Manipulation of exercise order and its influence on the number of repetitions and effort subjective perception in trained women

Walace Monteiro[1,2,4], Roberto Simão[1,3] and Paulo Farinatti[1,4]

ABSTRACT

Resistance exercises (RE) are prescribed in function of the combination of several variables. For some variables such as the exercises ordering, the evidences that guide the available recommendations reveal to be insufficient. The objective of this study was to investigate the influence of different RE execution orders on the number of repetitions and effort subjective perception (ESP) in trained women. The sample was composed of 12 women (22 ± 2 years) with at least six months of practice in RE. The data were collected in five alternated days. In the first, the PAR-Q questionnaire was applied, anamnesis for the identification of the physical activities performed and the anthropometrical measures. In the second and third days, the maximal load was measured and the reproducibility of the 10-maximum repetitions tests (10RM) in the selected exercises was tested. In the fourth and fifth days, the sessions with the two sequences proposed (SEQA and SEQB) were performed; one session with exercises involving the larger muscular groups and the other involving the smaller ones. Thus, the following exercises were performed in the SEQA: horizontal supine (HS), standing development (SD) and triceps in the pulley (TR), while in the SEQB, the following order was performed: TR, SD and HS. The volunteers performed three series of each exercise with loads of 10RM and intervals of three minutes between series and exercises. In each series, the maximum number of repetitions was measured. The results revealed significant differences in the average of repetitions in each sequence for all exercises, unlike what was observed for the ESP. In the sequences investigated, the last exercise performed always presented a lower number of repetitions, regardless the muscular group involved. In short, the exercise order tended to change the performance in both sequences observed, at least with regard to the training volume. This influence was more associated with the position of the exercise in the sequence than with the size of the muscular group or with the number of joints involved. The ESP results were similar in both sequences, suggesting that its value as fatigue indicative in RE sessions should be better analyzed.

1. Physical Activity and Health Promotion Laboratory – Rio de Janeiro State University (LABSAU-UERJ).
2. Exercise Physiology Laboratory – Air Force Physical Activity Sciences Institute (ICAF).
3. Physical Education Post-graduation Program – Gama Filho University (PPGEF-UGF).
4. Physical Activity Sciences Post-graduation Program – Salgado de Oliveira University (PGCAF-Universe).

Received in 14/12/04. 2nd version received in 8/3/05. Approved in 14/3/05.

Correspondence to: Walace Monteiro, Laboratório de Atividade Física e Promoção da Saúde, Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier, 524, 8º andar, sala 8.133F, Maracanã – 20599-900 – Rio de Janeiro, RJ, Brasil. E-mails: walacemonteiro@uol.com.br

Key words: Muscular strength. Training. Borg scale. Exercise. Physical fitness.

INTRODUCTION

The strength training is prescribed in function of the combination of several variables. Among them, the number of series, the recovery intervals and volume and the type and ordering of the selected exercises may be mentioned. The way these variables are manipulated results in different effects on the strength improvement and muscular hypertrophy. The position stand for healthy adults of the American College of Sports Medicine (ACSM)[1] presented an extend review on the progression models in resistance training involving these prescription variables.

Although doubts on the dose-response relation concerning many of these variables still remain, with regard to the exercise ordering, the evidences seem to be even less consistent. The only investigation mentioned by the ACSM[1] in its recommendations was published by Sforzo and Touey[2], proposing that the large muscular groups should be requested before the small ones in all training situations.

In order to investigate this question, two studies were performed[3,4] in our laboratory. In the first one[3], no difference in the effort subjective perception (ESP) was verified at the end of two sequences with different ordering for exercises involving the upper limbs, although the number of repetitions for the same load had been different. On the other hand, in the second study[4], when the effects of the exercise ordering in upper and lower limbs were compared, Simão *et al.*[4] verified differences on the manipulated loads and on ESP in distinct sequences. One observes that the ESP results were conflicting, indicating the necessity of new investigations for a better understanding on the problem. Thus, the objective of the present study was to investigate the effect of the exercise order manipulation on the number of repetitions and ESP in exercises for upper limbs for women with previous strength training experience.

