Influence of familiarization process on muscular strength assessment in 1-RM tests

Raphael Mendes Ritti Dias[1], Edilson Serpeloni Cyrino[1], Emanuel Péricles Salvador[1], Lúcio Flávio Soares Caldeira[1], Fábio Yuzo Nakamura[1], Rafael Raul Papst[1], Nelson Bruna[1] and André Luiz Demantova Gurjão[1]

ABSTRACT

Although the use of maximum repetition tests (1-RM) is frequent for assessment of the muscular strength, one believes that the results obtained may be affected by the lack of previous familiarization, even in skilled subjects in exercises with weights. Thus, the objective of this study was to investigate the impact of the familiarization process on the muscular strength assessment in 1-RM tests. To do so, 21 men (24.5 ± 3.8 years of age), apparently healthy and with previous experience of at least six months on weight training, were submitted to repetitive tests of 1-RM in bench press, squat, and arm curl exercises. The tests were performed in four sessions with intervals every 48-72 hours. A maximum number of three attempts with 3-5 minutes interval for recovery was used in each exercise in the four testing sessions. The analysis of variance ANOVA for repeated measures followed by the *post hoc* Tukey test when $p \leq 0.05$ were used for the data treatment. Significant increases on the muscular strength ($p \leq 0.01$) were found in the three exercises analyzed between the first and the fourth familiarization session (2.4% in bench press, 3.4% in squat, and 5.4% in the arm curl). However, no statistically significant difference was found between the second and fourth familiarization sessions in the arm curl ($p > 0.05$) as well as between the third and fourth sessions in the bench press and squat ($p > 0.05$). The results indicate that the lack of previous familiarization with 1-RM tests may impair the muscular strength evaluation. Therefore, the performance of two to three familiarization sessions in adult men with previous experience with weightlifting is suggested for a more accurate muscular strength assessment by means of the 1-RM tests.

Key words: Muscular strength. Weight exercises. Neural adaptations. 1-RM tests. Familiarization.

INTRODUCTION

Muscular strength is an important component of the physical fitness related to health, besides playing relevant role in the physical performance in several sports modalities. Among the several training means for the development of the muscular strength, the weightlifting is emphasized.

In this context, significant increases on the muscular strength may be observed through the application of specific tests already at the first weeks of weight training (WT) in subjects from both genders, presenting different age ranges and physical fitness levels[1-6].

According to the literature, it is verified that the maximum repetition test (1-RM) has been the most frequently applied test for the evaluation of the dynamic force, above all by researchers and professionals who work in the physical exercise and sport areas, once it is a low operational cost and apparently safe practical method for most populations.

However, recent studies have indicated significant increases on the muscular strength in 1-RM tests in young men and women as well as in elderly women without previous or late experience with weightlifting[7-9]. These results indicate that the lack of previous familiarization to procedures involving the performance of 1-RM tests may impair the analysis of information, especially in follow-up studies.

On the other hand, no additional information has been produced by literature along the last three decades with regard to the behavior of subjects with previous experience with weightlifting during 1-RM repetitive tests. Thus, one believes that the familiarization process in these individuals may be shorter than that observed in untrained individuals.

Thus, the objective of this study was to verify the number of sessions required for the familiarization to 1-RM tests in physically active men with previous experience with weightlifting.

METHODOLOGY

Subjects

Twenty-one men (24.5 ± 3.8 years of age) apparently healthy, participated voluntarily in this study. As inclusion criteria, the participants should be physically active (systematized regular physical activity > twice a week) and present experience of at least six months with weight training. The subjects, after being previously informed of the purposes of this investigation and about procedures to which they would be submitted, signed a free consent form. This study was approved by the Ethics Research Committee of the Londrina State University, according to resolution 196/96 of the National Health Council on researches involving human beings.

Anthropometry

The body mass was measured in digital platform balance label *Urano*, model PS 180 with accuracy of 0.1 kg and the stature was obtained in wooden stadiometer with accuracy of 0.1 cm, according to procedures described by Gordon *et al.*[10]. All individuals were measured and weighted barefoot and wearing bathing suit only. Based on these measures, the body mass index (BMI) was determined through the body mass/stature^2 ratio, and the body mass was expressed in kilograms (kg) and the stature, in meters (m).

