INFLUENCE OF EXERCISE ORDER ON MAXIMUM STRENGTH AND MUSCLE VOLUME IN NONLINEAR PERIODIZED RESISTANCE TRAINING

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ABSTRACT

Spineti, J, Freitas de Salles, B, Rhea, MR, Lavigne, D, Matta, T, Miranda, F, Fernandes, L, and Simão, R. Influence of exercise order on maximum strength and muscle volume in nonlinear periodized resistance training. J Strength Cond Res 24(11): 2962–2969, 2010—The purpose of this study was to examine the influence of exercise order on strength and muscle volume (MV) after 12 weeks of nonlinear periodized resistance training. The participants were randomly assigned into 3 groups. One group began performing large muscle group exercises and progressed to small muscle group exercises (LG-SM), whereas another group started with small muscle group exercises and advanced to large muscle group exercises (SM-LG). The exercise order for LG-SM was bench press (BP), machine lat pull-down (LPD), triceps extension (TE), and biceps curl (BC). The order for the SM-LG was BC, TE, LPD, and BP. The third group did not exercise and served as a control group (CG). Training frequency was 2 sessions per week with at least 72 hours of rest between sessions. Muscle volume was assessed at baseline and after 6 weeks and 12 weeks of training by ultrasound techniques. One repetition maximum strength for all exercises was assessed at baseline and after 12 weeks of training. Effect size data demonstrated that differences in strength and MV were exhibited based on exercise order. Both training groups demonstrated greater strength improvements than the CG, but only BP strength increased to a greater magnitude in the LG-SM group as compared with the SM-LG. In all other strength measures (LPD, TE, and BC), the SM-LG group showed significantly greater strength increases. Triceps MV increased in the SM-LG group; however, biceps MV did not differ significantly between the training groups. In conclusion, if an exercise is important for the training goals of a program, then it should be placed at the beginning of the training session, regardless of whether or not it is a large muscle group exercise or a small muscle group exercise.

KEY WORDS muscle adaptation, weight lifting, physical fitness, periodization, muscular hypertrophy

INTRODUCTION

The choice of exercises and the order of exercises performed during a resistance training session is an important consideration in program design (6). Typically, exercise order dictates that large muscle group or multi-joint exercises be performed before small muscle group or single joint exercises (1,6,12). Recently, some studies (13,14,16) have observed that performing either large or small muscle group exercises at the end of an exercise sequence resulted in significantly fewer repetitions compared with when the same exercises were performed early in an exercise sequence. With results quite similar to these studies in relation to the number of repetitions, Gentil et al. (5) recommended that exercises needing maximal adaptation be placed at the beginning of an exercise session (5). Bellezza et al. (2) suggested that small to large exercise order may have beneficial physiological and psychological outcomes and potentially influence exercise adherence.

To our knowledge, there are only 2 studies that involve manipulating exercise order with the investigation of the influence on strength (3) and muscle thickness (15). Dias et al. (3) examined the influence of exercise order on strength in untrained young men after 8 weeks of non-periodized resistance training. One group began with large muscle group exercises and progressed to small muscle group exercises, whereas another started with small muscle exercises and advanced to large muscle exercises. Both groups resulted in significant increases in 1 repetition maximum strength (IRM) compared with the control group (CG). The small muscle exercises revealed significantly higher strength gains when placed first, demonstrating that the exercise order to small muscle exercises may be particularly important during the initial stages of resistance training in untrained young men.
On the other hand, Simão et al. (15) examined the influence of exercise order on strength and muscle thickness in untrained men after 12 weeks of linear periodized resistance training and the effect size data demonstrated differences in strength and muscle thickness based on exercise order. In conclusion, if an exercise is important for individual training goals, it should be performed at the beginning of the training session, whether or not it is a large or a small muscle group exercise.

It appears that there is a need for further investigation of exercise order. Therefore, the purpose of this study was to examine the influence of exercise order on strength and muscle volume (MV) during 12 weeks of nonlinear periodized training in untrained men. It was hypothesized that strength and MV changes would be negatively impacted among exercises placed at the end of an exercise session when compared with those conducted early in the session.

**METHODS**

**Experimental Approach to the Problem**

Thirty men were randomly assigned to 3 groups. One group trained with large muscle group exercises, progressing toward small muscle group exercises (LG-SM) (n = 11). The second group trained using the exact opposite exercise order, beginning with small muscle group exercises and progressing toward large muscle group exercises (SM-LG); and the third group served as a CG. The study was a randomized controlled trial, and the subjects performed 1RM on 2 non-consecutive days for all exercises using a counterbalanced order. Before the first 1RM testing session, the MV was measured using an ultrasound (US) technique. During the following 12 weeks (2 sessions/week), the 2 training programs were performed in nonlinear periodized fashion. Follow-up testing of strength and MV was conducted to examine each variable before and after 12 weeks of training.