MATERIAL AND METHODS

Sample

Twelve women (22 ± 2 years; 64 ± 11 kg; 166 ± 7 cm; 22 ± 2% of fat) with at least six months of RE experience participated in this study. All participants practiced the activity at least three times a week. Before data collecting, the volunteers answered to the PAR-Q[5] questionnaire and signed the term of post-informed consent, according to Resolution 196/96 of the Health National Council and the study protocol was approved by the Ethics Research Committee. Individuals presenting osteo-myo-articular problems that could influence on the performance of the exercises proposed were excluded from the study.

Protocol

Data collecting

The data collecting was performed in five alternated days for each volunteer. In the first laboratory visit, the following procedures were applied: PAR-Q questionnaire, anamnesis aimed at the identification of the physical activities and anthropometrical measures. In the second and third days, 10 maximum repetition tests (10RM) in the exercises selected for each volunteer were conducted in order to identify the maximal load and its respective reproducibility. Finally, in the fourth and fifth days, training sessions for both sequences proposed were conducted.

Anthropometrical measures

The body mass and stature were assessed, according to standardizations described by Gordon *et al.*[7] and Martin *et al.*[8], respectively. In order to estimate the body density and the fat percentile, the equations proposed by Jackson and Pollock[9], and Siri[10] were used.

10 maximum repetition test (10RM)

The 10RM test was performed according to the following order: horizontal (HS), standing development (SD), and triceps in the pulley (TR). The exercises were selected due to their dissemination in training centers and execution easiness.

With the objective of reducing the error margin in the 10RM tests, the following strategies were adopted: a) standardized instructions were provided before the test, so that the appraised subject was aware of the entire routine involving the data collection; b) the appraised subject was instructed on the exercise execution technique; c) the appraiser was watchful with regard to the position adopted by the appraised at the measurement moment, once small variations in the positioning of the joints involved in the movement could involve other muscles, leading to misinterpretations of the scores obtained; d) verbal encouragements were performed in order to maintain the stimulation level high; e) additional weights used in the study were previously calibrated in precision scale. Intervals between attempts in each exercise during the 10RM test were fixed between two and five minutes[6]. After load attainment in a given exercise, intervals not shorter than 10 minutes were given before starting the next exercise.

The following exercise execution steps were defined: initial position and development, the latter involving contraction concentric and eccentric phases. These steps are described as follows:

1) Horizontal supine – a) initial position: dorsal decubitus with arms raised supporting the bar, semi-inflected knees and hips with feet on the support of the device; b) development: from the eccentric phase (90º between arm and forearm), the complete extension of the elbow and the horizontal flexion of shoulders were performed.

2) Standing development – a) initial position: standing in the development device, semi-inflected knees with extended elbows and arms raised; b) development: from the eccentric phase (90º between arm and forearm), the complete extension of the elbow with shoulders abduction were performed.

3) Triceps in the pulley – a) initial position: individual on her foot, legs in parallel with a small lateral spacing, semi-inflected knees, hips at anatomical position, extended elbows with hands in pronation position holding bar and head positioned at the Frankfurt plane; b) development: from the eccentric phase (90º between arm and forearm), the complete extension of the elbow was performed.

After the attainment of the maximum loads in the 10RM test, the individuals rested for 48 hours, being reevaluated for the attainment of the test reproducibility (test and retest). The load corresponding to 10RM was considered as the load established in both days with difference lower than 5%. In case of higher difference, the subjects should attend to the laboratory once again, in order to perform new test, and the difference calculation was performed. In intervals between the test sessions, the performance of exercises was not allowed for not influencing the results. The loads used in the training sequences were the highest obtained in the test and retest situations for individuals who did not obtain exactly the same loads in both situations.

After attainment of the 10RM loads, two RE sessions with interval of 48 hours were performed in two sequences: sequence A (SEQA): HS, SD and TR; sequence B (SEQB): TR, SD and HS. The inclusion of individuals in the performance of sequences was defined alternately through the Latin square technique.

Before performing the first exercise in the sequence adopted, 12 repetitions with 40% of the 10RM were performed. After warm-up exercises, a 2-minute interval before the exercise session was given. Three series of each exercise were performed in both sequences with loads of 10RM up to the concentric failure, with 3-minute intervals between series and exercises. For the performance of the maximum number of repetitions until voluntary exhaustion, the appraiser encouraged the volunteers. In each series, the maximum number of repetitions performed was measured. At the end of the performance of each ordered sequence, the appraised was questioned with regard to her ESP, adopting the Borg scale (CR10)[11] as reference.

