Variation of the muscular strength in repetitive 1-RM test in prepubescent children*

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ABSTRACT

Although one-repetition maximum repetition tests (1-RM) are widely employed to evaluate the muscular power, the lack of previous familiarization with the test procedures may cause erroneous interpretations. Thus, the purpose of this study was to analyze the behavior of the muscular strength in prepubescent children during 1-RM repetitive tests. For this, nine boys (9.5 ± 0.5 years; 35.1 ± 6.9 kg; 138.3 ± 6.1 cm) with no previous experience in weight exercises were submitted to eight sessions of 1-RM tests in the leg extension and arm curl exercises, and with a 48 hours interval between sessions. Three trials with 3-5 minutes of resting interval were performed by subjects in each of the chosen exercises. It was observed significant increases of 30.2% and 22.7% between the first and eighth session in the leg extension and arm curl exercise tests, respectively ($P < 0.05$). However, no statistically significant difference was found between the third and eighth session in the leg extension exercise, and between the fifth and the eighth session in the arm curl exercise ($P < 0.05$). These results indicate that the number of sessions necessary to stabilize the muscular strength in 1-RM tests seems to depend upon the motor task performed, and possibly upon the size of the agonist muscular group involved in performing the motor task. Therefore, the results suggest that to attain a more accurate evaluation on the muscular strength in prepubescent boys by means of 1-RM tests, it is necessary to perform three to five familiarization sessions.

Keywords: Muscular strength. Weight exercises. Neural adaptations. 1-RM tests. Reliability. Prepubescent.

INTRODUCTION

The one-repetition maximum test (1-RM) has been widely used as reference pattern to evaluate the muscular strength in different populations, and based on the results obtained, it is possible to analyze the behavior of the muscular strength in different muscular groups, in order to evaluate whether regular programs of physical activities are effective or not to increase the muscular strength or even to prescribe the ideal intensity to be applied in weight exercises.

The main advantages brought by the use of 1-RM tests are related to the easiness to interpret the information produced at a low operational cost, and the possibility to apply it to populations of quite different trainability levels. Despite of this, several researches are still resistant to use such 1-RM tests to evaluate the muscular strength levels in some populations, mainly children and adolescents, choosing to apply sub-maximal 3, 8 or 10-RM tests. Thus, the ability to produce maximal strength in prepubescent children has not been evaluated in the majority of the studies available in the literature, once the execution of a higher number of repetitions is much more connected to the strength resistance than to the maximal strength[1].

The decision to use multiple repetition tests rather than 1-RM tests to evaluate the muscular strength in children and adolescents is supported by the lack of a higher amount of information on the existence or not of injuries or structural damages to the musculoskeletal system (growth cartilage, and bone epiphysis) associated to the execution of the 1-RM tests specifically in those populations.

In such sense, Faigenbaum *et al.*[2] recently have shown the safety character and the effectiveness in using 1-RM tests to evaluate the muscular strength in healthy 6 to 12 year old children, reporting the inexistence of injuries during the period of the study, as well as pointing out that the test protocol was well tolerated by every individual investigated.

On the other hand, some factors may sensitively interfere in the quality of the information attained through the 1-RM tests, and this has generated strong discussions, particularly in the academic mean, on the confidence of the information produced by the use of such kind of test. The lack of previous familiarization with the test procedures may be the most important of all these factors, once recent researches performed with young and elder adults has indicated that both inexperienced and those individuals with previous experience in weight exercises[3], but with no specific training for at least six months[4,5] may have their muscular strength underestimated by the 1-RM tests performed by individuals with no previous familiarization. This fact may compromise in a very sensitive way the muscular power evaluation as well as the prescription of the training overload, mainly in weight exercise programs that follow the intensity reference loads set through 1-RM values.

Searching in the research performed on the major database available in the literature in May, 2005, it was found no study on the familiarization process using 1-RM tests in children and adolescents. Therefore, the initial purpose of this study was to analyze the behavior of the muscular strength in prepubescent children in repetitive 1-RM tests, and next, using weight exercises in different body portions, seeking to achieve a more accurate evaluation on the muscular strength specifically among that population.

METHODOLOGY

Subjects

It was selected initially 15 boys to participate in this study, after being widely divulged at an Application School of the Londrina State University. Every subject was classified as prepubescent according to the criteria proposed by Tanner[6]. From that initial number, only nine boys were effectively present in every testing session, and it was included in every analysis.

