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PREDICTION MODEL OF ONE REPETITION MAXIMUM (1RM) BASED ON ANTHROPOMETRICAL CHARACTERISTICS ON MALE AND FEMALE

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ABSTRACT
MATERKO, W.; SANTOS, E. L. Prediction model of one repetition maximum (1RM) based on anthropometrical characteristics on male and female. Brazilian Journal of Biomotricity. v. 7, n. 1, p. 43-52, 2013. The goal of the present study was to determine a model for predicting one maximum repetition (1RM) based on anthropometrical characteristics for exercises leg abduction (LA) and leg curl (LC) on males and females. Forty-eight volunteers trained in strength training were submitted to an anthropometric evaluation, followed by a 1RM test for exercises LA and LC. After resting for at least 48h, they randomly underwent either a new 1RM. The model's for predicting 1RM strength were obtained by multiple linear regression for LA and LC exercises assuming as independent variables: fat-free mass and gender. The best model's explained 66% and 78% of the known variance and have a standard error of estimate of 15.5% and 15.4% of the measured 1RM for LA and LC, respectively. The measured 1RM were 54.4 ± 14.3 Kg and 54.0 ± 17.4 Kg and predicted 1RM were 54.4 ± 11.8 Kg and 54.0 ± 15.4 Kg, with the difference between achieved and predicted 1RM in mean 0.0 ± 8.3 Kg and 0.0 ± 8.1 Kg for LA and LC, respectively ($P < 0.01$). The obtained model's showed an acceptable validity, and further can be currently used as a tool for predicting the 1RM workload.
Key-words: strength training. anthropometric evaluation. free fat mass. anthropometry. resistance training

INTRODUCTION

Resistance training has been assumed as the most effective method for developing musculoskeletal strength (MATERKO et al., 2008) and has been currently prescribed either for health, athletic performance or prevention and rehabilitation of orthopedic injuries (ACSM, 2009). This kind of training, particularly when incorporated into a comprehensive fitness program, can reduce the risk factors associated to coronary arterial disease (CASSILAS et al., 2007), obesity (WILLIAMS and HAYES, 2010), non-insulin-dependent diabetes and metabolic syndrome (SUZUKI et al., 2011).

The best method for assessing muscular strength resides in determining a lifter's one repetition maximum (1RM) lifting ability. Nevertheless, this assessment may be contraindicated for untrained subjects (BRAITH et al., 1993), because lifting a maximal weight may cause either test-induced muscle soreness or muscular injury (KURAMOTO and PAYNE, 1995). A simple, safe, and accurate procedure for estimating the 1RM would be a benefit to strength and conditioning specialists, sports medicine physicians, athletic trainers, and weight trainers.

Accordingly, several studies focused on the prediction of 1RM strength, investigating aspects such as: the predictive accuracy of prediction equations (WOOD et al., 2002; ABADIE et al., 1999), the differences among various groups of male subjects (SOUZA et al., 2011; BRECHUE and MAYHEW, 2009; MATERKO and SANTOS, 2009; MAYHEW et al., 2007), the difference in athletic populations (DESGORCES et al., 2010; CARUSO et al., 2009) or even the differences between males and females performance (MATERKO et al., 2007). Thus, the purpose of the present study was to determine and validate a model for predicting 1RM based on anthropometrical characteristics for the exercises leg abduction and leg curl on males and females subjects.

METHODS

Subjects

This study was designed as a cross-sectional, community-based survey, in which participants were randomly drawn from gym academies in Rio de Janeiro City, Brazil. Forty-eight volunteers (24 male and 24 female) ranging from 18 to 29 years, all trained in strength training program for more than one year were selected for the present work. All volunteers were free of physical limitations that would prohibit them from lifting maximal weight and were instructed to avoid strenuous activity in the 24 hours prior to each testing session and to avoid alcohol, caffeine, smoking as well as the consumption of large meals for, at least, three hours prior testing. The Ethics Committee of the Federal University of Rio de Janeiro approved the study protocol, and an informed written consent was obtained from all participants. The study was conducted according to the instructions of the Helsinki Declaration of 2008.