Statistical treatment

The reproducibility of the 10RM tests was determined through the intraclass correlation coefficient. In order to verify differences on the results obtained for the number of repetitions in the different sequences and series performed, the two-way analysis of variance ANOVA with repeated measures was used, followed by the Tukey *post-hoc* test. In the case of ESP, the differences were verified by the Wilcoxon test. In all treatments, the significance level adopted was of $p < 0.05$. The software *Statistica* was used for the analyses (Statsoft, Tulsa, USA).

RESULTS

The load measure reproducibility in the 10RM test and retest was considered as satisfactory, with intraclass correlation coefficients of 0.91, 0.93 and 0.94 for HS, SD and TR, respectively. Table 1 illustrates the values observed for the number of repetitions in each series, as well as the total average in each sequence. In SEQA, no differences between the three series were identified. On the other hand, in SEQB, differences were only observed for exercise HS between the 1st and 2nd series and between the 1st and 3rd series. The comparison of series between sequences identified differences for the 2nd and 3rd series of HS and for the 3rd series of TR. In relation to the total average of repetitions developed in each exercise per sequence, differences were observed in all exercises (figure 1). With regard to the ESP, no differences were identified between SEQA (median = 5.5) and SEQB (median = 6.5) ($p = 0.59$).

TABLE 1
Number of repetitions for horizontal supine (HS), development (SD) and triceps in the pulley (TR) in each series

Series	Sequence A (SEQA)			Sequence B (SEQB)		
	SH	DP	TR	SH	DP	TR
1st series	9.9 ± 0.3	8.9 ± 1.6	9.3 ± 0.6	9.5 ± 1.0*†	9.9 ± 0.3	9.9 ± 0.3
2nd series	9.9 ± 0.3*	8.8 ± 1.7	9.7 ± 0.5	8.6 ± 1.4	9.6 ± 0.6	9.9 ± 0.3
3rd series	9.1 ± 0.9†	8.5 ± 1.6	9.3 ± 0.6‡	8.0 ± 1.6	9.3 ± 1.4	9.9 ± 0.3
Total average	9.6 ± 0.7#	8.7 ± 1.6#	9.4 ± 0.6#	8.7 ± 1.5	9.7 ± 0.9	9.9 ± 0.3

* significant difference for the 2nd series of the HS of SEQB.
† significant difference for the 3rd series of the HS of SEQB.
‡ significant difference for the 3rd series of the TR of SEQB.
# significant difference for the total average of repetitions of HS, SD and TR.

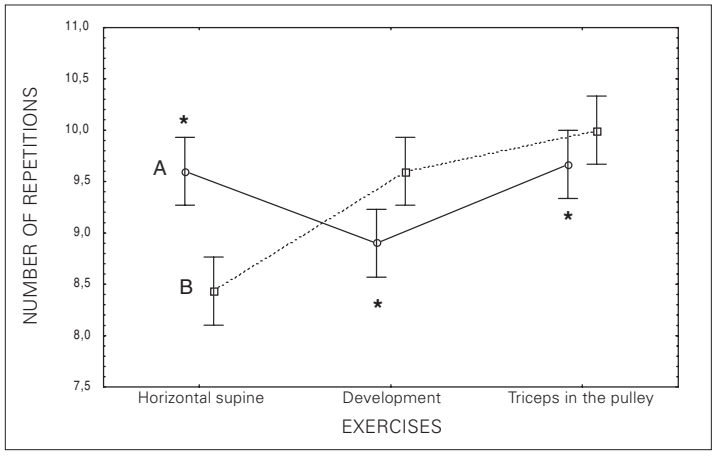

Fig. 1 *– Average and standard deviation for the number of repetitions in each exercise in sequences A and B. Asterisks indicate significant difference between sequences for a given exercise.*

DISCUSSION

An important information to verify whether the load in a given exercise is actually maximal is to know if this load is reproducible. Thus, before testing the effect of different exercises orderings on the strength performance, the reproducibility for loads obtained at 10RM in test and retest situations is verified. The intraclass correlation coefficients showed to be high in all exercises tested. One aspect that may have influenced these results is the fact that the individuals were trained to perform exercises at 10RM. Furthermore, the exercises selected were part of the training usual routine. The loads reproducibility in the exercises investigated assured the data quality for the performance of the training sessions in the different sequences adopted.