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None of the individuals reported any previous skills in weighted exercises or even the participation in systematic programs of regular physical activity with a higher than two sessions per week periodicity in the six previous months to the beginning of this investigation.

Before the beginning of the study, every child and their respective caretakers were clarified on the purpose of this investigation, as well as to the procedures adopted. Next, the children's caretakers signed a free and clarified consent term. This study was developed according to instructions contained in the Resolution 196/96 of the National Health Council for studies conducted with human beings of the Ministry of Health, being approved by the Ethics in Research Committee of the Londrina State University.

Anthropometry

The body mass was attained through a 0.1 kg accuracy Filizola digital scale, and the height was determined using a 0.1 cm accuracy wooden stadiometer, according to procedures described by Gordon *et al.*[7].

The body composition was determined by the skinfold thicknesses technique. For this, the triceps and subscapular skinfold thicknesses were measured by a sole researcher using a Lange scientific caliper (Cambridge Scientific Industries Inc., Cambridge, Maryland). The test-retest coefficient was higher than 0.95 in every anatomic point, with a $\leq$ 5% measurement error. Every measurement was rotationally taken, with a three time repetition, and the mean value was recorded. Based on the skinfold thickenesses values, the relative body fat was estimated by means of the equations proposed by Slaughter *et al.*[8].

Evaluation of the muscular strength

Due to the fact that all participants had no previous experience in weight exercises, a previous familiarization process was adopted as to the technical gestures demanded by the leg extension and arm curl exercises. For that purpose, it was performed four sessions, each of them composed by three sets of 10-12 repetitions with no overloading in each exercise. The rest interval between series was approximately of 90 seconds, while the interval between sessions was of 48 hours.

After that period, all individuals were submitted to eight 1-RM test sessions in the leg extension and arm curl exercises, with a 48 hours interval between each session. Three tries of each exercise were performed with a 3-5 minutes resting interval. The order of execution was arranged according to the size of the higher agonist muscular group involved, i.e., the leg extension and arm curl exercise, respectively. The transition interval between exercises was five minutes. The exercises were chosen because they are quite often used in studies searching for the effects of the weight training on prepubescent children. The execution form and technique were standardized[9] and individually monitored.

Warming sets preceded each exercise (6 to 10 repetitions) with approximately 50% of the estimated load for the first try of the 1-RM test. After a two minute rest, the test began. Individuals were guided to try to complete two repetitions. When two repetitions were completed in the first try, or even when it was completed no repetition, a second try was performed after a three to five minutes rest interval with a higher load (first possibility) or a lower load (second possibility) to the one employed in the previous try. This procedure was repeated in a third last try in the event the individual did not complete a single maximal repetition. The load recorded as 1-RM was the one in which each individual was successful in completing a single maximal repetition[10].

Statistical treatment

Initially, data was treated from descriptive procedures, and all information was processed through the STATISTICA Version 5.1 software. The analysis of variance (ANOVA) for repeated measurements was used to make a comparison between the scores attained in different 1-RM test sessions in the leg extension and arm curl exercises. The Scheffé's post hoc test was employed to identify specific differences in those variables where the F values found were higher than set by the statistical significance criteria ($P < 0.05$). The concordance limit between familiarization sessions where it occurred the supposed muscular power stabilization in each exercise investigated was analyzed through the procedures proposed by Bland & Altman[11].

RESULTS

Table 1 presents information on the age, body mass, height, relative body mass, lean body mass, and fat mass of the individuals investigated.

TABLE 1
Physical characteristics of subjects (n = 9)

	Mean	DP	Minimal	Maximal
Age (years)	9.5	0.5	9.0	10.0
Body mass (kg)	35.1	6.9	24.7	47.4
Height (cm)	138.3	6.1	127.0	146.5
% Fat	18.8	8.1	10.0	30.6
Lean body mass (kg)	28.1	3.1	22.1	32.9
Fat mass (kg)	7.1	4.4	2.6	14.5

The mean values (± DP), as well as the magnitude (minimal and maximal values) of the results found in the leg extension and arm curl exercises in eight 1-RM test sessions are presented in table 2. Statistically significant differences were identified in the load lifted of the leg extension exercise from the third test session in relation to the first session ($P < 0.05$). However, results attained in the third test session did not statistically interfere from those found in the next sessions ($P > 0.05$).

On the other hand, it was found statistically significant differences for the arm curl exercise only in the fifth session of the 1-RM test ($P < 0.05$). However, it was verified a relative stabilization of the lifted loads between the fifth and eighth session ($P > 0.05$).

