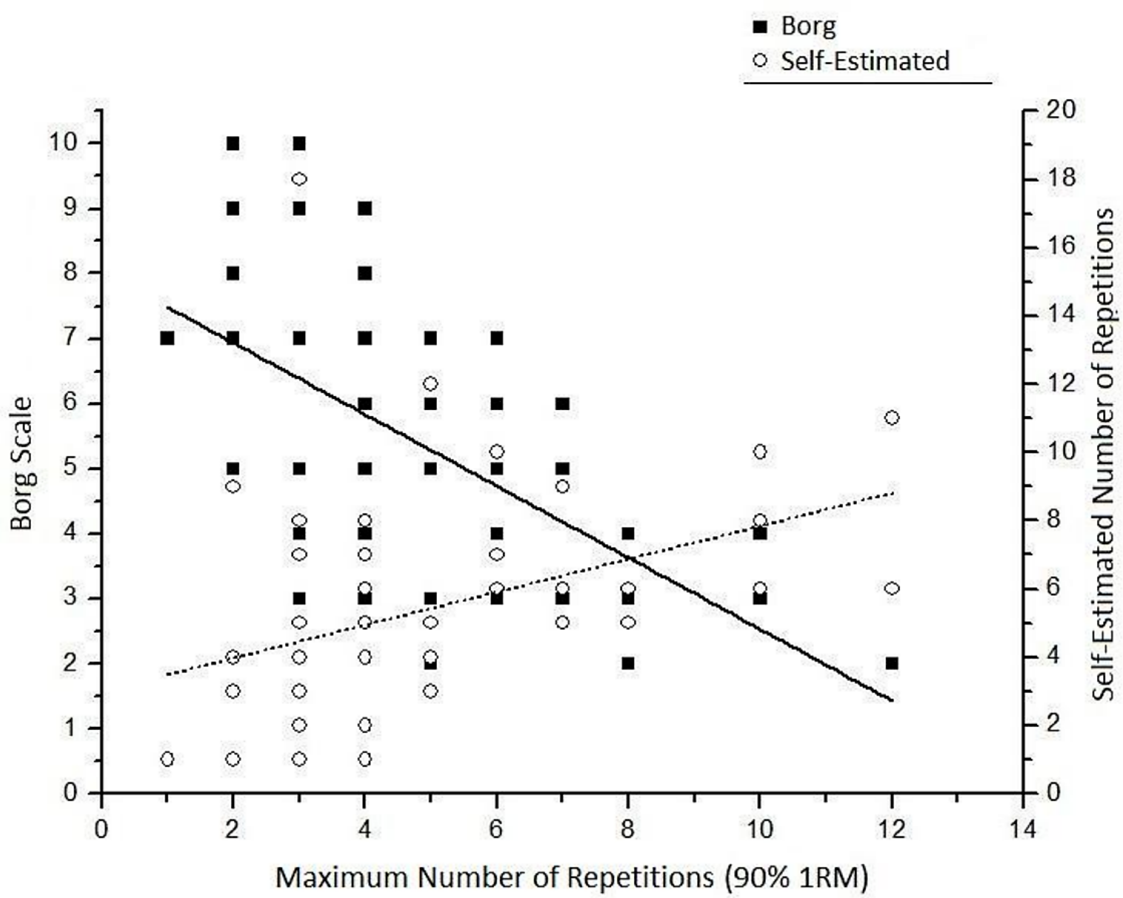

Figure 3. Correlations for maximal number of repetitions vs. self-estimated number of repetitions and Borg scale depicted by Double-Y scatter plot at 90% of 1RM. The dashed line trend is Borg scale.

Table 1. The standard error of estimate (SEE) obtained during linear regression used to determine the extension of the relationship between maximum of repetitions vs. one-repetition maximum (1RM) load.

Exercises	SEE (50% of 1RM)	SEE (70% of 1RM)	SEE (90% of 1RM)
Chest fly	39.9%	42.2%	32.7%
Seated leg extension	26.5%	32.0%	35.1%
Front pull-down pulley	27.3%	35.5%	55.3%
Lying leg curl	36.0%	25.7%	22.8%
Low-pulley biceps curl	37.5%	39.3%	45.2%
Triceps extension	48.4%	45.8%	62.7%
Military press machine	27.9%	39.9%	52.1%
Mean	34.8%	37.2%	43.7%

SEE is show in percentage from the mean of maximum repetitions.