One of the few studies in literature that analyzed the effects of the exercise order on the number of repetitions was conducted by Sforzo and Touey[2]. These authors investigated trained men who performed two training sessions involving three exercises for lower limbs and three exercises for trunk. As result, it was verified that for both types of exercises, the manipulation of the exercise order affected the number of repetitions for a given load. It was also observed that, when starting with the small muscular groups, this affected the performance of the large ones and vice-versa, thus promoting a decrease on the number of repetitions performed. Although the first worked muscular group, regardless its size, has affected the load supported in the subsequent exercises, when the work started with the large muscular groups, the work load tended to be higher, considering the sum of loads in exercises.

Although there are some differences in the methodology of the present study from that conducted by Sforzo and Touey[2], the results of both studies were corroborated, as the number of repetitions seemed to be influenced by the order of the exercises performed. It is worth emphasizing that, in both works, the exercises were conducted in a sole session for upper limbs involving the same joints. These results allow inferring that, regardless the initially worked muscular group, the fatigue levels tend to influence the performance in the subsequent exercises.

Also with the objective of investigating the influence of different exercise execution orders on the number of repetitions performed, Simão *et al.*[3] researched the effects of five exercises for lower limbs. A 10RM test was initially applied in the exercises performed by 18 individuals. Each subject accomplished two training sessions separated by an interval of 48 hours. One session started with the large muscular groups and proceeded to the small ones according to the following order: horizontal supine, front pull, sitting development, biceps and triceps, while the other session was performed the other way around. During both sequences, three series of each exercise were performed up to the concentric failure with two minutes of interval between series and exercises. The performance both in the large and in the small muscular groups for exercises latter executed resulted in a smaller number of repetitions, except for the sitting development. One reason that could have influenced in this result particularly is the fact that its positioning was not changed in both sequences proposed: in fact, this exercise was always found in between sequences.

In the present study, the data obtained corroborated almost fully with data presented by Simão *et al.*[3], except for the development, for which a statistical difference for the number of repetitions was observed. A hypothesis that could explain this difference is related to the fact that the supine exercise requires higher recruitment of motor units of the scapular waist. Therefore, a higher fatigue could occur when performing the development after horizontal supine. Although there are some similarities between the present study and the one previously developed by our group[3], some differences are remarkable. In that study, five exercises in which no muscular group was primarily requested in two successive sequences were evaluated, and only four women composed the sample. Besides, the recovery intervals between series and exercises were of two minutes. In the present investigation, exercises that primarily requested the same muscular groups in almost all sequences were used. In addition, only trained women composed the sample and the interval between series and exercises was of three minutes. Therefore, the training load imposed in this study was far lower, when compared to the load applied in the experiment mentioned above[3]. Even considering these methodological differences, one may assure that the results of both studies were quite similar.

In another study, Simão *et al.*[4] investigated the influence of different resistance exercise orders on the number of repetitions in women presenting at least two years of training experience. Initially, the maximum load was tested (1RM) in exercises leg-press (LEG), horizontal supine (HS), knees extension in extensor chair (EXT), sitting development (SD), knees flexion in flexor chair (FLE) and triceps extension in the pulley (TR). Next, three series with 80% of the 1RM until exhaustion were performed. The exercises were conducted in two different sequences with two minutes of interval between series and exercises. In the first sequence, the exercises were performed according to the following order: HS, SD, TR, LEG, EXT and FLE, while in the second sequence the order was: FLE, EXT, LEG, TR, SD and HS. Considering the number of repetitions in each sequence, a significant difference was observed in all exercises. Thus, regardless the size of the muscular group, the last exercise in the sequence presented the lower number of repetitions.