Procedures

Anthropometric Measurements

During an orientation session, testing procedures and time commitment required for participation in this study were verbally explained to potential participants. They were assessed for height, body mass, age, circumferences of thigh, hip and leg, lower limbs length and skinfold measurement. The height was measured in centimeters while the body mass was measured to the nearest 0.1 kg with mechanics scale (Filizola, Brazil). A skinfold caliper (Cescorf, Brazil) was used to take skinfolds measurements. Body density (JACKSON et al., 1980; JACKSON and POLLOCK, 1978) was estimated based on skinfolds and the percent body fat, free fat mass (FFM) and fat mass (FM) were determined based on body density using the Siri (1961) equation. Thigh circumference was taken around with thigh muscle of the side right extended distant of body, in the greatest circumference of the segment, hip circumference was taken at the point of the maximum protuberance of the buttocks and leg circunference was taken around of the triceps surae muscle, in the maximum circumference between the knee and ankle (LOHMAN, 1992) were used tape measure (Sanny, Brazil).

Protocol Tests

During the second testing session, subjects were assessed for 1RM in the exercises leg abduction and leg curl and were instructed about the proper lifting technique for accomplishing both the leg abduction and leg curl along the familiarization test (PLOUTZ-SNYDER and GIAMIS, 2001). The repeatability of 1RM strength test was assured by performing each test twice (familiarization test and second test). All of the strength assessments were conducted on leg abduction and leg curl weight lifting machine (Buick Industries, Brazil) according the following protocol (BROWN and WEIR, 2001). All attempts were done at a moderate contraction velocity (1-2s concentric and 1-2s eccentric), maintaining a resting period of 3-5 minutes. For the 1-RM test subjects initially lifted weights around 50% of estimated 1-RM. Weight increments were dependent upon the effort required for the lift. The weight added became smaller as the effort to lift the weight increased. When the subject could only lift the weight once, the last weight successfully lifted was considered the subject's 1RM strength.

For leg abduction technique, subjects were instructed to sit on the machine and the leg pad was adjusted for touching the outer side of knees. Then, the movement away from the middle of the body by abduction hips. For leg curl technique, subjects were instructed to lay prone on the machine, stand between bench and lever pads, maintaining the knees just beyond edge of bench and lower legs under lever pads. Then, they moved the legs toward to back of thighs by flexing knees.

Data processing

Data was processed using Matlab v6.2 (Mathworks, EUA). The Kolmogorov-Smirnov test confirmed the normality of distribution and a power sample analysis determined the sample size. The repeatability of 1RM strength test was tested through Student´s t test for dependent variables, and the association between test and re-test was expressed by the Person's correlation coefficient.

The model's for predicting 1RM strength were obtained by multiple linear regression through least squared error (forward stepwise method) for leg abduction and leg curl exercises assuming as independent variables: gender and FFM. The model's accuracy was determined by the Pearson´s correlation coefficient, the adjusted r^2 value, and the standard error of the estimate (SEE) between the measured and predicted 1RM. The SEE was calculated as $Sy/(1-r^2)$, where Sy is the standard deviation (s) of the measured 1-RM and r^2 is the determination coefficient. Finally, in order to establish a cut-off criteria for inclusion of independent variables, the best model was considered when the increasing of r^2 was lower than 0.01.

Measured and estimated values for 1RM were compared through the Bland and Altman (1986) method and the model's reliability were expressed by the limit of agreement (LOA), calculated as ± 2SD. All procedures assumed $P \leq 0.01$ for statistical significance. All data were processed in the Matlab v6.2 (Mathworks, EUA), and the descriptive statistics were expressed as mean and SD.

RESULTS

The general characteristics and performance in 1RM tests are summarized in Table 1.The size effect of sample was considered large with actual power of 0.85. No significant differences between the familiarization and the second test were achieved for either the leg abduction (54.4 ± 14.1 kg; 56.0 ± 14.5 kg; r = 0.98), or leg curl (52.5 ± 17.2 kg; 54.0 ± 17.4 kg; r = 0.99) 1RM strength tests. Therefore, both the second 1RM tests were assumed as dependent variables, for regression analysis.

Table 1 - Descriptive characteristics of subjects

Variables	Male	Female
Age, year	23 ± 3.0	21.7 ± 3.3
Height, cm	177.5 ± 6.4	161.2 ± 6.2
Body mass, kg	74.4 ± 8.7	55.0 ± 7.2
Percent body fat, %	11.3 ± 4.6	21.0 ± 3.0
Free Fat Mass, kg	66 ± 6.0	43.4 ± 5.4
Thigh Circumference, cm	53.3 ± 4.2	53.0 ± 3.0
Hip Circumference, cm	96.1 ± 4.4	95.0 ± 4.1
Leg Circumference, cm	36 ± 2.0	34.7 ± 3.8
Lower Limbs Length, cm	99.2 ± 4.8	92.1 ± 4.8
Leg Abduction 1-RM, kg	56 ± 14.5	46.0 ± 8.5
Leg Curl 1-RM, kg	54 ± 17.4	40.1 ± 7.6

Values are mean ± standard deviations.

