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ORIGINAL ARTICLE

Correlation Between the 1RM Test and Maturational, Neuromotor, Anthropometric Aspects and Body Composition in Children and Adolescents

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ABSTRACT

1 Repetition Maximum (1RM) tests have been used in research on strength training effects in children and adolescents. However, little is known about the association between 1RM tests and morphologic, neuromotor and biological maturation variables. Therefore, the purpose of the present study was to analyze the relationship between 1MR tests and body composition, anthropometric variables, neuromotor tests and biological maturation. For such purpose, correlational methodology was used. The study involved 10 boys with average age of 10.28 (±2.20) years old. The variables analyzed were: body mass, stature, circumferences, skinfolds and biological maturation (pubic and axillary pilosity and genital development). Hence the sample was submitted to a battery of five neuromotor tests and six 1RM tests sessions for upper (UL) and lower (LL) limbs. Data analysis was developed using the Shapiro-Wilk's test ($p \leq 0.05$), descriptive statistics and the Spearman Correlation Coefficient ($p < 0.01$; $P \leq 0.05$). A strong correlation between age and the 1RM load for UL and moderate for LL was found. Stature presented a moderate correlation with 1MR of UL and strong correlation for 1RM of LL; absolute lean body mass presented moderate and strong correlation for UL and LL, respectively. The 1RM test for UL presented moderate correlation for pubic hair and strong correlation for axillary pilosity. These results indicated a multifactorial influence in the 1RM test loads demonstrating the importance in the use of morphological aspects, biological maturation and/or chronological age in the results analysis. Considering the weak relationship between the neuromotor and the 1RM tests, although they have been well used in research related to strength training on children and adolescents, their results should be carefully used when the purpose is to get information on the magnitude effects of strength training in that age range.

Keywords: muscle strength, sexual maturation, children and adolescents, strength training.

INTRODUCTION

The one repetition maximum test (1RM) consists in the dislocation of the maximum weight amount in only one repetition(1). However, this test can be performed by different protocols, with difference in warm-up method, number of trials, time of rest between sets and muscular groups tested, among other factors.

The 1RM test has been extensively used in the evaluation of muscle strength, being considered as a reference in different populations. It enables to obtain information concerning the strength behavior in different muscle groups, to analyse the effects of regular programs of physical activities with the aim to increase strength or prescription of the intensity to be used in the exercises with weight(2, 3). Thus, the 1RM test presents great usefulness, since weight training is currently one of the modalities of physical exercise which has demonstrated remarkable increase in the number of practitioners, being performed by individuals of different age groups, both sexes and with varied levels of physical fitness. This fact can be explained by the positive aspects derived from this practice, which can include important morphological, neuromuscular, physiological and even social and behavior alterations(4).

In this context, different researchers have investigated the effect of weight training in children on variables such as growth, muscular strength increase, performance improvement in sports practice and alterations in the body composition, as well as its role concerning the onset of injuries(2,5-8).

In a trial to collect information on the effects of weight training on muscular strength of children, the 1RM tests have been used in many studies(2,7,9,10).

Relevant points concerning the use of tests with load dislocation by children have been analysed, such as: stabilization of loads in repetition maximum tests(2) and confidence in isokinetic tests of muscle endurance in knee extension and flexion for children(11).

Neuromotor tests have constantly been proposed as indicators of muscular strength and endurance in children and adolescents(12-14), and research has reached to assess the correlation between performance in neuromotor tests and body composition(15). However, little is known about the association between 1RM tests concerning body composition, anthropometrical and neuromotor variables and the biological maturation stage.

Thus, the present study had the aim to analyse whether the results in 1RM tests present correlation with body composition, anthropometrical variables, performance in neuromotor tests and biological maturation of children and adolescents.

METHODOLOGY

Subjects

10 male children, mean age of 10.28 (±2.20) years, all from the same school of the Londrina-PR city were part of this study. These children had no previous experience in weight training or participation in any kind of regular physical training with periodicity higher than two weekly sessions preceding the study.

Prior to the study's performance, the children and their parents or legal tutors were informed on the investigation's aims and its conduction, and signed a Free and Clarified Consent Form. The study was developed according to the instructions present in the Resolution196/96 of the National Health Board for studies with humans, from the Ministry of Health, having been approved by the Ethics in Research Committee of the State University of Londrina.