When results of our study are compared with results presented by Simão *et al.*[4], one verifies similarities between exercises for upper limbs and in the fact that the sample was composed of young trained women. The differences lay in the test to establish the maximum load, and in the interval time between series and exercises. In the present study, a lower number of repetitions in exercise SD after HS was observed. On the other hand, Simão *et al.*[4] verified a higher number of repetitions after supine execution. One of the factors that could have led to differences between both experiments may have been the body posture adopted for the performance of the exercises. In the present study, the SD was performed with appraised on her foot, while Simão *et al.*[4] adopted the sitting posture. One speculates that, when the exercise is performed in sitting position, a higher body stabilization is obtained, causing a lower actuation of the stabilizer muscular groups, unlike exercises performed in standing position, in which a higher body unbalance and oscillation may lead to a differentiated recruitment of motor units. Some studies reinforce the argumentation in behalf of this hypothesis. For example, Clark *et al.*[12], and Sternlicht and Rugg[13] recently investigated the influence of the body posi-

tion on the fibers recruitment in abdominal exercises, and verified differences in the electromyographic responses and the recruitment of the motor units for exercises conducted at different body positions. These findings were corroborated by Anderson and Behm[14], when investigating other exercises.

With regard to the use of the ESP for the follow-up of the effort intensity in programs involving resistance exercises, initial investigations suggest that the Borg scale (CR10) may be used with this purpose[15,16]. Despite the ESP being frequently used as effort intensity indicative in aerobic activities, its utilization is still a little limited in resistance exercises. Recent studies have demonstrated that the ESP may reflect the intensity of this type of training, being more sensitive to the fatigue relative to the active musculature during exercise[15,17,18] than in the discrimination of the fatigue level in general[19]. However, generally, one may consider that the literature is poor with regard to the determination of the potential use of the ESP in order to verify the influence of the manipulation of variables of the strength training prescription on the muscular fatigue, as well as its relation with the number of repetitions.

In the present study, the ESP was measured shortly after the end of the proposed sequences. Significant differences between sequences were not found, maybe due to the fact that the total work volume in each sequence was similar and the small number of exercises performed. These findings were in agreement with findings of Simão *et al.*[3], but conflicting with findings of Simão *et al.*[4]. Some differences in the methodological designs of some studies may be in the origin of this discrepancy. One of the factors that could be mentioned are related to the way loads were established for the conduction of exercises. In Simão *et al.*[4], the training prescription was conducted at 80% of the 1RM until exhaustion, with no previous limitation on the number of repetitions, unlike in Simão *et al.*[3], where the effort time was shorter due to the fact that the individuals necessarily performed a maximum of 10RM.

The interval between series, regardless the exercises execution order, may influence the maximum number of repetitions performed. In this study, 3-minute fixed intervals between series and exercises were adopted. In investigations previously performed[3,4], 2-minute intervals were applied for exercises involving the same body segments. One should emphasize that the overall fatigue could influence the performance on the subsequent exercises. According to Kraemer *et al.*[20], there would be influence of the rest periods on some fatigue indicatives, such as blood lactate, hormone concentrations and metabolic reactions.

Although in 1RM tests, the application of intervals from one to five minutes presents no significant differences concerning the load moved in the next attempt[21-25], in works with higher training volume (series x repetitions), this may occur. Therefore, the results of this study could have been affected, in case intervals longer or shorter than three minutes between series and exercises were applied. However, the influence of intervals on the responses to resistance exercises still requires higher scientific evidences, especially concerning the role the exercise order plays in training programs.

Generally, the results obtained suggest that the musculature requested in the first exercise performs a higher number of repetitions for a given effort load. On the other hand, these exercises, when performed at the end of the session, present a decline on the mount of repetitions. In this context, in the prescription of a resistance exercise session aimed at maximizing strength and muscular hypertrophy, the first exercise of the sequence should probably be the exercise one desires to privilege in the strength gains. Other studies should be conducted in order to verify the influence of the exercise order manipulation on strength and muscular hypertrophy responses.

In conclusion, the manipulation of the exercise order in a sequence of resistance exercises for the upper limbs tends to change the performance at least in relation to the work volume. The yield of exercises performed at the end of a session was negatively affected with regard to the number of repetitions performed, regardless the size of the muscular group and number of joints involved in the exercises. In relation to the ESP, at least considering the sequences investigated, the results did not follow the reduction on the number of repetitions. Indeed, at the end of sequences, the exertion perception – and, hence, the fatigue – was similar. This result makes us believe that the value of the local ESP as fatigue indicator in strength training sessions should be better analyzed in the future.