Table 2 presents the correlation coefficients among anthropometrical variables (independent variable) and the 1RM load (dependent variable) for leg abduction and leg curl exercises. The FFM was highly correlated to the load of 1RM, for leg curl exercise (female: $r = 0.42$, $p < 0.01$; male: $r = 0.73$, $p < 0.01$) and leg abduction exercise (female: $r = 0.43$, $p < 0.01$; male: $r = 0.69$, $p < 0.01$). In addition, the load of 1RM for leg abduction showed moderate correlations ($p < 0.01$) with the thigh circumference, body mass and lower limbs length on both males ($r = 0.49$, $r = 0.58$ and $r = 0.48$, respectively) and females ($r = 0.48$, $r = 0.43$ and $r = 0.59$, respectively). However, significant correlations were achieved only on males ($r = 0.41$, $r = 0.66$ and $r = 0.42$, respectively) for leg curl exercise.

Table 2 - The partial correlation of anthropometric variables with load of 1RM for leg abduction and leg curl exercises in both genders.

Variables	Male LA *R*	Male LC *R*	Female LA *R*	Female LC *R*
Age	-0.07	-0.10	-0.23	-0.10
Height	-0.34	0.39	0.51*	0.33
Body mass	0.58*	0.66*	0.43*	0.33
Percent body fat	0.03	0.11	0.04	-0.22
Fat Mass	0.21	0.28	0.27	0.03
Free Fat Mass	0.69*	0.73*	0.43*	0.42*
Thigh Circumference	0.49*	0.41*	0.48*	0.37
Hip Circumference	0.33	0.33	0.27	0.28
Leg Circumference	0.55*	0.53*	0.33	0.20
Lower Limbs Length	0.48*	0.42*	0.59*	0.37

LA= leg abduction and LC= leg curl. *$p < 0.01$

The coefficients were found for each model for predicting 1RM for both exercises in the experimental group are summarized in Table 3. The best model to estimate 1RM was attributed to that which presented the best correlation coefficient and the least SEE. For leg abduction exercise, regarding the moderate correlation coefficient ($r^2 = 0.66$, $p < 0.01$) between predicted and measured 1RM, the SEE was equivalent to 15.5% of the measured 1-RM (8.4 Kg). No significant difference was recorded between the differences achieved (54.4 ± 14.3 Kg) and predicted (54.4 ± 11.8 Kg) 1RM for model in the leg abduction exercise. Leg curl exercise showed moderate correlation coefficient, ($r^2 = 0.78$, $p < 0.01$) between predicted (54.0 ± 15.4 Kg) and measured (54.0 ± 17.4 Kg) 1-RM. The SEE (8.3 Kg) was equivalent to 15.4% of measured 1RM.

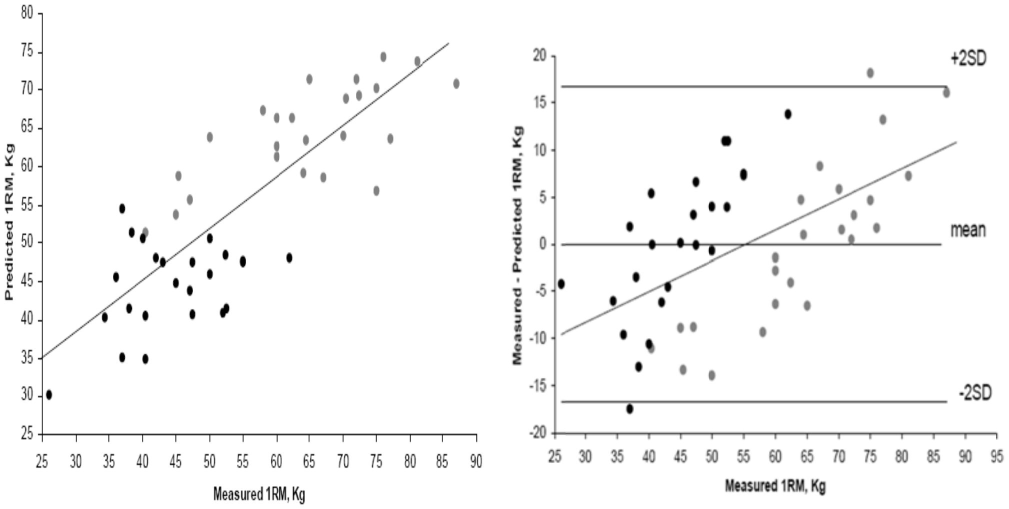
Table 3 - Prediction models for 1RM.