Figures 4, 5, and 6 depict the relationship between maximum number of repetitions obtained directly vs. Self-estimated number of repetitions at 50%, 70%, and 90% intensities. The Self-estimated number of repetitions significantly underestimated ($P < .05$) the mean of repetitions obtained directly at intensities of 50% and 70% (44% and 30%, respectively; See data heterogeneity on the box-plot, on left of Figures), supporting the results found in linear regression. In respect of 90% intensity, underestimation (12%) was not statistically significant.

Considering that the mean does not represent individual data, we drew a Multi-series line diagram (right of Figures 1, 2, and 3) that permit viewing of the direction of connections between each individual data of Maximum number of repetition obtained directly with the Self-estimated number of repetitions. Considering a high estimation capacity scenario using Self-estimated numbers of repetitions, the direction of the lines should be horizontal. However, as can be seen in Figures 4, 5, and 6 (left side) there were obvious excessive slopes and line intersections for all intensities, highlighting the possibility that Self-estimated number of repetitions is not a good strategy for estimating TZ.

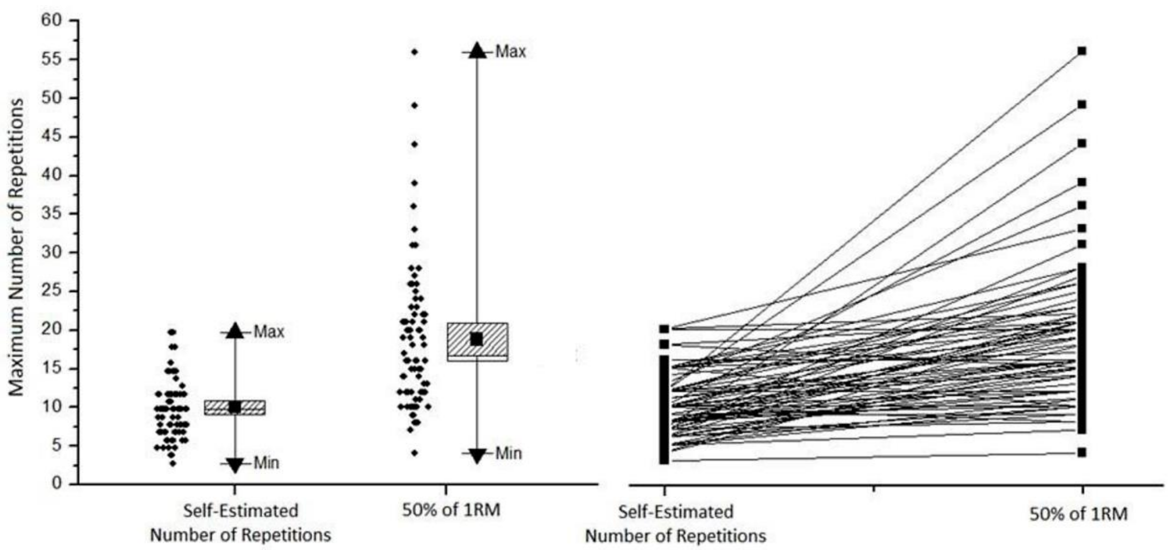

Figure 4. Box-plot (on left) and multi-series line (on right) of the self-estimated number of repetitions and maximum number of repetitions for 50% of 1RM. The upper and lower limits of the rectangle refer to the 95% confidence interval (CI: 1.96 x SE); Square and horizontal line into the rectangle are the mean and median, respectively.