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

REFERENCES

1. American College of Sports Medicine. Position stand on progression models in resistance training for healthy adults. Med Sci Sports Exerc 2002;34:364-80.
2. Sforzo GA, Touey PR. Manipulating exercise order affects muscular performance during a resistance exercise training session. J Strength Cond Res 1996;10:20-4.
3. Simão R, Farinatti PTV, Polito MD, Maior AS, Fleck SJ. Influence of exercise order on the number of repetitions performed and perceived during resistive exercises. J Strength Cond Res 2005;19:84-8.
4. Simão R, Fleck SJ, Polito MD, Viveiros L, Farinatti PTV. Influence of exercise order on the number of repetitions performed and perceived exertion during resistive exercises in trained women. J Strength Cond Res 2005;19:no prelo.
5. Shephard RJ. PAR-Q: Canadian home fitness test and exercise screening alternatives. Sports Med 1992;5:185-95.
6. Baechle TR, Earle RW. Essentials of strength training and conditioning. Champaign: Human Kinetics, 2000.
7. Gordon C, Chunlea WC, Roche AF. Stature, recumbent length, and weight. In: Lohman TG, Roche AF, Martorell R, editors. Antropometric standardization reference manual. Champaign: Human Kinetics, 1988;3-8.
8. Martin AD, Carter JEL, Hendy KC, Malina RM. Segment lengths. In: Lohman TG, Roche AF, Martorell R, editors. Anthropometric standardization reference manual. Champaign: Human Kinetics, 1988;9-26.
9. Jackson AS, Pollock ML. Generalized equations for predicting body density for men. Br J Nutr 1978;40:497-504.
10. Siri W.E. Body composition from fluid spaces and density. Washington: National Academy of Science, 1961.
11. Borg G. Perceived exertion and pain scales. Champaign: Human Kinetics, 1998.
12. Clark KM, Holt LE, Sinyard J. Electromyographic comparison of the upper and lower rectus abdominis during abdominal exercises. J Strength Cond Res 2003; 17:475-83.
13. Sternlicht E, Rugg S. Electromyographic analysis of abdominal muscle activity using portable abdominal exercise devices and traditional crunch. J Strength Cond Res 2003;17:463-8.
14. Anderson KG, Behm DG. Maintenance of EMG activity and loss of force output with instability. J Strength Cond Res 2004;18:637-40.
15. Day ML, McGuigan R, Glenn B, Foster C. Monitoring exercise intensity during resistance training using the session RPE scale. J Strength Cond Res 2004;18: 353-8.
16. Lagally KM, McCaw ST, Geoff GT, Medema, Thomas DQ. Ratings of perceived exertion and muscle activity during the bench press exercise in recreational and novice lifters. J Strength Cond Res 2004;18:359-64.
17. Lagally KM, Robertson RT, Gallagher KI, Goss FL, Jakicic JM, Lephart SM, et al. Perceived exertion, electromyography, and blood lactate during acute bouts of resistance exercise. Med Sci Sports Exerc 2002;34:552-9.
18. Tomporowski PD. Men's and women's perception of effort during progressive-resistance strength training. Percept Motor Skills 2001;92:368-72.
19. Lagally KM, Robertson RJ, Gallagher KI, Goss FL. Ratings of perceived exertion during low- and high-intensity resistance exercise by young adults. Percep Motor Skills 2002;94:723-31.
20. Kraemer WJ, Noble BJ, Clark MJ, Culver BW. Physiologic responses to heavy-resistance exercise with very short rest period. Int J Sports Med 1987;8:247-52.
21. Matuszak ME, Fry AC, Weiss LW, Ireland TR, McKnight MM. Effect of rest interval length on repeated 1 repetition maximum back squats. J Strength Cond Res 2003;17:634-7.
22. Pincivero DM, Lephart SM, Karunakara RG. Effects of intrasession rest interval on strength recovery and reliability during high intensity exercise. J Strength Cond Res 1998;12:152-6.
23. Pincivero DM, Lephart SM, Karunakara RG. Effects of rest interval on isokinetic strength and functional performance after short-term high intensity training. Br J Sports Med 1997;31:229-34.
24. Sewall LP, Lander JE. The effects of rest on maximal efforts in the squat and bench press. J Appl Sport Sci Res 1991;5:96-9.
25. Weir JP, Wagner LL, Housh TJ. The effect of rest interval length on repeated maximal bench press. J Strength Cond Res 1994;8:58-60.