Medicina Sportiva
Med Sport 16 (3): 111-117, 2012
DOI: 10.5604/17342260.1011391
ICID: 1011391

PREDICTION OF ONE REPETITION MAXIMUM LOAD BY TOTAL AND LEAN BODY MASS IN TRAINED AND UNTRAINED MEN

Eduardo Lusa Cadore(A,B,C,D,E,F), Ronei Silveira Pinto(C,D,E,F), Michel Arias Brentano(A,B,C,D,E,F), Rodrigo Ferrari Silva(A,B,C,F), Eduardo Marczwski da Silva(A,B,C,F), Rafael Spinelli(A,B,C,F), Cleiton Silva Correa(C,D,E,F), Luiz Fernando Martins Kruel(A,B,C,D,E,F)

Exercise Research Laboratory, Physical Education School, Federal University of Rio Grande do Sul, Porto Alegre, Brazil

Abstract

Introduction: One repetition maximum test (1RM) is often used to evaluate muscle strength and to prescribe the intensity of strength training. However, the determination of the initial test load, and duration of the test make difficult to use the same in non-individualised environments.

Objective: To determine coefficients to estimate the maximum strength (1RM), based on the relationship between muscular strength, lean body mass and total body mass.

Methods: Twenty-eight strength-trained and non-strength-trained men participated in this study. Muscle strength was determined using the 1 RM test in the bench press, supported barbell row, 45° leg press and squat exercise, while body composition was measured using the skinfolds method. After verifying the correlations between muscular strength and body mass and composition, the coefficients to predict the maximal strength were calculated by dividing the value of the 1 RM by the total body mass and lean body mass (kg) and by linear regression equation based in these parameters.

Results: Significant correlations were found between body mass and lean body mass with muscular strength in all the exercises (r = 0.47 - 0.76, P < 0.05). The greatest correlations were observed between the muscular strength values and lean body mass. There was a significant difference between the coefficients obtained from trained and non-trained subjects in all the tested exercises (P < 0.05).

Conclusions: The results suggest that the coefficients of prediction of the 1RM should take into account the body composition and the training status of the individuals.

Key words: *strength training, fat-free mass, force development, body composition*

Introduction

Strength training promotes neuromuscular adaptations which are dependent of the intensity relative to maximum load (% of 1-RM) at which the training is performed. Low to moderate intensity of training (40-60% of 1-RM) result in an increase in the local muscular endurance, while moderate to high intensity training (65 to 90% of 1-RM) result in greater increases in the maximum strength and of the cross-sectional area – CSA [1]. The prescription of the overload in each exercise in the training routine can be determined using a percentage relative to the 1-RM (i.e. 50, 70, 80%) [2], using a range of maximum repetitions – RMs (i.e. 8-10 RMs, 12-15 RMs) [3], or using scales of perceived exertion (i.e. Borg, OMNI) [4]. Different overloads result in distinct physiological responses, and it may be modulated accordingly with the aims of the training program [5,6].

The 1-RM test is a method widely used for the determination of the intensity of strength training. Nevertheless, the 1-RM test is difficult to apply in health gyms, physical training centres and rehabilitation clinics. Among the factors that limit its utilisation in these environments are the lack of valid criteria for establishing the initial overload (i.e., first trial), and the total time spent in its performance [7]. Given this situation, some investigators have proposed the prediction of the 1-RM values in strength exercises using linear regression equations, based on the inverse relationship observed between the overload lifted with the number of maximum repetitions performed with this overload (RMs) [8-16]. With the same purpose, some investigators have proposed the use of coefficients to predict the maximum strength, calculated using the total body mass (TBM) values [17-18]. In study of Baechle and Groves [18], specific coefficients calculated from the quotient between 1RM and the TBM values were proposed for each exercise, based on the relationship between TBM and the strength development. Hence, these authors suggested that each exercise presents a specific coefficient, and the 1RM value in each exercise may be obtained by the product between these generic coefficient calculated and the TBM. However, in this purpose, the investigators did not take into consideration the subjects' body composition, particularly the lean body mass (LBM), which is a determinant variable in the force production. Another unconsidered factor in this method was the physical fitness status of the subjects (i.e. trained, untrained), which could change the relationship between TBM and LBM with maximum strength, due to the possible neural adaptations resulting from strength training in trained individuals [19]. Therefore, this methodological approach may have conditioned the results, since the strength development appears to be greatly affected by the body composition or the quality of the neuromuscular function of the subjects.