Exercise	***Models***	***R²***	**SEE**	3#
Leg Abduction	$1RM = -5.4 + [(-4.0 * Gender) + 1.1 * FFM]$	0.66	8.5	<0.01
Leg Curl	$1RM = -4.5 + [(-3.0 * Gender) + 1.0 * FFM]$	0.78	8.3	<0.01

Gender (0 – male and 1 – female); FFM = Free fat mass; SEE = standard error of the estimate.

Figure 1 illustrates the relation between measured and predicted 1RM for leg abduction (A) and leg curl (B) model's (left panel), whereby the coordinates are well near of the line of identity, demonstrating, therefore, a moderate correlation for both model's. The right panel (Figure 1) presents the Bland and Altman (1986) plot for leg abduction (A) and leg curl (B) exercises, showing the difference between measured and predicted 1RM as a function of the measured 1RM. Centerline represents the mean difference, and outer-lines, the LOA. Despite the high variability between expected and observed values for leg abduction and oppositely, a low variability for leg curl model, the error tended to increase according to the workload for both models. Regardless of the reliable 95% LOA, only 4% for leg abduction model and 2% for leg curl model of the coordinates were expressed outside the LOA.

(A)



(B)

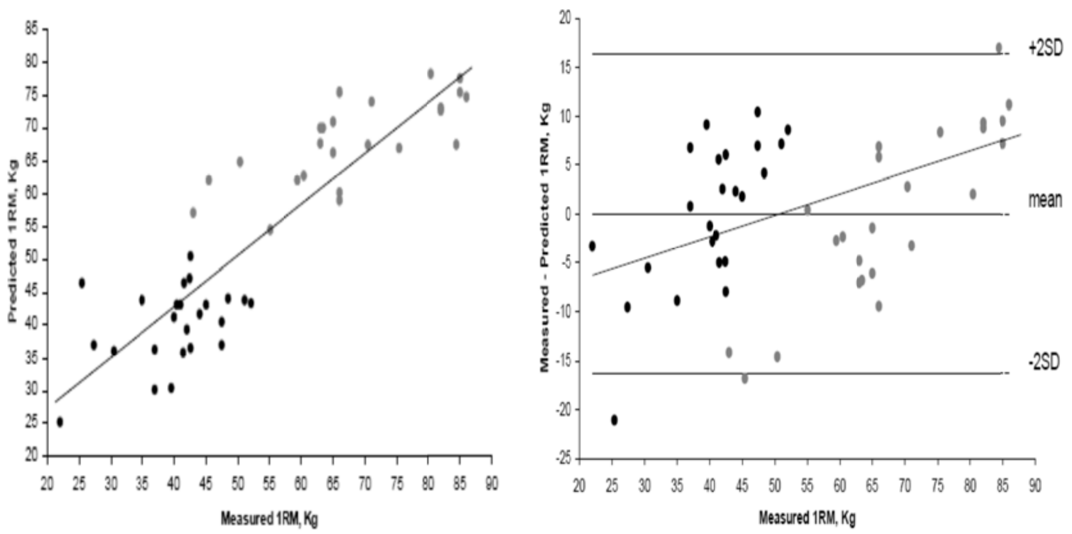


Figure 1 - Linear regression of 1RM predicted by the leg abduction (A) and leg curl (B) models against 1RM measured by 1RM strength test in healthy adults (left panel) and the Bland and Altman (1986) plot (right panel), where the difference between measured and predicted 1RM is expressed against the measured 1RM. Besides, center lines represent the mean difference, the outer-lines, the 95% limit of agreement (LOA), expressing ±2standard deviation (2*s*), and the diagonal lines are the error regression line. Coordinates of the points in black (male) and gray (female).

DISCUSSION

The results of this study provide encouraging support for the efficacy of using anthropometrical characteristics values to predict the 1RM in the exercises leg abduction and leg curl on males and females subjects. No significant difference was found between measured 1RM and predicted 1RM values derived from regression equations for both the exercises.

