Validation of the Brzycki equation for the estimation of 1-RM in the bench press

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ABSTRACT

The aim of the present study was to analyze the validation of the equation proposed by Brzycki for the prediction of a maximum repetition (1-RM) in the bench press. Fifty sedentary or moderately active male subjects (22.2 ± 3.5 years; 64.7 ± 8.6 kg), were initially submitted to six test sessions of 1-RM in the bench press, with 48 hours of interval between each session, in order to determine the maximum workload. A protocol of force resistance was then performed for the determination of 7-10-RM. The used criteria for the validation included: t-Student test for dependent samples, for comparison among the mean values obtained by the predictive equation and by the 1-RM test; Pearson correlation coefficient for analysis of the association degree among the measurements; standard error of estimate (SEE) for evaluation of the mean deviation degree of the individual data along the produced line; total error (TE) for the verification of the mean deviation of the individual values of the identity line; constant error (CE) for analysis of the difference among the mean values obtained in the 1-RM test and predicted by the proposed equation. None statistically significant difference was verified among the values produced by the 1-RM test and the Brzycki equation ($P > 0.05$). Both the SEE and the TE were relatively low (2.42 kg or 3.4% and 1.55 kg or 2.2%, respectively), as well as the CE found (0.22 kg or 0.3%). Moreover, the correlation coefficient value found was extremely high ($r = 0.99$; $P < 0.05$), thus showing a strong association between the values found by the 1-RM test and the Brzycki equation. Therefore, the equation analyzed by this study satisfied the validation criteria established by the literature. The results suggest that the Brzycki equation seems to be a fairly attractive alternative for the estimation of 1-RM values in the bench press from the performance of submaximal tests of 7-10-RM, in sedentary or moderately active male adults.

Keywords: Muscular strength. 1-RM tests. Submaximal tests. Predictive equations. Motor performance. Familiarization.

INTRODUCTION

Among the main indirect tests applied for evaluation of muscular strength are the one maximal repetition (1RM) and multiple repetitions (6-10 RM) tests. The 1-RM test despite being one of the most used and mentioned by the literature, may be influenced by countless factors, once it requires great concentration and previous knowledge of the performance technique from the evaluated subject, besides other important characteristics[1]. Moreover, the performance of exertions with maximal workloads may lead to high muscular, bone and ligament stress, triggering important metabolic alterations[2].

Conversely, multiple repetitions tests are able to be much more applicable to different populations in several situations. It is worth mentioning that the recommendation for prescription of training programs with weights published by the ACSM[3] for healthy adults emphasizes the utilization of multiple repetitions, especially for strength, strength endurance, hypertrophy and muscular power development. Thus, the use of multiple repetitions tests may relatively reproduce to the demands of the very regular training sessions, contrary to what is observed during the application of 1-RM tests.

Within this context, researchers have searched to develop and/or validate predictive equations for the estimation of the 1-RM values through submaximal tests, based on the performance of multiple repetitions[2,4-10].

Nonetheless, little has been published concerning the validation of the majority of the predictive equations proposed so far for the estimation of 1-RM, as well as concerning the possible positive impact of the application of these equations in different situations which involve muscular strength analysis. Such data may be very useful for application in different populations in several places that make space available for training with weights, such as clinics, gymnasiums, and clubs, among others.

Based on the data previously presented, the aim of this study was to analyze the validation of the Brzycki equation for the prediction of 1-RM in the supine exercise on horizontal bench (bench press), in sedentary or moderately active young adult men.

METHODOLOGY

Subjects

Ninety-nine male college students, age between 18 and 32 years, were voluntarily selected in order to participate in this study. The initial inclusion criteria were: the subjects should be sedentary or moderately active (regular physical activity < 2X per week) and should not have regularly participated of any training program with weights during the eight weeks prior to the beginning of the experiment. Only 50 subjects of the ones initially selected effectively came to all testing sessions and followed all pre-established requirements for the study, being hence, included in all analyses.

This study is part of a broader research project of longitudinal character, which has been conducted by our laboratory and has investigated the impact of training with weights over different variables. All subjects after having been clarified about the study's aim and procedures signed a free and clarified form. The study was approved by the Committee of Research Ethics of the State University of Londrina, according to the regulations of the 196/96 Resolution of the National Health Council about research involving humans.

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Methods

Maximal strength test (1-RM)

The maximal strength was determined through the 1RM test in the bench press. This exercise was chosen once it is very popular in the training with weights of individuals with different levels of training.

The beginning of the testing was preceded by a warm-up series (6 to 10 repetitions) with approximately 50% of the estimated workload for the first try in the 1RM test. After two minutes of rest, the test was initiated. The individuals were instructed to try to complete two repetitions. Would the two repetitions completed in the first try, or even if none of the series were completed, a second repetition was performed, after a three-to five minute recovery interval, with a workload higher (first possibility) or lower (second possibility) than that applied in the previous try. Such procedure was repeated again in a third and last try in case a single maximal repetition had not been determined yet. The workload registered as 1-RM was that in which each individual was able to complete a single maximal repetition[11].