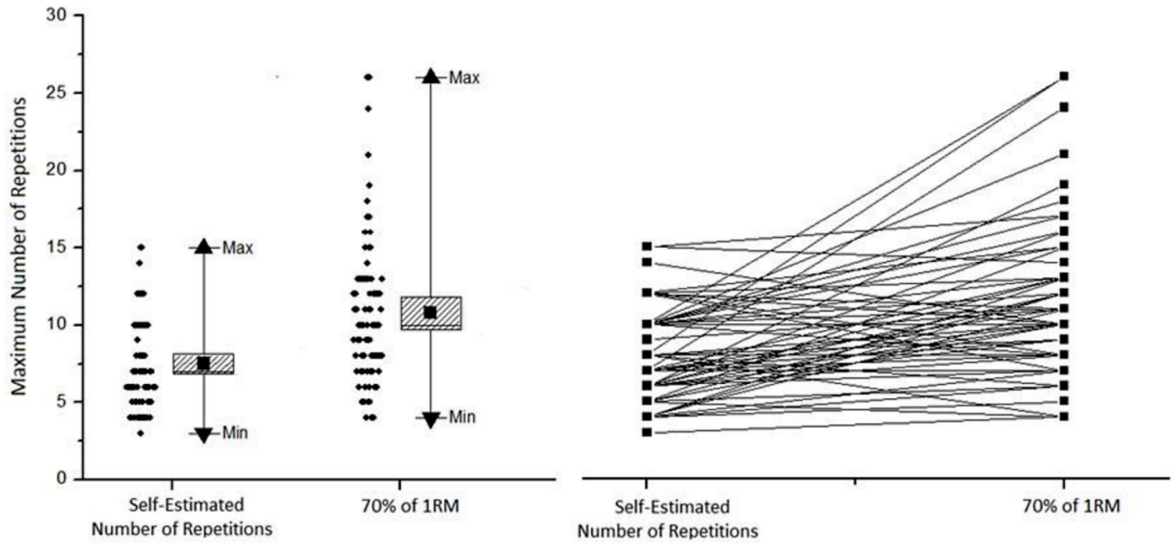

Figure 5. Box-plot (on left) and multi-series line (on right) of the self-estimated number of repetitions and maximum number of repetitions for 70% of 1RM. The upper and lower limits of the rectangle refer to the 95% confidence interval (CI: 1.96 x SE); Square and horizontal line into the rectangle are the mean and median, respectively.

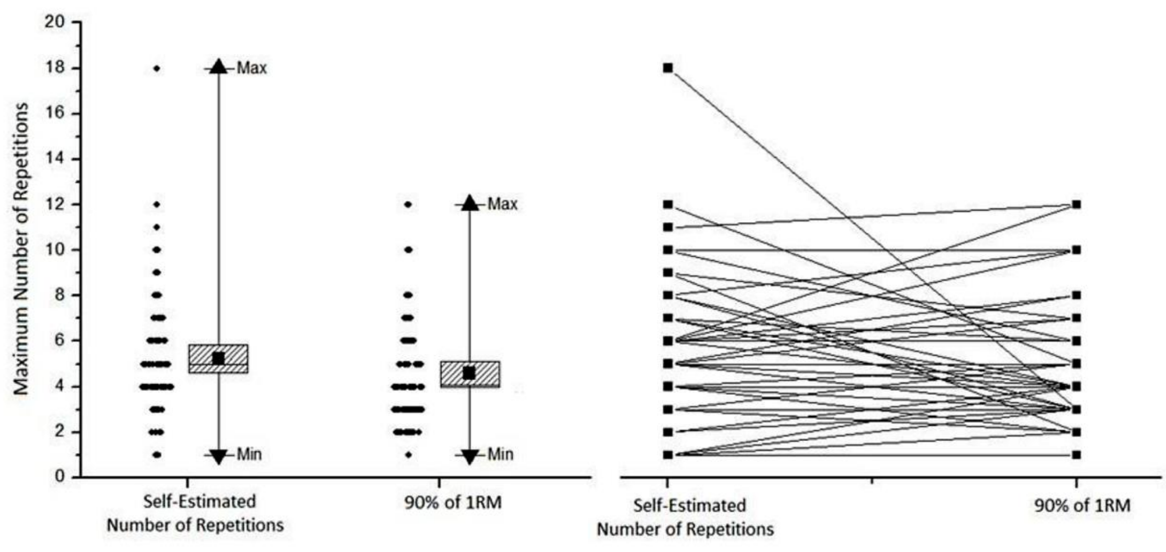

Figure 6. Box-plot (on left) and multi-series line (on right) of the self-estimated number of repetitions and maximum number of repetitions for 90% of 1RM. The upper and lower limits of the rectangle refer to the 95% confidence interval (CI: 1.96 x SE); Square and horizontal line into the rectangle are the mean and median, respectively.