Anthropometry and body composition

Body mass (BM) was measured with a Filizola scale with 100 grams precision and stature with wooden stadiometer with 0.1cm precision, according to the procedures described by Gordon et al.[16]. Body mass index (BMI) was calculated by the division of body mass (kg) by stature (m) to the square.

Body composition was assessed through the skinfold thickness technique. The skinfolds were collected with a scientific adipometer brand name Cescorf, with precision of 0.1mm. The subscapular (SB) and triciptal (TR) skinfolds were measured three consecutive times, by the same evaluator, and either the median or the result of two equal measurements was used for the calculations. Fat percentage was estimated by the equations proposed by Slaughter et al.[17]. Lean body mass (LM) and fat body mass (FM) in their absolute content; that is, in kg, were obtained based on the results of the estimation equations of relative body fat percentage as follows: FM by multiplying the BM by the fat percentage fraction, therefore, FM = BM (%F / 100), while LM was estimated as follows: LM = BM – FM. The arm and proximal thigh circumferences were measured according to Callaway et al.[18].

Neuromotor tests

Flexibility was assessed with the sit and reach (SR) test. The used instrument was a wooden Box with specific dimensions and for the test performance the evaluees were barefoot.

Lower limbs Power was assessed with the steady distance jump (SDJ), with an approximate three-meter measuring tape being attached to the ground, which served as measure. The evaluee performed the jump three times and the result of the longest distance obtained was used.

Strength and endurance of upper limbs was assessed by the arm flexion and extension test on bar suspension (FEB); for this test, a wooden framing especially built for his aim was used. The evaluee tried to perform the maximum possible repetitions with no time limit.

Strength and endurance of trunk region were assessed through the modified abdominal test (ABD), in which the individual was on dorsal decubitus on a gym mat. The individual received orientation to perform the highest number of complete performances during one-minute time lapse, with only one trial.

Velocity was assessed in the 50-meter race (50m). In this test, a sound was triggered so that the individual started running and tried to complete the 50 meter distance in the shortest time as possible, and the lap watch was stopped at the moment the individual crossed the finish line. The tests were performed according to the procedures described by Guedes and Guedes[19].

1RM Test

In the 1RM test for lower limbs the movement used was the leg extension on extensor table, while for upper limbs the exercise chosen was the elbow flexion in biceps curl. In the week prior to the 1RM test, the individuals performed the movements with weight lower than the supposedly supported; just to learn the movement's performance. The exercises were composed of three sets with 12 repetitions and the recovery interval between sets was of approximately 90 seconds[2].

1RM was typically determined within four-six experimentations[9]. Firstly, the evaluee performed warm-up of six to 10 repetitions, with approximately 50% of estimated maximum load for the first trial in the test. After warm-up, the subject had a two-minute interval and he started the test immediately after it.

The subjects were told to try to complete two repetitions. In case two repetitions were completed in the first trial, or even one repetition was not completed, a second trial was given after a three to five-minute recovery interval with load higher (first possibility) or lower (second possibility) than that used in the previous trial. Such procedure was repeated again on a third and last trail, in case the 1RM load had not been determined yet, with the interval between exercises was of five minutes[2]. All test procedures were strictly supervised and uniform encouragement was given to all subjects.

Firstly, the test on extensor chair was performed being followed by the biceps curl and performance order followed the size of the biggest agonist muscle group involved. Performance way and technique were standardized according to Faigenbaum and Westcott[20]. A badly movement was defined when it was not performed in its complete amplitude in the two repetitions[2].

Chronological age and sexual maturation

Chronological age was expressed in its millesimal according to procedures presented by Healy *et al*.[21]. Biological maturation was shown through the method of secondary sexual characteristics and it was performed by the assessment of the genital development as well as pubic pilosity with self-evaluation and use of the photographic patterns proposed by Tanner[22] and modified by Matsudo[23], and by visual analysis of axillary pilosity.

Statistical analysis

Data distribution normality was performed by the Shapiro Wilk test where the significance adopted was of $p \leq 0.05$. Descriptive analysis was used (mean, standard deviation, median, minimum and maximum) for sample characterization. Association between variables was checked with the application of Spearman's correlation coefficient; statistical significance established for the analyses was of $p < 0.01$; $p \leq 0.05$. Analyses were performed with the use of the SPSS 13.0 program.

RESULTS

Table 1 presents the general characteristics of the sample including chronological age, body composition and anthropometrical variables.