Due to the greater relationship between the LBM, even assessed using indirect methods, with the muscle strength, when compared with the relationship between TBM with muscular strength [8,20-22], the determination of specific coefficients for each exercise, based on the LBM, may improve the 1RM prediction. Furthermore, to take into consideration the subjects' training status (i.e. strength-trained and untrained) could better explain the relationship between maximum strength with the LBM, and consequently provide more accurate coefficients of strength prediction.

Therefore, the aim of this study was to calculate coefficients to predict the maximum strength (1RM) of strength-trained and untrained men, based on the relationships between the muscle strength with the LBM, as well as the relationship between the muscle strength with the TBM. Our hypothesis is that the LBM, even when measured indirectly, will have a greater correlation with the maximal strength than the TBM. In addition, our second hypothesis is that the coefficients of 1RM prediction will be different between strength-trained and untrained subjects.

Methods

Experimental Design

The subjects attended the laboratory on two different days. Firstly, their anthropometric characteristics were measured. On a second test day, the subjects performed the maximum dynamic strength tests (1RM) in four free-weight exercises. After that, the relationship between maximum strength (1RM values) with total body mass and lean body mass were evaluated in both groups (i.e. trained and untrained). Based on these relationships, the coefficients were calculated using the quotient between the individual maximal strength values and the corresponding total body mass and lean body mass. After that, the coefficients obtained from the different groups were compared.

Participants

Twenty-eight healthy (40 ± 4 years) strength-trained and untrained men volunteered for this study after completing an ethical consent form. Subjects were carefully informed about the design of the study with special information given regarding the possible risks and discomfort related to the procedures. The study was conducted according to Declaration of Helsinki and was approved by Ethics Committee of Federal University of Rio Grande do Sul, Brazil. According with their characteristics, subjects were divided into two groups: the strength-trained group (TG, n = 13) and the untrained group (UG n = 15). Those subjects that were able to perform a squat exercise with 130% of their body weight and the bench press with 100% of their body weight were considered trained. The subjects of TG used to practiced non-competitive strength training composed by multiple sets of 6-12 maximum repetitions (RM), 4 to 6 weekly training sessions with the aim of hypertrophy for at least three years. The UG included sedentary individuals who had not engaged in any regular or systematic training program during the year prior to the study. None of the subjects were using anabolic steroids or any medication that might have influenced the muscle-skeletal metabolism. Moreover, none of the subjects were on a controlled diet or any other kind of dietary restriction. The anthropometric characteristics and the strength values (1 RM) of both groups are shown in table 1. There were no significant differences between the groups

Table 1. *Physical characteristics and muscular strength*

	Trained	Untrained
Age (years)	40.3 ± 4.7	39.9 ± 3.7
Height (cm)	173.2 ± 5.3	173.7 ± 7.3
Body mass (kg)	79.3 ± 9.7	79.7 ± 10.9
% Fat mass	19.4 ± 5.6	25 ± 4.8†
% Lean mass	80.6 ± 5.6	74.9 ± 4.8†
Bench Press (kg)	87.2 ± 19.2	56.6 ± 11.9†
Supported Row (kg)	84.7 ± 18.4	61.5 ± 9.7†
Squat (kg)	139 ± 50.2	90.3 ± 15.4†
Leg Press (kg)	385.8 ± 84.8	231.2 ± 37.3†

Values are mean ± SD; Strength-trained group (n = 13); and untrained group (n = 15), respectively. Significant difference between groups: †P < 0.01

in relation to age, total body mass and height. The subjects in the TG had significantly greater 1RM values (P<0.001) in all the assessed exercises, as well as greater lean body mass (P<0.001).