A familiarization protocol was applied prior to the beginning of the study in the trial to reduce the learning effects as well as to establish the reproducibility of the tests in the exercise. All subjects were tested in a situation similar to the adopted protocol, in six distinct sessions intervaled by 48 h-periods.

It is worth mentioning that the performance means and technique of the used exercise was standardized and continuously monitored in order to try to guarantee the efficiency of the test.

Submaximal strength test

An exertion test to fatigue at 80% of 1-RM was applied approximately 48 h after the end of the last session of the six of the 1-RM tests, in the exercise previously mentioned.

A warm-up series of 6 to 10 repetitions with approximately 50% of the workload established for this test was previously performed. After two-minute rest, the test was initiated. The subjects were told to try to perform the most of repetitions until the offered resistance was impossible to be sustained. All subjects who reached between 7 and 10 RM were selected for the sample to be investigated, once this repetitions interval seems to be the best for the estimation of 1-RM values from submaximal strength tests[10].

Mathematical model

From the equations available in the literature, the mathematical model proposed by Brzycki[2] was chosen for crossed validation effect:

$$1\text{-RM} = 100 * \text{load rep} / (102.78 - 2.78 * \text{rep})$$

where:

- load rep: workload value of repetitions performance, expressed in kg;
- rep: number of repetitions performed.

Statistical treatment

The criteria adopted for the validation of the Brzycki equation for 1-RM estimation in the bench press were the following: t-Student test for independent samples for comparison between the mean values obtained by the prediction equation and by the 1RM test; Pearson correlation coefficient for analysis of the degree of association between measurements; estimation standard error (ESE) for evaluation of the degree of deviation of the individual data in the produced line; total error (TE) for evaluation of the mean error of the individual values of the identity line; constant error (CE) for analysis of the difference between the mean values obtained in the 1RM test and estimated by the proposed equation. The adopted significance level for the analyses was of $P < 0.05$.

RESULTS

The description of the general characteristics of the sample is presented in table 1. It is worth mentioning the great heterogeneity of the investigated subjects concerning weight, height and BMI.

TABLE 1
Physical characteristics of the subjects (n = 50)

Variables	Mean	SD	Minimum	Maximum
Age (years)	22.2	3.5	18.0	32.0
Weight (kg)	69.8	8.7	45.7	91.2
Height (cm)	174.7	5.9	165.0	192.0
BMI (kg/m^2)	22.8	2.4	15.8	28.3

In figure 1, the mean values (± SD) in the bench press in the six sessions of the 1RM test performed are observed. A progressive increase of the lifted workload was verified, reaching approximately 8% between the first and sixth test sessions ($P < 0.05$). However, there was stabilization in the results found from the fourth session on, that is, between tests 4 and 6 no significant differences were found ($P > 0.5$).

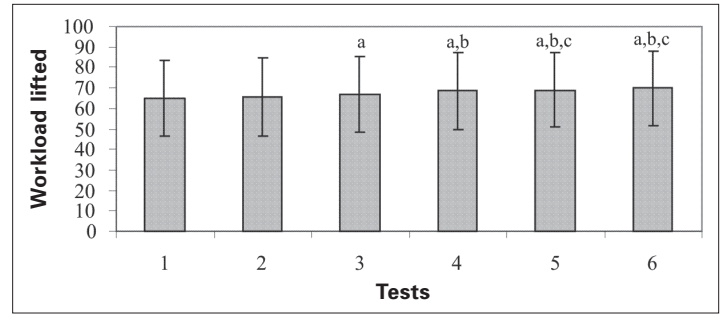

Figure 1 *– Mean values (± SD) of the workloads lifted by adult men during six 1-RM tests, performed at every 48 h, in the bench press exercise (n = 50)*

[a] $P \leq 0.05$ vs. Test 1; [b] $P < 0.05$ vs. Test 2 and; [c] $P < 0.05$ vs. Test 3.

The data necessary for the validation analysis of the Brzycki equation for the used exercise are presented in table 2. The mean values of 1-RM in the bench press exercise estimated by the Brzycki equation were similar to the ones obtained in the 1-RM test ($P > 0.05$), with ESE of 2.42%.

TABLE 2
Crossed validation of the Brzycki equation for the bench press exercise in men aged 18 to 32 years (n = 50)

Variables	Mean ± SD	t	r	ESE	TE	CE
1-RM (kg)	70.3 ± 18.5	–	–	–	–	–
Brzycki (kg)	70.6 ± 18.9	0.47	0.99*	2.42	1.55	0.22

Note: t = calculated t value; r = correlation coefficient; ESE = estimation standard error; TE = total error; CE = constant error.
* $P < 0.05$.