DISCUSSION AND CONCLUSIONS

The main results from this study are that neither the Self-estimated number of repetitions nor the Borg scale of perceived exertion stated by volunteers during the first two repetitions have proved to be an adequate tool for estimating strength TZ. Despite significant correlations between Borg scale and Self-estimated number of repetitions vs. Maximum number of repetitions, the inflated SEE found using linear regression (SEE > 40%) have clearly shown that it would not be appropriate to propose any equation to estimate TZ. The perception of effort was not even better than 1RM test for estimating TZ.

It is well-known that the intensity and volume of strength training are positively associated with the effort perceived (Costa & Fernandes, 2007; Day et al., 2004; Pincivero et al., 2003; Testa et al., 2012; Tiggemann et al., 2010) displaying a linear or quadratic relationship (Pincivero et al., 2003; Suminski et al., 1997). This is in agreement with the classical psychophysical power law described by Stevens (1957) regarding the close relationship between the strength of stimuli and perceived sensations. Thus, as expected, we have also found significant correlation between perceived exertion and Maximum number of repetitions.

In our study, in addition to the Self-estimated number of repetitions, we used the Borg scale, a validated instrument of exertion perception evaluation in resistance training (Berchicci et al., 2013; Charro et al., 2010; de Morree et al., 2012; Hampton et al., 2014; Pincivero et al., 2003). Indeed, the coefficients of correlation found between strength exercise intensity and effort perceived by Borg scale were greater than 0.82 (Day et al., 2004; Tiggemann et al., 2010). For this reason, some researchers have used the Borg scale to identify the internal training load for resistance training (Charro et al., 2010; Day et al., 2004), showed that the perception of effort measured by the Borg scale at three intensities of exercise was as follows: 90% > 70% > 50% of 1RM. Afterward Costa and Fernandes (2007) confirmed these results, and even before Day et al. (2004) there were already similar results published by others (Pincivero et al., 2003; Suminski et al., 1997) whom also demonstrated that perception of exertion given by the Borg scale could be accurately used for monitoring exercise session intensity and that effort perceived was independent of exercise type.

We have only studied women because the number of men who volunteered to the study was insufficient. Despite it, it is known that women and men show similar ratings of perceived effort in aerobic and anaerobic training (Pincivero et al., 2003; Scherr et al., 2013), even though large absolute and relative loads are lifted (Pincivero et al., 2003).

We did not find any difference regarding the behavior of effort perception over the seven exercises used in the current study, justifying our collective treatment of all data from our seven different exercises. This result was similar that found by Day et al. (2004) and Shimano et al. (2006).

Initially, we find a moderate-to-strong correlation between the Borg scale and Self-estimated maximum repetitions, suggesting that a strategy as simple as self-perception could be used to evaluate effort. Indeed, when load stimulus is varied, other similar instruments (e.g., OMNI Scale) might be used successfully in a different framework (Colado et al., 2012; Garber et al., 2011), and may be strongly associated with Borg scale (Muyor, 2013).

Our decision for using Self-estimated number of repetitions as an approach to estimating the TZ was made because strength-training professionals have habitually used this strategy in their practice. Primarily on the first day of training, it is usual for professionals to ask their clients or beginner athletes to perform some repetitions; afterwards they are asked about how many repetitions they believe they would be capable of until failure. Such empirical comprehension makes sense because maximum number of repetitions are associated with perceived effort. Indeed, as mentioned before, there is a linear or quadratic relationship between intensity and perception of effort (Suminski et al., 1997; Tiggemann et al., 2010). Furthermore, it has been shown that is possible to feel the effort during the first repetitions (Pincivero et al., 2003).

However, contrary to our expectations, we could not confirm that this strategy is enough to achieve the TZ. Even though we found a significant correlation between Self-believed number of repetitions and number of maximum repetitions, the SEEs were so elevated. More plausible explanations for refuting our hypothesis are discussed below.