Anthropometric measurements

Body mass and height were measured using an Asimed analog scale (resolution of 0.1 kg) and an Asimed stadiometer (resolution of 1 mm), respectively.. Body density was estimated using the skinfold protocols proposed by Jackson and Pollock [23]. In order to measure the skinfolds, a plicometer (CESCORF) with a resolution of 0.1 mm was used. Body composition was assessed using the skinfold technique. A seven-site skinfold equation was used to estimate body density [23] and body fat was subsequently calculated using the Siri equation [24].

Dynamic muscular strength

The 1RM test was performed in the bench press, supported barbel row, 45° leg press and squat exercises, using free weights with 0.5 kg of resolution. One week prior to the test day, subjects were familiarized with all procedures in two sessions. On the test day, the subjects warmed up for five minutes on a cycle ergometer, stretched all major muscle groups, and performed specific movements for the exercise test. To avoid the influence of fatigue in the 1RM values, each subject's maximal load was determined with no more than five attempts with a four-minute recovery between attempts and 5 minutes between exercises. Performance time for each contraction (concentric and eccentric) was two seconds, controlled by an electronic metronome (Quartz, CA, USA). The test-retest reliability coefficients (ICC) were over 0.95 in all strength tests.

Calculation of the coefficients

In order to calculate the coefficients, the data from the 1 RM in each exercise were normalized by the body mass (formula 1) and by the lean body mass (formula 2), individually for each exercise, and then the mean for each group was calculated. Basically, the formulas used were:

$$\text{Coefficient}_{\text{body mass}} = 1\ \text{RM/TBM}$$
$$\text{Coefficient}_{\text{lean body mass}} = 1\ \text{RM/LBM}$$

Which 1 RM is the dynamic maximum strength (kg), TBM is the body mass (kg) and LBM is the lean body mass (kg).

Statistical analysis

The data are expressed as means ± standard deviation. After determining normality and homogeneity, by means of the Shapiro-Wilk and Levene tests respectively, the differences in the muscle strength between groups was tested using independent t tests. Pearson's product-moment correlation tests were employed to investigate the possible correlations between the muscle strength in the different exercises with the lean body mass and the body mass values in the different groups. To establish equations to estimate maximal strength based on total and lean body mass, linear regression equation was employed. Because of the differences between the muscle strength values between groups, different coefficients to estimate maximal strength were determined in each group. Differences between coefficients obtained in each groups were tested using independent t tests. Furthermore, ANOVA one-way was used to compare the muscle strength tested and those predicted by the coefficients and linear regression equations. The level of significance adopted was $P < 0.05$, the statistical power was over 0.90 and all the tests were done in SPSS 15.0 software.

Results

The correlations between individual values of 1RM in the different exercises with the corresponding values of TBM and LBM are shown in the figures 1 to 8. There were significant correlations between the individual 1RM values and the corresponding values of TBM and LBM in the bench press and r = 0.78; P = 0.0001, respectively); squat (r = 0.4; P = 0.035 and r = 0.65; P = 0.0001, respectively), and only between the between the 1 RM values and the LBM in the supported barbel row (r = 0.64, P = 0.001) and

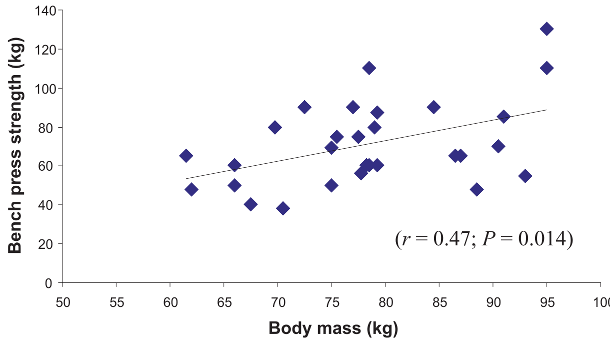

Fig. 1. *Relationship between bench press 1 RM values (kg) and total body mass (kg)*

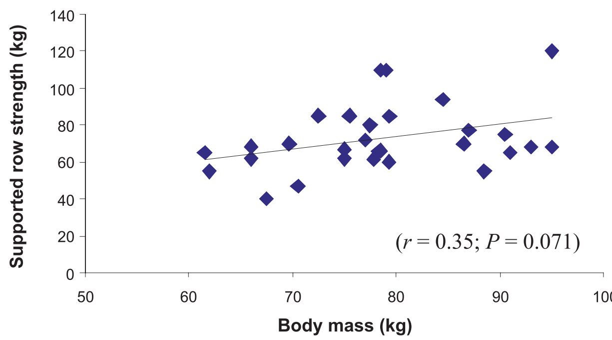

Fig. 2. *Relationship between supported barbell row 1 RM values (kg) and total body mass (kg)*

