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

Walace Monteiro¹,²,⁴, Roberto Simão¹,³ and Paulo Farinatti¹,⁴

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 sequence, 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 and effort subjective perception (ESP) was verified at the end of two investigations for a better understanding on the problem. Thus, the ESP results were conflicting, indicating the necessity of new investigations for a better understanding on the problem. 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)¹¹ presented an extend review on the progression models in resistance training involving these prescription variables.

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)¹¹ 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 ACSM¹¹ in its recommendations was published by Sforzo and Touey⁵, 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 performed³,⁴ in our laboratory. In the first one³, 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 study⁴, 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-Q³ 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.

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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 influence 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 (90° 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 (90° 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 (90° 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 with 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>
<thead>
<tr>
<th>TABLE 1</th>
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<tbody>
<tr>
<td>Number of repetitions for horizontal supine (HS), standing development (SD) and triceps in the pulley (TR) in each series</td>
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<td>Series</td>
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<td>3rd series</td>
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<td>Total average</td>
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* 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 2nd series of the TR of SEQB. § significant difference for the total average of repetitions of HS, SD and TR.
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.(15) 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.(15), 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(28), 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. Thus, regarding the recovery intervals between series and exercises, the difference between both works may 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 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 muscle mass 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 during exercise[15,17,18] rather than in the discrimination of the fatigue level in general[19]. However, in general, 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 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