TABLE 2
Mean values (± DP) of prepubescent boys in 1-RM tests in the leg extension and arm curl exercises (n = 9)

Session	Leg extension (kg)	Range (kg)	Arm curl exercise (kg)	Range (kg)
1	23.5 ± 4.5	16.0-31.0	13.2 ± 2.2	11.0-18.0
2	25.7 ± 4.8	16.0-32.5	14.0 ± 3.0	10.0-20.0
3	27.7 ± 4.4*	18.0-32.5	15.1 ± 2.5	12.0-20.0
4	28.9 ± 4.2*	20.0-34.5	15.1 ± 2.1	12.0-19.0
5	29.7 ± 4.2*	20.0-34.5	15.5 ± 2.2*	12.0-19.0
6	30.4 ± 5.4*	18.0-36.0	16.2 ± 2.7*	13.0-22.0
7	30.6 ± 6.0*	18.0-37.0	16.1 ± 2.6*	13.0-22.0
8	30.4 ± 5.8*	18.0-37.0	16.0 ± 2.6*	13.0-22.0

* *P* < 0,05 vs. Session 1.

Table 3 presents the plottage results proposed by Bland & Altman[11]. According to the concordance limits, the mean differences and the confidence interval have shown to be reduced in both analyzed exercises in the sessions where the stabilization of the 1-RM values occurred compared to the other tries.

TABLE 3
Differences mean (DM) and confidence interval (CI) in kilograms, in evaluating the maximal strength (1-RM) according to the progression between sessions, and where it was found the load stabilization (LS) in both exercises investigated (n = 9)

Leg extension			Arm curl exercise		
Sessions	**DM**	**CI**	**Sessions**	**DM**	**CI**
1-2	–2.22	17.84	1-2	–0.78	6.12
1-3	–4.22	16.97	1-3	–1.89	5.33
1-4	–5.39	19.64	1-4	–1.89	5.68
1-5	–6.22	17.69	1-5	–2.33	5.17
1-6	–6.89	18.46	1-6	–3.00	4.78
1-7	–7.05	21.09	1-7	–2.89	6.68
1-8	–6.88	20.03	1-8	–2.78	5.56
LS			**LS**		
3-4	*–1.17*	*6.38*	**5-6**	*–0.67*	*4.78*

Figures 1 and 2 illustrate the plottage between sessions 1 and 8 for both studied exercises (fig. 1A and fig. 2A). Furthermore, according to the results produced by the multiple comparison tests, the information obtained is presented through the Bland & Altman's plottage[11] comprised by the load stabilization sessions, that means, 3 and 4 tests of the leg extension exercise (fig. 1B), and 5 and 6 tests of the arm curl exercise (fig. 2B). The analysis is set by the relationship between the mean values between the moments confronted (x axis), and the individual difference of each subject between two 1-RM tests (y axis).