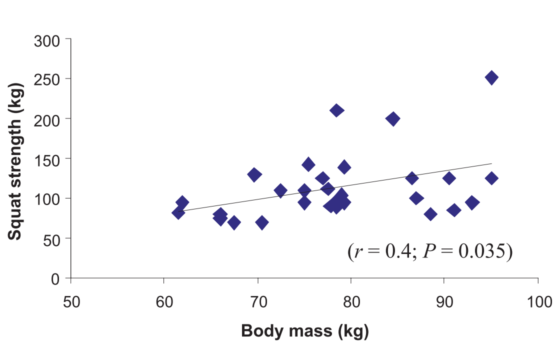

Fig. 3. *Relationship between squat 1 RM values (kg) and total body mass (kg)*

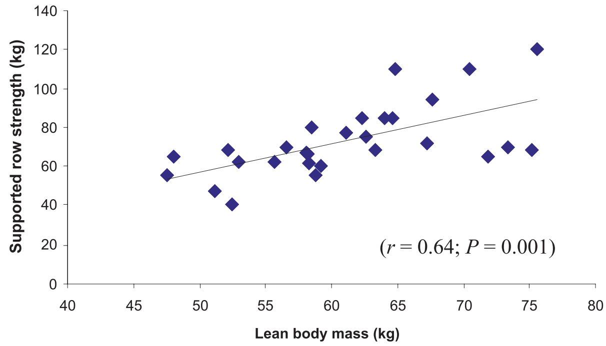

Fig. 6. *Relationship between supported row 1 RM values (kg) and lean body mass (kg)*

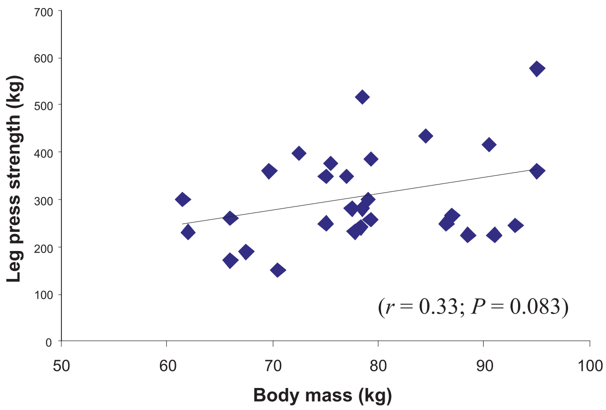

Fig. 4. *Relationship between leg press 1 RM values (kg) and total body mass (kg)*

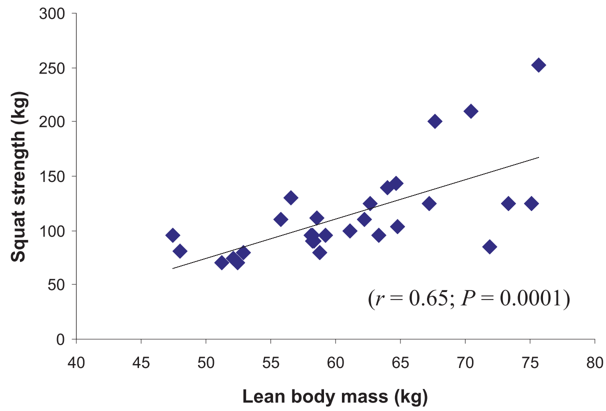

Fig. 7. *Relationship between squat 1 RM values (kg) and lean body mass (kg)*

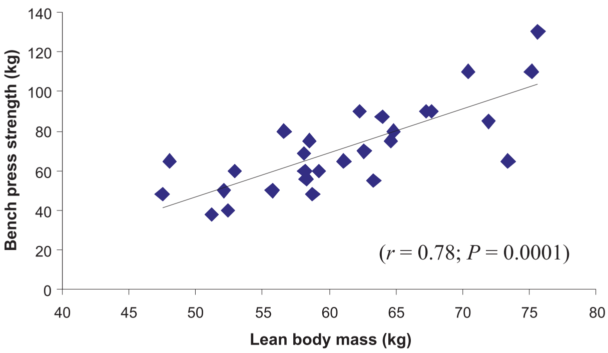

Fig. 5. *Relationship between bench press (kg) 1 RM values and lean body mass (kg)*