The elevated coefficients of correlation between strength exercise intensity and effort perceived found by other authors (e.g.; > 0.80) as compared with our smaller coefficients (0.25 to 0.41) must be explained by an important difference. We only evaluated the perception of effort during the two first repetitions, while most researchers have evaluated the effort perception after concentric failure or at the end of a training session (Costa & Fernandes, 2007; Day et al., 2004; de Morree et al., 2012). It is known that fatigue is positively associated with perception of effort (de Morree et al., 2012), and increased brain activity has been confirmed in conditions of muscle fatigue (Berchicci et al., 2013; de Morree et al., 2012). However, in our study the volunteers performed just two repetitions, which should have prevented this variable.

However, it is also important to mention that coefficients of correlation found between a number of physiological variables and effort perception have not been as high as conventionally thought (e.g., r = 0.80 to 0.90), but around 0.50 to 0.70 (Chen, Fan, & Moe, 2002). Indeed, there are authors who do not believe that perceived effort methods are sufficient as a primary strategy for exercise prescription (Garber et al., 2011).

The perception of effort is, in fact, subjective and complex. It integrates neurophysiological pathways recruited to interpret a number of variables such as muscle activity, tension, fatigue, and discomfort (Berchicci et al., 2013; de Morree et al., 2012; Pincivero et al., 2003). As suggested by the “sensation of innervation theory", the perception of effort reflects the central motor command during the movement performance (Berchicci et al., 2013; de Morree et al., 2012). Although localizing the sensation of effort inside the brain has proven problematic, it has been suggested that the perception of effort involves supplementary, premotor, primary motor cortex, and prefrontal areas of the brain (Berchicci et al., 2013).

Some of our results agree with this complexity. Indeed, our volunteers felt the effort more significantly when they performed proportionally more repetitions at each intensity tested. For example, underestimation of the 90% intensity level was around 12%, with 44% and 30% underestimation for the 70% and 50% intensities respectively. This result seems be explained by the proximity to the maximum number of repetitions. In respect of 50% intensity, two repetitions represent nearly 20% of the mean of maximum repetitions performed, while at 90% intensity two repetitions represent nearly 40% of such mean. In a study comparable to ours, concordant results were found (Pincivero et al., 2003).

Pincivero et al. (2003), however, administered just one exercise (knee extension). In their study, the participants completed two submaximal contractions at 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90% of their 1-RM. The perceived exertion was measured by asking participants to give a number that corresponded to their feelings after completing the two repetitions, on viewing a modified category-ratio (CR-10) scale. The findings demonstrated that perceived exertion was significantly lower (underestimated) than expected at 10% to 60% of 1-RM, but was not different from 70% to 90% 1-RM. In other words, the closer a person gets to doing maximum repetitions, the easier it is to estimate the TZ. Others have also shown that it is easier to perceive effort at the highest intensities (Day et al., 2004; Suminski et al., 1997; Tiggemann et al., 2010). Together, these results support the complexity behind the neurophysiological pathways concerning perception of effort.

Despite the coefficients of correlation that we found between maximal number of repetitions vs. perceived effort were relatively weak, they were always statistically significant. To this end, we performed linear regressions to evaluate the possibility of establishing equations of estimation. We found very high SEE (> 40%), thus making it impossible to propose TZ estimating equations. Certainly, the high SEEs are explained by the considerable variations between participants (see all figures). Such variation has also been the most significant problem in using 1RM as a strategy to estimate TZ, and apparently, this variation problem extends to the perception of effort.

In our current study, part of our sample (n = 6) had some experience in strength training, while the remainder (n = 5) had none. It could be speculated that participants without previous experience could not even imagine being able to perform dozens of repetitions, for example. Indeed, it has shown that training status may influence perception of exertion (Pierce, Rozenek, & Stone, 1993; Testa et al., 2012; Tiggemann et al., 2010), and it also has been shown that perceived effort ratings might be better when the exercise tasks are unusual. In this light, we performed comparisons between these subgroups (experience vs. no experience), but we did not find any difference or trend. Evidently, our sample size in both subgroups was very small (low statistical power), and this is the reason why we did not show these results before. Thus, this hypothesis must be delineated in a future study.