The body composition was determined through the skinfolds thickness technique. Three measures were taken in each anatomic point (abdomen, suprailliac, medial axillary, subscapular, triceps, chest and thigh) in rotational sequence at the right side of the body, where the average value was recorded. Such measures were per-

1. Research and Study Group in Metabolism, Nutrition and Exercise – Physical Education and Sports Center – Londrina State University, PR.

Received in 19/7/04. 2nd version received in 22/11/04. Approved in 20/12/04.

Correspondence to: Grupo de Estudo e Pesquisa em Metabolismo, Nutrição e Exercício, Centro de Educação Física e Desportos, Universidade Estadual de Londrina, Rod. Celso Garcia Cid, km 380 – Campus Universitário – 86051-990 – Londrina, PR – Brazil. E-mail: dias.raphael@uol.com.br

formed by a single appraiser who used a scientific skinfold caliper label *Lange*, according to techniques described by Slaughter *et al.*[11]. The test-retest coefficient exceeded 0.95 for each anatomic point, with maximum technical measure error of ± 1.0 mm.

The relative body fat (% fat) was calculated through Siri formula[12], based on the estimation of the body density determined through the equation involving the thickness of seven skinfolds proposed by Jackson and Pollock[13].

Muscular strength

All subjects were submitted to four 1-RM tests sessions in bench press, squat and arm curl exercises, in this order respectively, with 48-72 hours interval between each session for the evaluation of the muscular strength.

Each one of the three exercises was preceded of a series of warm-up exercises (6-10 repetitions) with approximately 50% of the load to be used in the first attempt of the 1-RM test. The testing was initiated two minutes after warm-up session. The subjects were oriented to try to accomplish two repetitions. In case two repetitions were accomplished at the first attempt, or even if no repetition was accomplished at all, a second attempt was performed after a 3-5 minutes recovery interval with load above (first possibility) or below (second possibility) that employed in the previous attempt. Such procedure was repeated again in a third and ultimate attempt in case the load corresponding to a single maximum repetition had not yet been established. Therefore, the load recorded as 1-RM was that in which it was possible for the individual to accomplish only one single repetition[14]. The transition interval between the exercises was of three to five minutes.

It is worth emphasizing that the execution form and technique of each exercise was standardized and continuously monitored in the attempt of assuring the quality of information. Besides, the subjects performed the tests at the same period of the day (morning, afternoon or evening) and were kept off the practice of physical exercises during the experimental period.

Statistical treatment

Data were initially treated based on descriptive procedures and the information was processed in the *Statistica* version 5.1 computational package. The analysis of variance ANOVA for repeated measures was used for the comparisons between the scores obtained in the 1-RM tests performed in different sessions in bench press, squat and arm curl exercises. The *post hoc* Tukey test was employed for the identification of specific differences in variables in which the F values found exceeded the statistical significance credit established ($p \leq 0.05$). The concordance limit between the familiarization sessions where the supposed stabilization of the muscular strength occurred in each one of the three exercises investigated was analyzed by means of the procedures proposed by Bland and Altman[15].

RESULTS

Table 1 presents the description of the physical characteristics of the subjects investigated.

TABLE 1
Physical characteristics of subjects (n = 21)

	Average	SD	Minimum	Maximum
Age (years)	24.5	3.8	20.0	36.0
Body mass (kg)	74.0	10.6	62.4	103.9
Stature (cm)	175.1	6.6	156.5	189.0
BMI (kg/m^2)	24.1	2.6	20.9	29.1
% Fat	12.5	3.4	5.8	19.2
Lean body mass (kg)	64.5	6.7	57.1	83.9
Fat mass (kg)	9.5	4.0	3.6	20.0

Table 2 presents the values of 1-RM obtained in the different tests sessions in all exercises performed. In exercises bench press and squat, the stabilization of the load corresponding to 1-RM only occurred between sessions three and four, whereas in arm curl, the ANOVA indicated stabilization of the muscular strength from the second session on. In percentages, the evolution of 1-RM between the first session and the session associated to the stabilization of the muscular strength was equivalent to 1.9% for the bench press, 2.4% for squat and 3.4% for the arm curl.