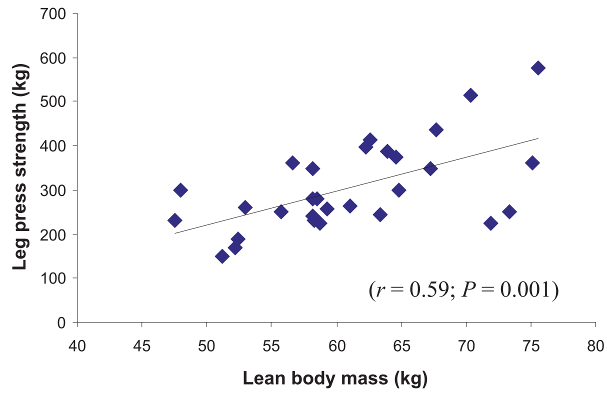

Fig. 8. *Relationship between leg press 1 RM values (kg) and lean body mass (kg)*

Table 2. *Coefficients to prediction 1 repetition maximum (1 RM) values by total body mass and lean body mass*

	Trained subjects TBM	Untrained subjects TBM	Trained subjects LBM	Untrained subjects LBM
Bench press	1.1 ± 0.7*	0.7 ± 0.12	1.4 ± 0.17*	1.0 ± 0.13
Squat	1.7 ± 0.5*	1.2 ± 0.2	1.3 ± 0.6*	1.1 ± 0.2
Supported row	1.1 ± 0.2*	0.8 ± 0.12	2.1 ± 0.2*	1.6 ± 0.13
Leg press	4.9 ± 0.8*	3.0 ± 0.5	6.0 ± 0.9*	4.0 ± 0.7

TBM, total body mass; LBM, lean body mass. *$P < 0.0001$, significant differences between groups. Strength-trained subjects (n=13) and untrained subjects (n=15).

leg press exercises (r = 0.59; P = 0.001). There were no significant correlations between the 1 RM and the TBM in the 1RM values of supported barbel row (r = 0.35; P = 0.071) and *45° leg press* exercises (r = 0.33; P = 0.083).

The coefficients determined by the relationship between 1 RM and TBM and 1 RM and LBM in the different exercises are shown in table 2; and, those predicted by linear regression equations are shown in table 3. There were significant differences between trained and untrained subjects in all coefficients calculated (P < 0.01). There were no significant differences between the assessed strength values and the strength values predicted by the total and lean body mass (Table 4).

Discussion

The primary findings of the present study were the greater correlation values found between 1RM values with LBM, even when determined indirectly (skinfolds measures), when compared with the correlations between 1RM values with TBM in the different strength exercises tested. Moreover, the present study has shown that the coefficients to estimate the 1 RM, based in the TBM and LBM were different between groups with different training status (i.e. strength trained, untrained). Thus, our results suggest that the quality of the neuromuscular function interferes in the estimation of the maximum strength by these coefficients. Our results confirm our hypotheses that LBM would obtain greater correlation values with muscle strength than TBM, and the coefficients would be different between strength-trained and untrained subjects.

Regarding the correlations between the 1 RM values with the anthropometric variables, the greater r values obtained between the 1 RM and the LBM are in accordance with observations reported in previous studies [8,15,27-29], in which higher correlation indices were noted between the 1 RM and the LBM (predicted by the skinfolds method), than between the 1 RM and the TBM. In study assessing the bench press exercise in a group of male strength-trained students, Mayhew et al. [28], found a significant correlation between the 1 RM and the TBM (r = 0.68, P < 0.01), and a greater correlation between the 1 RM and the LBM (r = 0.73, P < 0.01). Similarly, in another investigation by Mayhew et al. [15], in which school-aged strength-trained soccer players were evaluated, greater correlations were reported between the 1 RM with the LBM, when compared with those observed between the 1 RM with the TBM in several strength exercises: bench press (r = 0.68 *vs.* r = 0.53; both P < 0.05), squat (r = 0.60 *vs.* r = 0.50; both P < 0.05) and dead lift (r = 0.64 *vs.* r = 0.50; both P < 0.05). Similar results were found in a study by Bale *et al.* [9] in which correlations were found