Table 2 presents mean values and their respective standard deviations, medians and minimum and maximum values concerning the neuromotor tests.

Table 3 presents mean values and their standard deviations, medians and minimum and maximum values concerning the 1RM tests of lower and upper limbs.

Correlation between 1RM tests and anthropometric variables, body composition, maturational level and neuromotor tests are presented in table 4.

Table 1. Values of the means (M), standard deviations (SD), medians (Md), as well as minimum and maximum values of the general characteristics of the sample.

	M	SD	Md	Minimum	Maximum
Age (years)	10.28	2.20	9.41	8.11	15.45
Body mass (kg)	38.44	9.89	41.75	23.10	53.40
Stature (m)	1.42	0.10	1.41	1.22	1.57
BMI (kg/m²)	18.87	3.43	18.21	14.76	24.38
Fat Mass (%)	22.94	11.01	15.93	13.38	41.38
Fat Mass (kg)	9.59	6.64	6.88	3.25	22.09
Lean Mass (%)	77.06	11.01	84.07	58.62	86.62
Lean Mass (kg)	28.85	5.34	29.53	19.85	36.54
Arm circumference (cm)	21.98	3.85	22.20	16.40	28.50
Thigh circumference (cm)	43.43	6.48	44.05	34.90	51.80

Table 2. Means (M), standard deviations (SD), medians (Md), as well as minimum and maximum values in the neuromotor tests.

	M	SD	Md	Minimum	Maximum
SR (cm)	20.40	7.63	22.80	7.70	28.50
SDJ (cm)	122.50	21.40	124.00	84.00	150.00
FEB (rep)	6.40	4.79	6.00	0.00	14.00
ABD (rep)	25.20	7.84	24.00	12.00	40.00
50m (seg)	9.76	1.40	9.54	8.32	13.10

Table 3. Means (M), standard deviations (SD), medians (Md) and their respective minimum and maximum values in the 1RM tests on the extensor table and biceps curl.

	M	SD	Md	Minimum	Maximum
1RM Extensor Table (kg)	21.60	6.50	20.50	14.00	34.00
1RM Biceps curl (kg)	14.80	3.91	13.00	12.00	24.00

Table 4. Correlation between the 1RM tests and neuromotor tests, anthropometric variables, maturational level and body composition.

	Biceps curl (kg)	Sig.	Extensor Table 1RM (kg)	Sig.
Age (years)	0.70	0.02**	0.68	0.03**
Body Mass (Kg)	0.38	0.27	0.58	0.08
Stature (m)	0.65	0.04*	0.76	0.01**
% Fat	0.11	0.76	0.36	0.30
% Lean Mass	-0.11	0.76	-0.36	0.30
Fat Mass (kg)	0.15	0.68	0.38	0.27
Lean Mass (kg)	0.66	0.04*	0.81	0.00**
Arm Circumference (cm)	0.17	0.65	-	-
Thigh Circumference (cm)	-	-	0.42	0.23
Genital Development	0.51	0.13	0.52	0.12
Pubic Pilosity	0.63	0.05*	0.50	0.14
Axillary Pilosity	0.81	0.00**	0.57	0.08
Sit-and -Reach (cm)	-	-	-0.29	0.41
Steady Distance Jump (cm)	-	-	-0.29	0.42
Arm Flexion and Extension (rep)	0.54	0.11	-	-
Ab Crunches (rep)	0.14	0.70	0.00	1.00
50m Race (sec)	-	-	-0.13	0.71
Biceps curl (kg)	-	-	0.80	0.01**

**p<0,01; *p≤ 0,05.

Strong correlation was observed between age and 1RM load assessed through the biceps curl, representing hence upper limbs (UL), and moderate correlation with the extensor table representing the lower limbs (LL). Stature presented moderate correlation with 1RM of UL and strong correlation with 1RM of LL and absolute lean body mass presented moderate and strong correlation for UL and LL, respectively. The result of the 1RM test of UL presented moderate correlation with maturational stage indicated by pubic pilosity and strong correlation with axillary pilosity.

It is important to highlight that only the motor tests which involved lower limbs with 1RM on extensor table were correlated, likewise the tests which demanded the upper limbs with 1RM of UL were correlated. Significant correlations have not been observed between the 1RM tests and the neuromotor tests. The only variables which demonstrated significant correlation were the 1RM tests of UL and LL, being interpreted as strong magnitude.