TABLE 2
Muscular strength of adult men with previous experience with weight exercises during 1-RM repetitive tests (n = 21)

Exercises	Average	SD	Range
Bench press (kg)			
Session 1	74.6	14.4	47.1-103.1
Session 2	75.7[a]	14.6	47.1-105.1
Session 3	76.0[a]	14.7	47.1-107.1
Session 4	76.4[a,b]	14.7	47.1-109.1
Squat (kg)			
Session 1	147.0	25.1	112.3-208.3
Session 2	149.6[a]	23.9	116.3-208.3
Session 3	150.5[a]	24.5	116.3-208.3
Session 4	151.9[a,b]	24.9	116.3-208.3
Arm curl (kg)			
Session 1	44.0	7.4	31.5-51.5
Session 2	45.5[a]	7.3	33.5-57.5
Session 3	46.0[a]	7.1	33.5-57.5
Session 4	46.4[a]	7.1	35.5-57.5

[a] $p \leq 0.01$ *vs* session 1 and [b] $p < 0.05$ *vs* session 2.

Figures 1, 2 and 3 present the plotting proposed by Bland and Altman[15] for the verification of concordance between the measures obtained in sessions in which the loads stabilization process was statistically configured. Figures 1 and 2 plot the individual differences (axis-y) of 1-RM between sessions three and four in function of the averages between both sessions (axis-x) for bench press and squat, respectively. The same type of graphic representation was used to express the concordance between sessions two and three for arm curl (figure 3).

It was verified in all exercises studied that the average difference (central line) and the space comprised between the concordance limits (upper and lower lines) were relatively small, above all when analyzed based on other paired comparisons (table 3).

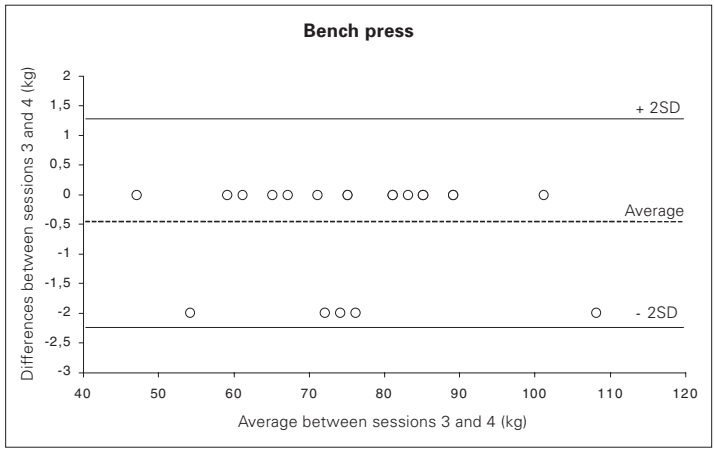

Fig. 1 *– Bland-Altman plotting for comparisons between sessions three and four of 1-RM tests for bench press exercise (n = 21)*
Note – *Four points are superposed*

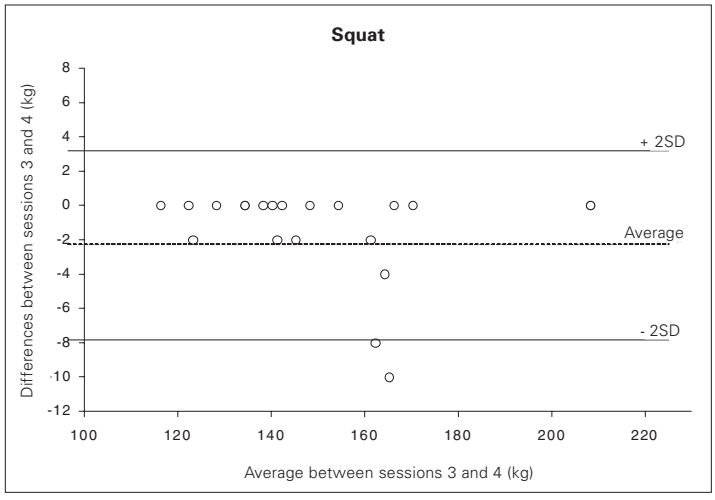

Fig. 2 *– Bland-Altman plotting for comparisons between sessions three and four of 1-RM tests for squat exercise (n = 21)*
Note – *Two points are superposed*