Table 3. *Linear regression equations based on total and lean body mass in trained and untrained subjects*

	Trained subjects by body mass	Untrained subjects by body mass	Trained subjects by Lean body mass	Untrained subjects by lean body mass
Bench press	y=1,243x – 11,4	y=0,628x – 6,49	y=2,22x – 54,3	y=1,152x – 12,05
Squat	y=2,825x – 84,6	y=1,6938x – 37,6	y=5,036x – 181,6	y=2,3953x – 45,2
Supported row	y=0,705x – 28,7	y=0,6923x – 7,9	y=1,563x – 14,93	y=0,9874x – 4,3
Leg press	y=4,586x – 22,1	y=3,2224x – 12,7	y=7,878x – 116,4	y=3,9978x – 6,12

Table 4. *Dynamic strength values (1 RM) based on test, calculated TBM and LBM coefficients, and calculated by linear regression equation based on TBM and LBM in strength-trained and untrained subjects*

	1 RM (kg)	1 RMTBM (kg)	1 RMLBM (kg)	1 RMTBMEQ (kg)	1RMLBMEQ (kg)
Bench press$_{TG}$	87 ± 19†	87 ± 10†	86 ± 10†	87 ± 12†	87 ± 16†
Squat$_{TG}$	139 ± 50†	138 ± 17†	137 ± 15†	139 ± 27†	139 ± 37†
Supported row$_{TG}$	84 ± 18†	84 ± 10†	84 ± 9†	84 ± 6†	84 ± 11†
Leg press$_{TG}$	385 ± 84†	386 ± 47†	384 ± 44†	385 ± 44†	385 ± 57†
Bench press$_{UG}$	56 ± 11	56 ± 7	56 ± 7	56 ± 6	56 ± 8
Squat$_{UG}$	97 ± 31	97 ± 13	97 ± 12	97 ± 18	97 ± 18
Supported row$_{UG}$	63 ± 11	63 ± 8	63 ± 8	63 ± 7	63 ± 7
Leg press$_{UG}$	244 ± 62	244 ± 33	244 ± 31	244 ± 35	244 ± 30

TG, Strength-trained subjects (n = 13); UG, untrained subjects (n = 15); TBM, total body mass; LBM, lean body mass; TBMEQ, linear regression equation based on TBM; LBMEQ, linear regression equation based on LBM. †Significant differences between groups: P<0.001

between the 1 RM value in the bench press with the TBM ($r = 0.54$; $P < 0.05$), and with the LBM ($r = 0.68$; $P < 0.05$), as well as between 1 RM in the dead lift with the TBM (r = 0.50) and with LBM ($r = 0.54$) in college-aged players. The greater correlation values between 1 RM with the LBM, though predicted by indirect methods (i.e. skinfolds measurements), such as in the abovementioned studies, as well as in the present investigation, could be explained by the fact that LBM is a more representative value of the muscle mass, and consequently, of the tissue responsible to the strength development. Indeed, it has been shown that the fat mass was related with lower strength performance in the bench press [15,28] and dead lift exercises [15], as well as in the isometric strength of the knee extensors muscles [27]. Moreover, athletes with a low percentage of fat mass used to have greater strength values [30].

In the present study, free weight exercises were used to calculate the prediction coefficients of the maximum strength (1 RM), based on anthropometric variables (TBM and LBM). The utilisation of free-weight exercises have an important practical application since these coefficients may have great reproducibility in any other location when the same free-weight exercises are employed. The 1 RM values may be greatly affected by the mechanical characteristics of the external load of the apparatus used in strength training (i.e. variable-radius pulleys – CAMS and invariables, position of the pulleys, different external moment).