DISCUSSION

The validity of the estimation equations for the 1-RM values through submaximal tests, instead of the application of the 1-RM traditional test has attracted the interest of researchers who study different populations of both sexes, in diverse age groups.

Thus, the present study limited to investigate the predictive potential of the Brzycki equation for the estimation of the 1-RM values in the bench press exercise, from validation procedures recommended by the literature, in sedentary or moderately trained male young adults.

The results showed a high correlation coefficient between the means of the 1-RM test values and the ones estimated by the analyzed equation (r = 0.99; $P < 0.05$), with a relatively low estimation standard error (ESE = 2.42). Moreover, no statistically significant difference was verified in the comparison between the mean values obtained in 1-RM tests and the mean values estimated by the Brzycki equation from the application of submaximal tests of 7-10 RM (t = 0.47; $P > 0.05$). These results are very interesting, once the estimation of 1RM from these submaximal tests usually present correlation values fairly high (r > 0.90), the ESE reported in the majority of the studies has been higher or equal to 10%[12].

It is believed that the pre-set range of repetitions for inclusion of subjects in the present study may have increased the quality of information produced, once some studies have indicated that submaximal tests of up to 10-RM provide a better estimation of the 1-RM values.

Whisenant *et al.*[10] after applying the maximal strength test (1-RM) and later the 225 ponds test (steady load) in a group of 69 American football players (18 to 24 years), verified that among the several estimation equations analyzed, the Brzycki equation, for a 10-RM interval, was the one that presented the highest correlation value (r = 0.89).

Similarly, Knutzen *et al.*[13], when testing the validity of four estimation equations (Brzycki, Epely, Lander, Mayhew) in 51 older individuals, 21 men (73.1 ± 6.0 years; 76.6 ± 15.1 kg) and 31 women (69.1 ± 5.7 years; 71.9 ± 13.7 kg), with -RM and 7 to 10-RM tests, in 11 exercises (among them the leg-press, supine, triceps pulley and lateral row), verified that the Brzycki equation was the one that presented the highest correlation coefficients in seven of the 11 exercises investigated, among them the bench press (r = 0.89). Besides that, a variation in absolute values, specifically for the supine, of 0.5 to 3.0 kg, between the measured and estimated values was verified. Based on these results, the authors suggested that in submaximal tests between 7 and 10-RM the Brzycki equation seems to be the one with the highest estimation potential.

It is relevant to mention that the single analysis of the product-moment correlation coefficient isolated does not allow a definite evaluation about the estimation potential of the applied model, since this index is not sufficiently sensitive for the analysis of individual behavior, through the values measured and estimated.

Another important factor for the analysis of the data obtained by the present study was the use of familiarization sessions in the 1-RM test in the investigated exercise, once none of the studies previously mentioned reported the use of familiarization procedures. Thus, in two reviews recently published by our group, we could verify the need for the use of this kind of procedure in 1-RM tests, especially in follow-up, in order to minimize the possible misunderstanding associated with underestimated initial values[14-15].

In a study by Ware *et al.*[1], 45 American football athletes were submitted to a 1-RM test, as well as to a strength resistance tests protocol with a workload equivalent to approximately 70% of 1-RM, in the supine exercise. Although the correlation coefficient found for the Brzycki equation was high (r = 0.92, $P < 0.05$), the authors reported that this equation did not present acceptable values for the evaluation of muscular strength in athletes. Probably these results have been compromised by the lack of previous familiarization of the subjects with the 1-RM test. Hence, the workloads concerning 1-RM may have been underestimated, as well as the used submaximal workloads. Moreover, the applied load percentage (70% of 1-RM) may not have generated the necessary stimulus, allowing the subjects to perform a number of repetitions higher than 10, which theoretically weakens the application of the model proposed by Brzycki.

Based on the results reached by the subjects investigated in this study, in the six 1-RM tests performed, it was really verified that the absence of familiarization sessions would have caused underestimation of the 1-RM values. Thus, the values to be obtained later in the 7-10 RM test could generate estimation very different from the measured values. Therefore, the adoption of this procedure seems to reinforce the quality of the data produced. It is worth mentioning that the results obtained in the present investigation showed the need of at least four familiarization sessions for the maximal load (1-RM).

CONCLUSION

The findings of the present study indicated that the Brzycki equation satisfactorily fulfilled the used validation criteria, once no statistically significant difference was verified between the values produced by the 1-RM test and the Brzycki equation ($P > 0.05$). Additionally, the ESSE, the TE and the CE were relatively low (3.4%; 2.2% and 0.3%; respectively), while the correlation coefficient found was extremely high (r = 0.99; $P < 0.05$), demonstrating thus, a strong association between the measured and estimated data.

The results suggest that the Brzycki equation may be considered an alternative fairly attractive for the estimation of the values of maximal load (1-RM) for the bench press, from the performance of submaximal tests of 7-10 RM, at least in sedentary or moderately active male adults.

All the authors declared there is not any potential conflict of interests regarding this article.

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