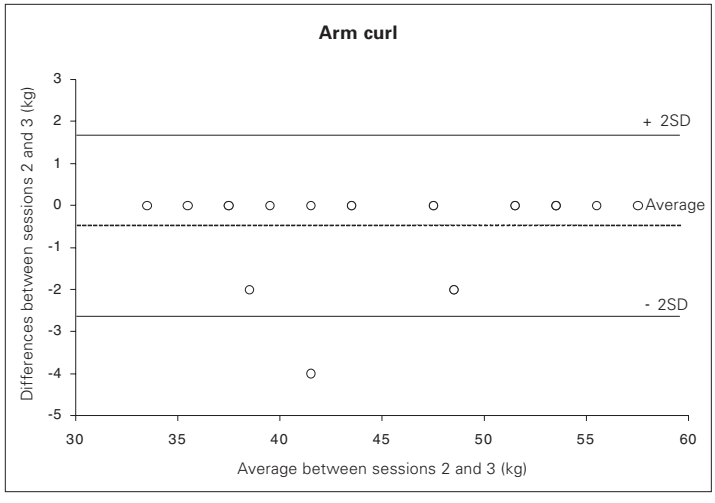

Fig. 3 *– Bland-Altman plotting for comparisons between sessions two and three of 1-RM tests for arm curl (n = 21)*
Note – *Seven points are superposed*

TABLE 3
Average of differences and confidence interval (95%) between pairs of evaluation of maximum strength by means of the 1-RM test (n = 21)

Bench press	**Sessions**			**Stabilization**
	1-2	**1-3**	**1-4**	**3-4**
Average of differences	–1.0	–1.3	–1.8	–0.5
Confidence interval	5.3	6.3	7.3	3.4
Squat	**Sessions**			**Stabilization**
	1-2	**1-3**	**1-4**	**3-4**
Average of differences	–2.7	–3.5	–5.0	–1.4
Confidence interval	12.7	16.0	22.7	10.9
Arm curl	**Sessions**			**Stabilization**
	1-2	**1-3**	**1-4**	**2-3**
Average of differences	–1.5	–2.0	–2.4	–0.5
Confidence interval	5.5	7.0	8.4	4.2

The results from table 3 demonstrate that both the average difference and the confidence interval, comprised between the concordance limits, were reduced in sessions where the 1-RM stabilization occurred, when compared with the other pairs of attempts. It is worth mentioning that this pattern was observed in all exercises investigated.

DISCUSSION

The results of the present study indicated significant increases on the muscular strength between different sessions of 1-RM tests in exercises bench press, squat and arm curl in subjects with previous experience with weight exercises.

These findings are quite interesting, once most studies using 1-RM tests for the evaluation of the muscular strength levels available in literature bring no information on the adoption of previous familiarization procedures of subjects to these types of tests in their experimental description. Thus, the interpretation of the results obtained in these studies may be quite impaired.

Although some authors report moderate or even high reliability indexes, according to the intra-class correlation coefficient for the 1-RM tests[7,8,16-18], the results must be carefully analyzed, once in the present study, despite the test and retest coefficients between the first and fourth sessions are high (bench press, r = 0.96; squat, r = 0.98; arm curl, r = 0.98), statistically significant differences between loads lifted were found in all exercises investigated when these two sessions were compared.

Thus, one believes that the use of the intra-class correlation analysis between measures would not be the most suitable procedure in these situations, once this index does not seem to be sufficiently sensible to analyze individual modifications[19].

In this context, the Bland and Altman[15] plotting was used in the present study, once it is a statistical resource that allows the analysis of concordance between measures obtained in the different 1-RM tests sessions. The results found enabled the corroboration of the moments in which the loads stabilization was verified in all exercises studied (figures 1-3).

It is worth mentioning that the values corresponding to the confidence interval between exercises were smaller for the stabilization sessions when compared with the other pairs of muscular strength evaluations (table 3). Therefore, a temporal pattern seems to be established when the concordance limits are adopted as reference for the identification of the occurrence of stabilization in 1-RM tests.