The results of the present study demonstrated that the LBM, calculated indirectly using a 2-component model, presented greater correlation coefficients than those obtained between muscle strength and TBM. Therefore, the LBM should be considered when elaborating maximum strength prediction coefficients. Nevertheless, the 1 RM values predicted by coefficients based on TBM, as well as by linear equation regression calculated by the TBM were not different from the real 1RM values. Thus, given the impossibility of measuring the lean body mass, the use of coefficients derived from the TBM may represent a practical and easy way to estimate the 1 RM, or at least the first test load during the 1RM test. Likewise, differences were observed in the coefficients between strength-trained and untrained subjects, with the strength-trained participants having greater strength values in all exercises. These differences appear to be associated with the neural adaptations resulting from strength training [2,19], such as the greater number of motor units recruited and the greater firing rate in this recruitment [2,19].

Based on the results reported here, it can be inferred that strength-trained would present greater coefficients of strength prediction. In the present investigation, the 1 RM prediction coefficients elaborated from the LBM, together with the consideration of the subjects' physical fitness levels, made possible to define the predicted 1 RM values, which did not differ significantly from the evaluated 1 RM values (Table 4). This methodological strategy for predicting the 1 RM based on specific coefficients in strength exercises appears to be both efficient and appropriate and its use reduces the time spent in maximum strength evaluation tests (1 RM). The coefficients calculated in the present study can be applied in any place, since the exercises used were performed with free weights.

In summary, the present study showed greater correlation values between maximum muscle strength (1 RM) with LBM, when compared with TBM. Furthermore, the coefficients to predict 1RM values were different between strength-trained and untrained subjects. The present results have a important practical application, since the 1RM test is widely used to investigate the neuromuscular adaptations to strength training, as well as to prescribe this type of physical training. Thus the coefficients calculated in the present study may be an useful method to reduce the time spent during this test, as well as to facilitate the same by providing the initial test overload, which can be very much closer of the real strength value. Further studies are required in order to establish coefficients of strength prediction in others populations, such as children and the elderly.

Acknowledgements

This study was partially supported by the National Council of Technological and Scientific Development (CNPq), Coordination of Improvement of Higher Education Personnel (CAPES).

Declaration of interest

The authors report no conflicts of interest.

References

1. Campos GER, Luecke TJ, Wendeln HK, et al. Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones. *Eur J Appl Physiol* 2002; 88: 50–60.
2. Häkkinen K, Pakarinen A, Kraemer WJ, et al. Selective muscle hypertrophy, changes in EMG and force, and serum hormones during strength training in older women. *J Appl Physiol* 2001; 91: 569-80.
3. Marx JO, Ratamess NA, Nindl BC, et al. Low-volume circuit versus high-volume periodized resistance training in women. *Med Sci Sports Exerc* 2001; 33(4): 635–43.
4. Gearhart RF, Goss FL, Lagally KM, et al. Ratings of perceive exertion in active muscle during high-intensity and low-intensity resistance exercise. *J Strength Cond Res* 2002; 16(1): 87-91.
5. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sports Exerc* 2004; 36(4): 674-88.
6. Knutgen HG, Kraemer WJ. Terminology and measurement in exercise performance. *J Appl Sport Sci Res* 1987; 1(1): 1-10.
7. Brown LE, Weir JP. ASEP procedures recommendation I: accurate assessment of muscular strength and power. *J Exerc Physiol* 2001; 4(3): 1-21.