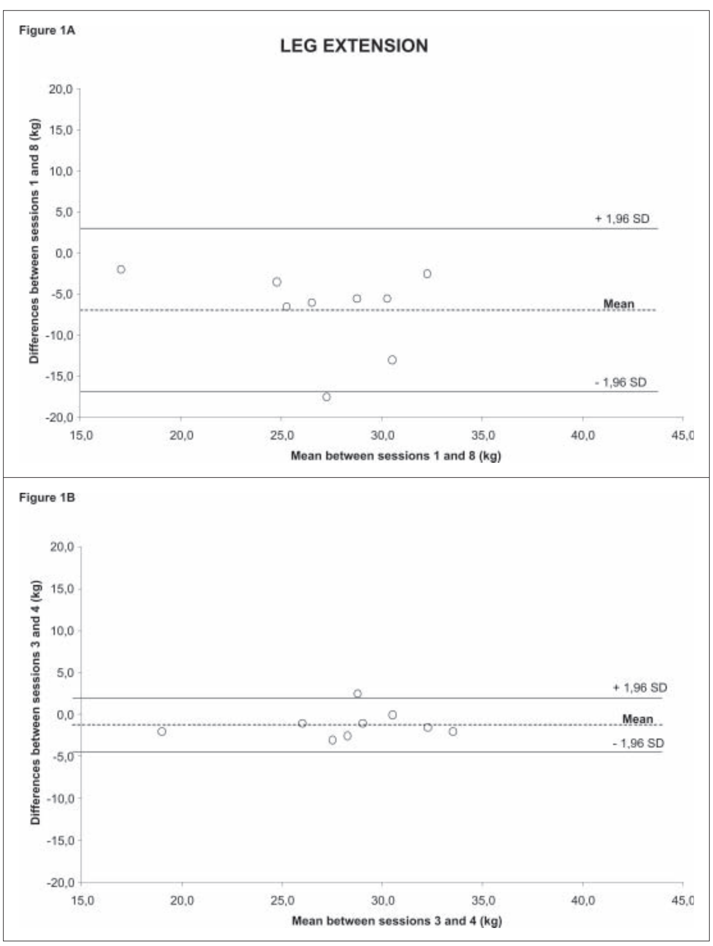

Fig. 1 *– Bland-Altman's plottage to make a comparison between 1-RM test sessions for the leg extension exercise between test sessions 1 and 8 (figure 1A) and the stabilization sessions 3 and 4 (figure 1B).*

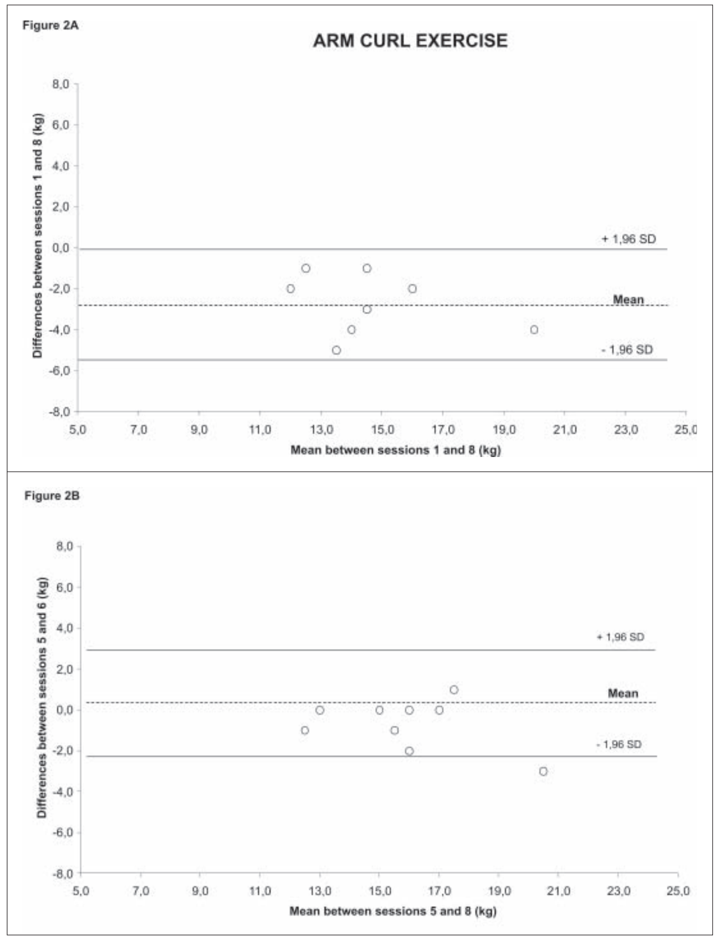

Fig. 2 *– Bland-Altman's plottage to make comparison between 1-RM test sessions for the arm curl exercise between test sessions 1 and 8 (figure 2A), and the stabilization sessions 5 and 6 (figure 2B).*
Note – There is a superposed spot in fig. 2A.

DISCUSSION

Although the application of the 1-RM tests in children and adolescents is a matter for several discussions, the hypothesis that this type of strength may cause structural damages in the muscle-skeletal system or injuries in the growth portions of the bone epiphysis in those populations still does not find up to this moment scientific support in the available literature.

On the other hand, in the last decade some researchers, have indicated that besides the 1-RM tests are able to be safely applied in young individuals, the demanded strength may be quite well physiologically tolerate by children and adolescents[1,2]. This information was confirmed in this study, since no apparent discomfort or any injuries was observed or reported by all individuals investigated.

Considering that the average time to execute the 1-RM test is quite short (< 5 s), the energetic demand for such kind of physical effort is predominantly supported by the phosphagenic system, mainly the ATP. It is believed that the rest interval to be adopted between multiple sets of 1-RM tests in children and adolescents shall be relatively the same ones adopted to the adult population (3-5 minutes), once the intramuscular concentrations of resting ATP and PCr are similar to those found in adult individuals[12].