The importance of familiarization sessions for the attainment of more accurate results in the 1-RM tests has been recently reported in other studies[7-9]. In one of these studies, Ploutz-Snyder and Giamis[8] found significant increases on the muscular strength ($p < 0.05$) both for young women (12%; n = 7) and for elderly women (22%; n = 6) when the familiarization process to 1-RM test was analyzed. However, the number of familiarization sessions required for the loads stabilization was lower in young women when compared with elderly women (3-4 and 8-9, respectively). These numbers were higher than those found in the present study, which indicated the need of only two sessions of 1-RM tests for the arm curl and three sessions for the bench press and squat.

The differences between the present study and the study by Ploutz-Snyder and Giamis[8] may be attributed, at least in part, to the types of exercises and equipments used, to gender and to the different trainability levels and samples used in each study, once this study investigated young men only with previous experience with weight exercises.

The results found in this study suggest that the familiarization process to the 1-RM test is important, not only for individuals with no previous experience with weight exercises[7,8], but also for individuals with experience with this type of physical exercise.

Although there are no consistent information on the mechanisms responsible for the increase on the muscular strength in 1-RM repetitive tests, one believes that the mechanisms involved are similar to those verified in the initial weightlifting sessions, such as: increase on the recruitment of high-threshold motor units, improvement on the coordination of antagonistic muscular groups, increase on the stimulation frequency, improvement on the synchronization

of the stimulated motor units, among others, called by literature as neural adaptations[20-24].

One of these mechanisms, the co-activation of the antagonistic muscles to the movement performed, was corroborated by Carolan and Cafarelli[25], who verified, after eight weeks of training with weights, significant increases on the legs extension and strength concomitantly with the reduction on the co-activation of the antagonistic muscles (thigh flexors). It is worth mentioning that the highest reductions on the co-activation of the antagonistic muscles occurred at the first week of training.

Another possible neural mechanism involved in the initial increases on the muscular strength, the increase on the agonistic musculature activation, was investigated by Häkkinen *et al.*[26]. The authors reported statistically significant increases in the electromyographic signal of the thigh extensors both in men and women during the first two weeks of weight training, regardless the age range and the trainability levels.

The results of this study yet indicated a similar temporal pattern for the familiarization to the 1-RM test in exercises involving large muscular groups (bench press and squat), unlike that observed in the arm curl that involves smaller muscular groups. These results are in agreement with findings by Cronin and Henderson[7], who verified temporal differences for the familiarization to the 1-RM test in bench press and squat exercises that, according to the authors, could be attributed to differences in the size of the agonistic muscular groups involved in the execution of each one of these exercises, or even to the different complexity levels of the execution techniques. Considering that our sample was composed exclusively of young men (n = 10; 21.0 ± 2.7 years of age) with athletic history and without previous experience with weightlifting for at least six months, it seems that the lack of specific experience of subjects may also have influenced the familiarization temporal pattern to the 1-RM test in the exercises investigated.

It is worth mentioning that the exercises involving weights used in this study are frequently used in different weight training programs. Thus, the previous experience of subjects in the exercises performance may have contributed for the familiarization process to 1-RM tests to occur more quickly. Probably, if the exercises were not familiar to the subjects investigated, the responses could have been differentiated. Unfortunately, this hypothesis was not tested in the present study and further investigations are suggested.

CONCLUSION

The information obtained in this study indicates that the previous familiarization to 1-RM tests is vital for the analysis of the muscular strength including individuals with previous experience with weightlifting. However, it seems that the temporal pattern of the familiarization process is below the pattern previously verified in other studies involving untrained subjects with regard to this type of physical exercise. Besides, when the exercises to be tested involve large muscular groups, a longer familiarization period seems to be necessary when compared to exercises involving small muscular groups.

The results suggest, for an adequate evaluation of the muscular strength of young adult men with previous experience with weightlifting, at least three familiarization sessions in 1-RM tests for bench press and squat exercises and two sessions for arm curl.