8. Baker D, Wilson Carlyon R. Periodization: The effect on strength of manipuling volume and intensity. *J Strength Cond Res* 1994; 8: 235-42.
9. Bale P, Colley E, Mayhew JL, et al. Anthropometric and somatotype variables related to strength in American football player. *J Sports Med Phys Fit* 1994; 34: 383-9.
10. Braith RW, Graves JE, Legget SH, et al. Effect of training on the relationship between maximal and submaximal strength. *Med Sci Sports Exerc* 1993; 25(1): 132-8.
11. Cummings B, Finn KJ. Estimation of a one repetition maximum bench press for untrained women. *J Strength Cond Res* 1998; 12(4): 262-5.
12. Jaric, S. Muscle Strength Testing: Use of Normalisation for Body Size. *Sports Med* 2002; 32: 615-31.
13. Lesuer DA, Mccormick JH, Mayhew JL, et al. The accuracy of prediction equations for estimating 1-RM performance in the bench press, squat and deadlift. *J Strength Cond Res* 1997; 11(4): 211-3.
14. Mannion AF, Adams MA, Cooper RG, et al. Prediction of maximal back muscle strength from indices of body mass and fat-free body mass. *Rheumatology (Oxford)* 1999; 38(7): 652-5.
15. Mayhew JL, Ware JS, Bemben MG, et al. The NFL-225 test as a measure of bench press strength in college footballplayers. *J Strength Cond Res* 1999; 13: 130-4.
16. Simpson SR, Rozenek R, Garhammer J, et al. Comparison of one repetition maximums between free weight and universal machine exercises. *J Strength Cond Res* 1997; 11(2): 103-6.
17. Ballman KL, Scanlan JM, Mayhew JL, et al. Prediction of bench press strength in untrained females from anthropometric dimensions and psychological indicators of activity involvement. *J Human Mov Studies* 1999; 37: 217-33.
18. Baechle TR, Groves BR. *Weight training: steps to success.* Champaign, IL: Human Kinetics, 1998.
19. Häkkinen K, Alen M, Kraemer WJ, et al. Neuromuscular adaptations during concurrent strength and endurance training versus strength training. *J Appl Physiol* 2003; 89: 42-52.
20. Hickner RC, Mehta PM, Dyck DP, et al. Relationship between fat-to-fat-free mass ratio and decrements in leg strength after downhill running**.** *J Appl Physiol 2001*; 90: 1334-41.
21. Pereira MIR, Gomes PSC. Testes de força e resistência muscular: confiabilidade e predição de uma repetição máxima – Revisão e novas evidências. *Rev Bras Med Esp* 2003; 9: 325-35.
22. Scanlan JM, Ballman KL, Mayhew JL, et al. Anthropometrics dimensions to predict 1-RM bench press in untrained females *J Sports Med Phys Fit* 1999; 39: 54-60.
23. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. *Brit J Nutr* 1978; 40: 497-504.
24. Heyward VH. *Advanced fitness assessment & exercise prescription.* Champaign, IL: Human Kinetics, 1997; 3th ed: 121-141.
25. Ploutz-Snyder L, Giamis EL. Orientation and familiarization to 1 RM strength testing in old and young women. *J Strength Cond Res* 2001; 15: 519-23.
26. Lombardi VP. *Beginning weight training: the safe and effective way.* Dubuque: Brown & Benchmark, 1989.
27. Mayhew JL, Ball, TE, Ward TE, et al. Relationships of structural dimensions to bench press strength in college males. *J Sports Med Phys Fit* 1991; 31(2): 135-41.
28. Mayhew JL, Piper FC, Ware JS. Anthropometrics correlates with strength performance among resistance trained athletes. *J Sports Med Phys Fit* 1993; 33: 159-65.
29. Mayhew JL, Ware JS, Cannon K, et al. Validation of NFL-225 test for predicting 1 RM bench press performance in college football players. *J Sports Med Phys Fit* 2004; 42: 304-8.
30. Roemmich JN, Sinning WE. Weight loss and wrestling training: effects on nutrition, growth, maturation, body composition, and strength. *J Appl Physiol* 1998; 85: 1349-56.

Accepted: September 15, 2012
Published: September 25., 2012

Address for correspondence:
Eduardo Lusa Cadore
LAPEX, Escola de Educação Física, UFRGS
Felizardo St, 750
Jardim Botânico
CEP: 90690-200
Porto Alegre/ RS,
Brazil
Phone: +5551 3308-5820
Fax: +5551 3308-5842
Email:edcadore@yahoo.com.br

Ronei Silveira Pinto: ronei.pinto@ufrgs.br
Rodrigo Ferrari Silva: rod.ferrari@terra.com.br
Cleiton Silva Correa: cleitonesef@yahoo.com.br
Michel Arias Brentano: michel.brentano@bol.com.br
Eduardo Marczwski da Silva: eduardomarczwski@yahoo.com.br
Rafael Spinell: larrys@terra.com.br
Luiz Fernando Martins Kruel: kruel@esef.ufrgs.br