Upon the establishment of the experimental outline to be used in this investigation, we believed it would demand a previous familiarization process as to the necessary technical gesture to perform the leg extension and arm curl exercises, having in mind that all participants had no previous experience in weight exercises. However, the hypothesis that that procedure may have some effect on the results found cannot be despised, although the use of reduced workloads and a relatively high number of repetitions (10-12) in multiple sets seem to affect mainly the physical ability of strength resistance, while the most demanded physical ability to the 1-RM tests is the maximal strength.

Similar to what was found in previous studies[3-5] performed in adult and/or elder individuals, it was verified in this study that the familiarization process is necessary to determine the maximal strength before the 1-RM test application in prepubescent children as well.

Despite the stabilization process of the muscular strength on the extensor table has been already identified in the third 1-RM test application session (figure 1), it was verified an increase in the loads lifted (with no statistical significance) in the subsequent sessions, and the peak values were attained in the seventh session. Thus, from the 30.2% increment observed in the muscular strength (difference between end values) about ~10% occurred from the establishment of a supposed plateau.

On the other hand, the stabilization of the muscular strength in the arm curl exercise occurred more lately (fifth test session). Furthermore, the next increment to the establishment of the plateau was of lower magnitude (~4%) compared to the one verified in the leg extension exercise (figure 4).

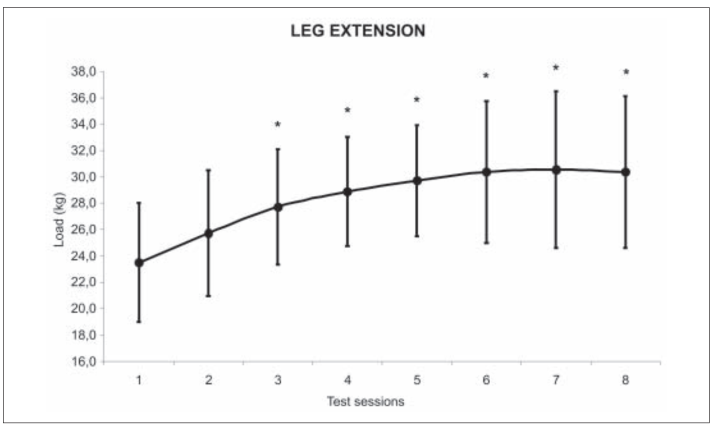

***Fig. 3** – Evolution of the loads of the 1-RM test in the leg extension exercise (n = 9)*
* $P < 0.05$ vs. Session 1.

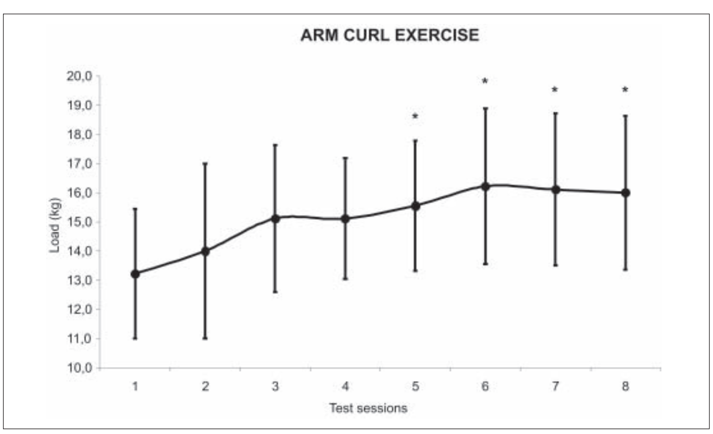

***Fig. 4** – Evolution of the loads of the 1-RM test in the arm curl exercise (n = 9)*
* $P < 0.05$ vs. Session 1.

The great advantage of using the analysis technique proposed by Bland & Altman[11], adopted in this study, is that it enables to perform individual changes, as well as to identify any spots out of the concordance limits (± 95%) so-called outliers. This fact may be used as one of the main criteria to the establishment of the familiarization sessions in 1-RM tests.

Results of this study indicate that the quantity of familiarization sessions to the 1-RM tests still deserves to be further investigated in individuals of both genders and different ages, and in different physical fitness levels, as the figures found in this study (3-5 sessions) are similar to those found by Ploutz-Snyder & Giamis[3] for young women (3-4 sessions), but quite different from those verified in elder women (8-9 sessions). According to what was reported by those researches, both young and elder women with no previous experience in weight exercises had an increase in the maximal lifted load of about 14.3 kg, and 13.0 kg, respectively.

Although in absolute terms these values are quite higher than those observed in the leg extension exercise performed in this study (± 4.2 kg), upon the analysis of the workload increment in relative values, it is verified that the prepubescent children investigated by us had an increase of about 30.2%, that means, this figure is quite higher than the one found both in young (12.5%) and elder (22.5%) women.