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

REFERENCES

1. Anderson T, Kearney JT. Effects of three resistance training programs on muscular strength and absolute and relative endurance. Res Q Exerc Sport 1982;53: 1-7.
2. Baker D, Wilson G, Carlyon R. Periodization: effect on strength of manipulating volume and intensity. J Strength Cond Res 1994;8:235-42.
3. Chestnut JL, Docherty D. The effects of 4 and 10 repetition maximum weight-training protocols on neuromuscular adaptations in untrained men. J Strength Cond Res 1999;13:353-9.
4. Häkkinen K, Alen M, Komi PV. Changes in isometric force and relaxation-time, electromyographic and muscle fibre characteristics of human skeletal muscle during strength training and detraining. Acta Physiol Scand 1985;125:573-85.
5. Häkkinen KA, Pakarinen A, Alen M, Kauhanen H, Komi PV. Relationship between training volume, physical performance capacity, and serum hormone concentrations during prolonged training in elite weight lifters. Int J Sports Med 1987;8: 61-5.
6. Kraemer JB, Stone MH, O'Bryant HS, Conley MS, Johnson RL, Nieman DC, et al. Effects of single vs. multiple sets of weight training: impact of volume, intensity, and variation. J Strength Cond Res 1997;11:143-7.
7. Cronin JB, Henderson ME. Maximal strength and power assessment in novice weight trainers. J Strength Cond Res 2004;18:48-52.
8. Ploutz-Snyder LL, Giamis EL. Orientation and familiarization to 1RM strength testing in old and young women. J Strength Cond Res 2001;15:519-23.
9. Salvador EP, Dias RMR, Braghin RS, Cyrino ES. Influência da experiência em treinamento com pesos no processo de familiarização ao teste de 1-RM. In: III Congresso Científico Latino-Americano de Educação Física, Piracicaba, Unimep, 2004;1159.
10. Gordon CC, Chumlea WC, Roche AF. Stature, recumbent length, and weight. In: Lohman TG, Roche AF, Martorell R, editors. Anthropometric standardization reference manual. Champaign: Human Kinetics Books, 1988;3-8.
11. Slaughter MH, Lohman TG, Boileau RA, Stillman RJ, Van Loan M, Horswill CA, et al. Influence of maturation on relationship of skinfolds to body density: a cross-sectional study. Hum Biol 1984;56:681-9.
12. Siri WE. Body composition from fluid spaces and density: analysis of methods. In: Brozek J, Henschel A, editors. Techniques for measuring body composition. Washington: National Academy of Science, 1961;223-44.
13. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. Br J Nutr 1978;40:497-504.
14. Clarke DH. Adaptations in strength and muscular endurance resulting from exercise. Exer Sports Sci Rev 1973;1:73-102.
15. Bland JM, Altman DJ. Regression analysis. Lancet 1986;1:908-9.
16. Pereira MIR, Gomes PSC. Testes de força e resistência muscular: confiabilidade e predição de uma repetição máxima – Revisão e novas evidências. Rev Bras Med Esporte 2003;9:325-35.
17. Rikli RE, Jones CJ, Beam WC, Duncan SJ, Lamar B. Testing versus training effects on 1-RM strength assessment in older adults. Med Sci Sports Exerc 1996;28:S153.
18. Braith RW, Graves JE, Leggett SH, Pollock ML. Effect of training on the relationship between maximal and submaximal strength. Med Sci Sports Exerc 1993; 25:132-8.
19. Vincent WJ. Statistics in kinesiology. Champaign: Human Kinetics Books, 1999.
20. Komi PV. Training of muscle strength and power: interaction of neuromotoric, hypertrophic, and mechanical factors. Int J Sports Med 1986;7(Suppl 1):10-5.
21. Enoka RM. Neural adaptations with chronic physical activity. J Biomech 1997; 30:447-55.
22. Sale DG. Neural adaptation to strength training. In: Komi PV, editor. Strength and power training. Oxford: Blackwell Scientific, 1992;249-65.
23. Moritani T, Devries HA. Neural factors versus hypertrophy in the time course of muscle strength gains. Am J Phys Med 1979;58:115-30.
24. Narici MV, Roi GS, Landoni L, Minetti AE, Cerretelli P. Changes in force, cross-sectional area and neural activation during strength training and detraining of the human quadriceps. Eur J Appl Physiol 1989;59:310-9.
25. Carolan B, Cafarelli E. Adaptations in coactivation after isometric resistance training. J Appl Physiol 1992;73:911-7.
26. Häkkinen K, Kallinen M, Izquierdo M, Jokelainen K, Lassila H, Malkia E, et al. Changes in agonist-antagonist EMG, muscle CSA, and force during strength training in middle-aged and older people. J Appl Physiol 1998;84:1341-9.