The 1RM test is often used by athletic trainers, health and fitness professionals and rehabilitation specialists in order to quantify the level of strength, to assess the strength imbalances, as well as to evaluate training programs (ACSM, 2009). However, musculoskeletal extreme efforts during 1RM tests should be avoided by some groups, such as elderly (PLOUTZ-SNYDER and GIAMIS, 2001), cardiac patients (BARNARD et al., 1999), adolescents (FAIGENBAUM et al., 2003) and also some sedentary people (BRAITH et al., 1993). It is widely accepted that lifting a maximal weight may cause test-induced muscle soreness or muscular injuries (KURAMOTO and PAYNE, 1995). In this context, it is irrefutable the importance of submaximal repetition tests or even, the application of accurate and precise methods for estimating the 1RM strength.

Based on these findings, several studies have developed submaximal strength tests in order to predict the 1RM maximal strength based on repetitions-to-fatigue (HORVAT et al., 2003), percentage of 1RM (KRAVITZ et al., 2003), anthropometrical measurements (SOUZA et al., 2011; CARUSO et al., 2009; MAYHEW et al., 2004; MAYHEW et al., 1993), submaximal repetitions (BRECHUE and MAYHEW, 2009; MATERKO and SANTOS, 2009; MAYHEW et al., 2007), use of submaximal repetitions more anthropometrical measurements (DESGORCES et al., 2010; MATERKO and SANTOS, 2009) and sub-maximal ratings of perceived exertion (ESTON and EVANS, 2009). In this context, the purpose of the present study was to determine a model for predicting 1RM based on antropometrical, resulting in significant moderate correlation and low SEE. Nevertheless, differently from the present work, none of these studies (CARUSO et al., 2009; MAYHEW et al., 1993) confirmed the validity and no included any anthropometrical variable for prediction of leg abduction and leg curl exercises.

While some studies (DIAS et al., 2005; PLOUTZ-SNYDER and GIAMIS, 2001) reported significant differences between test and re-test, in accordance to others (MATERKO and SANTOS, 2009; WOOD et al., 2002), no significant differences between familiarization and re-test were achieved for the 1RM strength tests in the present study. In fact, as reported previously (RUDWIK et al., 2007), the experience in strength training may be considered as a strong intervenient factor causing noise in the repeatability of the results. Similarly to other works (MATERKO and SANTOS, 2009; RUDWIK et al., 2007), the results obtained here were achieved in experienced subjects, justifying the absence of differences between test and re-test.

Hanson et al. (2009) showed that the FFM is an excellent predictor of strength training, but this variable is associated with the increase of the strength, the muscle volume, and the body composition. Former studies demonstrated in moderate-intensity weight training program increased strength and fat-free mass and decreased body fat in normal-weight young women (CULLINEN and CALDWELL, 1998) and men (VAN ETTEN et al., 1994). Therefore, we supposed that the FFM is an outstanding variable for predicting of the load of 1RM, due to the association to the muscular strength during weight training programs. The FFM represented the best anthropometric variable for correlation in the leg curl exercise (female: r= 0.42 and male: r= 0.73) and leg abduction exercise (female: r= 0.43 and male: r= 0.69), resulting in a good predictor of the load of 1RM for leg abduction exercise (r^2= 0.66) and leg curl exercise (r^2= 0.78). In accordance, previous study have showed moderate correlation between the FFM and the load of 1RM in male for bench press (r= 0.68), squat (r= 0.60) and deadlift (r= 0.54) exercises (MAYHEW et al., 1993). Furthermore, Materko et al. (2007) studied recently the correlation between the FFM and the load of 1RM in shoulder press exercise, resulting in moderate correlation for male (r= 0.56) and low correlation for female (r= 0.44).

Although previous studies have found errors ranging from 1 to 10% using model's based on 7-10RM tests (ABADIE et al., 1999; BRAITH et al., 1993), herein only anthropometric measures were used without requesting any physical stress generating satisfactorily consistent results. Furthermore, the model achieved here can be considered as an alternative tool for estimating of the load of 1RM. In addition, further researches are needed to determine the validity of such prediction equations for male and female subjects with different characteristic means (age, height, weight and % body fat), adolescents, elderly, and some other groups.

CONCLUSION

The models may be considered acceptable to assess the degree of prediction for 1RM workload in leg abduction and leg curl exercises and all data demonstrated within limit reliability of Bland and Altman (1986).

PRACTICAL APPLICATIONS

Direct evaluation of maximal strength 1RM testing has been shown to be a reliable and useful testing tool and, when properly conducted, 1RM tests are safe for most people. However, there are special circumstances when 1RM is contraindicated, therefore the use of valid submaximal repetition tests in order to estimate 1RM strength would be preferable. The use of such prediction equations to determine 1-RM has practical value for allied sports medicine physicians, athletic trainers or weight trainers in assessing and prescribing strength training program.

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