In conclusion, either the Self-estimated number of repetitions or the Borg scale of perceived exertion, reported by volunteers during the first two repetitions from a set, are not a satisfactory tool for estimating strength TZ. Therefore, other strategies will subsequently need to be designed and tested.

REFERENCES

1. American College of Sports Medicine. (2009). American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Medicine and Science in Sports and Exercise*, *41*(3), 687–708. doi:10.1249/MSS.0b013e3181915670
2. Berchicci, M., Menotti, F., Macaluso, A., & Di Russo, F. (2013). The neurophysiology of central and peripheral fatigue during sub-maximal lower limb isometric contractions. Frontiers in Human Neuroscience, 7, 135. doi:10.3389/fnhum.2013.00135
3. Campos, G. E. R., Luecke, T. J., Wendeln, H. K., Toma, K., Hagerman, F. C., Murray, T. F., … Staron, R. S. (2002). Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones. European Journal of Applied Physiology, 88(1-2), 50–60. doi:10.1007/s00421-002-0681-6
4. Charro, M. A., Aoki, M. S., Coutts, A. J., Araújo, R. C., & Bacurau, R. F. (2010). Hormonal, metabolic and perceptual responses to different resistance training systems. The Journal of Sports Medicine and Physical Fitness, 50(2), 229–34.
5. Chen, M. J., Fan, X., & Moe, S. T. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. Journal of Sports Sciences, 20(11), 873–99. doi:10.1080/026404102320761787
6. Colado, J. C., Garcia-Masso, X., Triplett, T. N., Flandez, J., Borreani, S., & Tella, V. (2012). Concurrent validation of the OMNI-resistance exercise scale of perceived exertion with Thera-band

resistance bands. Journal of Strength and Conditioning Research, 26(11), 3018–24. doi:10.1519/JSC.0b013e318245c0c9

7. Costa, A., & Fernandes, C. (2007). Utilização da percepção subjectiva do esforço para monitorização da intensidade do treino de força em idosos. Motricidade, 3(2), 37–46.
8. Day, M. L., McGuigan, M. R., Brice, G., & Foster, C. (2004). Monitoring exercise intensity during resistance training using the session RPE scale. Journal of Strength and Conditioning Research, 18(2), 353–8. doi:10.1519/R-13113.1
9. de Morree, H. M., Klein, C., & Marcora, S. M. (2012). Perception of effort reflects central motor command during movement execution. Psychophysiology, 49(9), 1242–53. doi:10.1111/j.1469-8986.2012.01399.x
10. Duncan, M. J., Birch, S. L., & Oxford, S. W. (2014). The effect of exercise intensity on postresistance exercise hypotension in trained men. Journal of Strength and Conditioning Research, 28(6), 1706–13. doi:10.1519/JSC.0000000000000322
11. Ferreira, S., Marins, J. C. B., da Silva, L. C., Lunz, W., Pimentel, G. G. de A., & Migliorini, E. M. (2006). Determination of the profile of maximum repetitions in the leg extension exercise and straight supino with different percentages of strength. Revista Da Educação Física, 17(2), 149–159.
12. Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I.-M., … American College of Sports Medicine. (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Medicine and Science in Sports and Exercise, 43(7), 1334–59. doi:10.1249/MSS.0b013e318213fefb
13. Hampton, S., Armstrong, G., Ayyar, M. S., & Li, S. (2014). Quantification of perceived exertion during isometric force production with the Borg scale in healthy individuals and patients with chronic stroke. Topics in Stroke Rehabilitation, 21(1), 33–9. doi:10.1310/tsr2101-33
14. Hurley, B. F., Hanson, E. D., & Sheaff, A. K. (2011). Strength training as a countermeasure to aging muscle and chronic disease. Sports Medicine (Auckland, N.Z.), 41(4), 289–306. doi:10.2165/11585920-000000000-00000
15. Kravitz, L., Akalan, C., Nowicki, K., & Kinzey, S. J. (2003). Prediction of 1 repetition maximum in high-school power lifters. Journal of Strength and Conditioning Research, 17(1), 167–72.
16. Mayhew, J. L., Ball, T. E., Arnold, M. D., & Bowen, J. C. (1992). Relative muscular endurance performance as a predictor of bench press strength in college men and women. Journal of Strength and Conditioning Research, 6(4), 200–206.
17. McGuigan, M. R., & Foster, C. (2004). A new approach to monitoring resistance training. Strength and Conditioning Journal, 26(6), 42–47. doi:10.1519/00126548-200412000-00008
18. Moraes, E., Alves, H. B., Teixeira, A. L., Dias, M. R., Miranda, H., & Simão, R. (2014). Relationship between repetitions and selected percentages of one repetition maximum in trained and untrained adolescent subjects. Journal of Exercise Physiology Online, 17(2), 27–35.
19. Muyor, J. M. (2013). Exercise Intensity and Validity of the Ratings of Perceived Exertion (Borg and OMNI Scales) in an Indoor Cycling Session. Journal of Human Kinetics, 39, 93–101. doi:10.2478/hukin-2013-0072
20. Pierce, K., Rozenek, R., & Stone, M. H. (1993). Effects of high volume weight training on lactate, heart rate, and perceived exertion. Journal of Strength and Conditioning Research, 7(4), 211–215. doi:10.1519/00124278-199311000-00004
21. Pincivero, D. M., Coelho, A. J., & Campy, R. M. (2003). Perceived exertion and maximal quadriceps femoris muscle strength during dynamic knee extension exercise in young adult males and females. European Journal of Applied Physiology, 89(2), 150–6. doi:10.1007/s00421-002-0768-0