The discrepancy in the number of sessions necessary to the familiarization with the 1-RM test among prepubescent boys and elder women can be probably explained by the fall in the neuromuscular performance caused by the major presynaptic inhibition of the motor units occurred along with the aging, mainly after 30-35 years[3]. It is worthy to mention that the neuromuscular activation capability (recruitment and frequency of the motor units' activation) is not yet completed in prepubescent children[13], and this can affect the speed of the familiarization process in the 1-RM test for that population. Unfortunately, in order to assert whether such hypothesis is confirmed or not needs the use of more sophisticated techniques, such as electromyography, which was not employed in this study.

When Dias *et al.*[4] investigated the familiarization process to the 1-RM test in previous skilled young male adults in the weighted exercises, in the bench press exercise, squat and in the arm curl exercise, they verified an increase of about 5.4% in the arm curl exercise, which is a lower value than the one attained by prepubescent children in this study (+ 22.7%). In absolute values, such difference may be attributed at least in part due to different age levels analyzed in both studies, to the higher number of 1-RM tests applied in the present investigation (eight x four), or even to the lack of experience as to the practice of weighted exercises of the studied children, once the contribution of the natural factors to the increasing muscular strength is inversely proportional to the previous experience related to the demanded motor task[14].

In another study, the changing in the maximal muscular strength output, and the muscular power in four 1-RM test sessions performed every 7-10 days were investigated by Cronin & Henderson[5] in 12 recreational athletes with no previous training in weight exercises (21.0 ± 2.7 years). The findings show that the muscular strength in the lying squat exercise in the equipment increased along the whole period of the study, while the muscular strength in the bench press exercise reached its plateau between the second and third session. The researches attributed the different behavior observed between exercises to the upper and lower limbs mainly to the complexity of the technique involved in the lifting, and to the amount of muscular mass. However, such hypothesis was not possible to be confirmed in the present study, and this may be justified by the simple lifting techniques used in the exercises adopted in this investigation (single-joint exercises).

Another point that deserves to be further studied is that the stabilization of the workloads occurred more rapidly in the present study in the exercise involving a major muscular mass (quadriceps) than to the lower size (biceps). This type of behavior is opposed to what was observed by Cronin & Henderson[5], indicating the need of further studies aiming to investigate this relationship from the analysis of the different mechanisms.

Some researchers believe that the neuromuscular adaptations are the major mechanisms responsible by the increasing muscular strength in prepubescent children, once there is no consistent reports in the literature on the possible morphological changes that could be attributed both to the strength training and to the 1-RM tests in such population[15-17].

In such extent, the possible neural mechanisms by the major part of the muscular strength gains in prepubescent children would be an increment in the neural system ability in the whole muscle activation, a better coordination of the synergist and antagonist muscles, or even an improvement in the coordination of the movement[18].

Considering that the muscular strength production depends on the activation level of the motor units, and by its turn, such activation is directly influenced by the level of development of the central nervous system, researchers have shown that pre-pubescent children may not voluntarily activate a high percentage of their available motor units, thus resulting in a lower ratio between the maximal strength/area of transverse muscular section when compared to adult men[13].

Although the neuromuscular capability in activating the musculature is not completely stabilized during the childhood, it has been reported that non-trained individuals can activate their muscles after a few experiences in weighted-exercises[19]. Thus, it is belived that the repetition of the motor task can improve the performance in the 1-RM test also for children[2].

CONCLUSION

The findings in this study have shown that the behavior of the muscular strength during repetitive 1-RM tests is quite variable in prepubescent boys. Thus, the ability to produce the maximal strength in this population in this type of test seems to be highly dependent on a specific familiarization process. Thus, most of the changes in the muscular strength in young individuals that are erroneous attributed to the effectiveness of the training programs may be in fact the result of an initial inadequate evaluation, mainly when the analysis is based on results attained in 1-RM tests with no reports of previous familiarization.

The results suggest that in order to achieve a more accurate assessment on the muscular strength in pre-pubescent boys thorugh the 1-RM tests, at least three testing sessions on the extensor bench must be performed, as well as five sessions for the arm curl exercise.

It is worthy to point out that future investigations with children of both genders and different maturation levels, as well as different levels of physical fitness are yet needed to analyze the behavior of the muscular strength using 1-RM tests. Furthermore, we believe that the use of other exercises added to the electromyographic technique may help to understanding the information found in the present study.

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

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