DISCUSSION

Weight training practice and application of tests such as 1RM ones generate discussions about their use in children and adolescents. However, within this discussion we still verify certain lack of information about several aspects which can influence on the application and even on the interpretation of the tests' results in this population.

The results of this study indicated that the morphological factors which presented significant correlation with load in the 1RM test were absolute lean body mass and stature. It can be related to factors such as hormone production, since chronological age and sexual maturation have also demonstrated significant correlation with the results. In this aspect, a study carried out by Hulthén et al.[24] indicated that sufficient endogenous production of growth hormone is important to the maturation of the lean mass as well as to muscular strength in adolescents and young adults. Thus, it is coherent when some investigations try to correct the 1RM load by the body mass (BM) as proposed by Vanderburgh[25], or by the lean body mass (LBM) as performed by Fontoura et al.[7], aiding hence in the results' interpretation.

Another aspect constantly approached in the literature is the capacity of children to be submitted to these tests. However, some studies suggest that children and adolescents have presented good physiological tolerance to 1RM tests besides being safe to be applied in young subjects[2,26]. The risk of injury in these tests is usually due to inappropriate lifting technique as well as lack of suitable supervision[26]. These facts corroborate what has been observed during this study, where it has not been reported any kind of injury or factor which would hamper the continuity of the tests.

The application of 1RM tests has been receiving massive criticism concerning its use in children and adolescents due to the supposition that they can cause structural harm in the musculoskeletal system or injuries in the growth areas of the bone epiphyses; however, there is not scientific support in the available literature until the present moment which corroborates this hypothesis[2].

Another important factor which has been considered in most of the studies which aim to investigate the strength alterations through 1RM tests is the use of adaptation to the test movements as well as its equipment, which usually occurs through a relatively high number of repetitions and reduced load in order to provide better familiarization with the movement.

Correct performance of the movement's technique as well as instructions about the control of the movement and breathing should be emphasized in these sessions introducing to the test. The adaptation is used with the purpose to decrease the effects of the movement's learning, avoiding hence possible misunderstanding in the determination of the RM load assessed[2,9,10,26]. Nevertheless, the number of sessions sued varies according to the study, and it seems no consensus has been reached concerning the adaptation sessions.

It is worth mentioning that, in prepubescent children, the capacity to produce maximum strength seems to be highly dependent on the familiarization process specific to the test. Thus, it is important to adapt it performance in order to avoid training efficiency mistakes due to inappropriate determination of its initial loading[2].

Concerning the neuromotor tests and their correlation with the 1RM load, it is observed that the arm flexion test was the only which obtained moderate correlation with the 1RM load; however, it was not significant. These results partially corroborate the findings by Woods et al.[27], in which muscular strength and endurance laboratory measurements presented weak association with the results in field tests. The fat percentage was indicated as an element significantly associated with the field tests' results for muscular strength and endurance of upper limbs.

The strong correlation obtained between the 1RM tests in the biceps curl and 1RM of extensor chair may have been influenced by the associations observed in the present study between age and lean mass (r=0.81, p=0.01), age and stature (r=0.73, p=0.02), since as previously mentioned, aspects related to hormone production are important to the biological maturation, increase of lean mass, muscular strength and stature growth[24,28]. In the present study strong correlation between lean mass and stature (r=0.97, p<001) was observed. Thus, the individuals with more advanced chronological age presented higher lean mass and stature and obtained higher loads in the 1RM tests.

CONCLUSION

Multifactorial influence in the determination of loads in 1RM tests was verified. Among the factors analysed in this study, the factors which demonstrated higher correlation with the loads obtained were stature, lean body mass and chronological age; maturational stage related to the 1RM test of barbell curl, indicating the importance to consider the use of morphological, maturational aspects and/or chronological age in the results' analysis.

Concerning the neuromotor tests correlation with the 1RM tests, the results presented from weak to moderate and not significant magnitude. Although the neuromotor tests have been frequently used for muscular strength analysis, they should be carefully applied when the aim is to obtain information about the magnitude of weight training efficiency. Having these findings as a starting point, the 1RM test seems to be the most suitable parameter for the assessment of the muscular strength alterations due to this training modality.

We suggest that for future investigation, that a higher number of subjects be applied in the assessment of the studied variables as well as the involvement of other anthropometric variables, nutritional aspects, level of physical activity and motivational status.

All authors have declared there is not any potential conflict of interests concerning this article.

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