22. Pollock, M. L., Carroll, J. F., Graves, J. E., Leggett, S. H., Braith, R. W., Limacher, M., & Hagberg, J. M. (1991). Injuries and adherence to walk/jog and resistance training programs in the elderly. Medicine and Science in Sports and Exercise, 23(10), 1194–200.
23. Richens, B., & Cleather, D. J. (2014). The relationship between the number of repetitions performed at given intensities is different in endurance and strength trained athletes. Biology of Sport, 31(2), 157–61. doi:10.5604/20831862.1099047
24. Scherr, J., Wolfarth, B., Christle, J. W., Pressler, A., Wagenpfeil, S., & Halle, M. (2013). Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. European Journal of Applied Physiology, 113(1), 147–55. doi:10.1007/s00421-012-2421-x
25. Shaw, C. E., McCully, K. K., & Posner, J. D. (1995). Injuries during the one repetition maximum assessment in the elderly. Journal of Cardiopulmonary Rehabilitation, 15(4), 283–7.
26. Shimano, T., Kraemer, W. J., Spiering, B. A., Volek, J. S., Hatfield, D. L., Silvestre, R., … Häkkinen, K. (2006). Relationship between the number of repetitions and selected percentages of one repetition maximum in free weight exercises in trained and untrained men. Journal of Strength and Conditioning Research, 20(4), 819–23. doi:10.1519/R-18195.1
27. Stevens, S. S. (1957). On the psychophysical law. Psychological Review, 64(3), 153–181. doi:10.1037/h0046162
28. Suminski, R. R., Robertson, R. J., Arslanian, S., Kang, J., Utter, A. C., DaSilva, S. G., … Metz, K. F. (1997). Perception of effort during resistance exercise. Journal of Strength and Conditioning Research, 11(4), 261–265. doi:10.1519/00124278-199711000-00012
29. Testa, M., Noakes, T. D., & Desgorces, F.-D. (2012). Training state improves the relationship between rating of perceived exertion and relative exercise volume during resistance exercises. Journal of Strength and Conditioning Research, 26(11), 2990–6. doi:10.1519/JSC.0b013e31824301d1
30. Tiggemann, C. L., Korzenowski, A. L., Brentano, M. A., Tartaruga, M. P., Alberton, C. L., & Kruel, L. F. M. (2010). Perceived exertion in different strength exercise loads in sedentary, active, and trained adults. Journal of Strength and Conditioning Research, 24(8), 2032–41. doi:10.1519/JSC.0b013e3181d32e29