**Subjects**

Thirty men from the Sergeants School from Brazil Navy were randomly assigned to 3 groups. One group trained with large muscle group exercises, progressing toward small muscle group exercises (LG-SM) (n = 11). The second group trained using the exact opposite exercise order, beginning with small muscle group exercises and progressing toward large muscle group exercises (SM-LG) (n = 10). The third group served as a CG (n = 9) and continued performing regular military physical activity during the 12-week period, devoid of any resistance training. There were no differences (p > 0.05) between groups in height, body mass, and percent body fat before training (Table 1). To meet the study inclusion criteria, all participants needed to have the following characteristics: (a) they were physically active but had not performed resistance training for at least 6 months before the start of the study; (b) they were not performing any type of regular physical activity for the duration of the study, other than the prescribed resistance training, and regular military physical activity program; (c) they did not have any functional limitation for the resistance training or the performance of the 1RM tests; (d) they did not present any medical condition that could influence the training program; and (e) they did not use any nutritional supplementation (the military diet was the same for all the participants). All participants read and signed an informed consent form, which thoroughly explained the testing and training procedures they would be performing during the study. The experimental procedures were approved by the Ethics Committee of Rio de Janeiro Federal University.

1 Repetition Maximum Strength Testing

After 2 weeks of the resistance training familiarization period (4 sessions), all participants completed 3 familiarization sessions of the 1RM test protocol with 48 to 72 hours between sessions. The 1RM tests were then performed on 2 non-consecutive days for all exercises using a counterbalanced order. On day 1, the first 1RM tests were performed, and after 48 to 72 hours, the 1RM tests were repeated to determine test-retest reliability. The heaviest load achieved on either of the test days was considered the pre-training 1RM. No exercise was allowed in the 48 hours between 1RM tests, so as not to interfere with the test-retest reliability results. The 1RM testing protocol has been described previously (14).

To minimize any error during 1RM tests, the following strategies were adopted: (a) standardized instructions concerning the testing procedure were given to participants before the test; (b) participants received standardized instructions on exercise technique; (c) verbal encouragement was provided during the testing procedure; and (d) the mass of all weights and bars used were determined using a precision scale. The 1RM was determined in fewer than 5 attempts with a rest interval of 5 minutes between 1RM attempts, and 10 minutes was allowed before the start of the test of the next exercise. After the 12 weeks of training, the 1RM test was performed similarly to the pre-training test to compare the strength gains in those exercises.

**Muscle Volume Measurements**

Muscle volumes for biceps and triceps muscles were assessed at baseline and after 6 and 12 weeks of training. Measurements were assessed by US techniques (EUB-405, Hitachi, Japan) with an electronic linear array probe of 7.5 MHz wave frequency. At 60% of the right arm length, the circumference and the muscle thickness measurements of elbow flexors (Figure 1) and extensors (Figure 2) were applied (7).

Muscle thickness was considered as the distance between the interfaces of the muscle tissue from the subcutaneous fat to the bone (Figures 1 and 2) (4,7).

The estimation of the MVs of the elbow flexors and extensors from muscle thickness was calculated using the equations described by Fukunaga et al. (4). Testing was conducted at the same time of day for all follow-up tests.

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Procedures
The exercise order for LG-SM was barbell bench press (BP), machine front lat pull-down (LPD), machine triceps extension (TE), and free weight standing biceps curl with a straight bar (BC). The exercise order for SM-LG was BC, TE, LPD, and BP. The CG did not take part in the resistance training program. In this study, a nonlinear periodized resistance training program was used. In one session, the subjects accomplished 4 sets with light intensity (12–15 repetitions) in each exercise with 1-minute rest between the sets; in the next session, the subjects accomplished 3 sets with moderate intensity (8–10 repetitions) in each exercise with 2-minute rest between the sets; and in the third and final session of the cycle, the subjects accomplished 2 sets with high intensity (3–5 repetitions) in each exercise with 3-minute rest between the sets. During the exercise sessions, participants were verbally encouraged to perform all sets to concentric failure and the same definitions of a complete range of motion used during the 1RM testing were used to define completion of a successful repetition. There was no attempt to control the velocity of the repetitions performed. Whenever an individual could perform more than the prescribed number of repetitions for all sets of a given exercise, the resistance for that particular exercise was increased. Frequency of the training program was 2 sessions per week with at least 72 hours of rest between sessions. A total of 24 sessions (8 cycles of 3 sessions) was performed in the 12-week training period with all sessions occurring between 7 and 8 AM. Before each training session, the participants performed a specific warm-up, consisting of 20 repetitions with approximately 50% of the resistance used in the first exercise of the training session. Adherence to the program was 100% for all training groups, but only 91.7% of LG-SM, 83.3% of SM-LG, and 75% of CG subjects accomplished all time point measures. It should be noted that all training sessions were supervised by an experienced strength and conditioning professional.

Statistical Analyses
Intraclass correlation coefficients (ICCs) were used to determine 1RM test-retest reliability. The ICC method was used based on a repeat measurement of maximal strength. Coefficient of variation (CV) was used to calculate within-participant variation (CV% = [SD/mean] × 100). The statistical analysis was initially done by the Shapiro-Wilk test.

| Table 1. Baseline anthropometric characteristics (mean ± SD).* |
|-----------------|-----------------|-----------------|-----------------|
| Group           | Age, y          | Height, cm      | Weight, kg      | Body fat, %     |
| LG-SM (n = 11)  | 29.7 ± 1.0      | 173.6 ± 7.2     | 79.4 ± 13.1     | 15.1 ± 5.1      |
| SM-LG (n = 10)  | 30.5 ± 1.7      | 173.0 ± 6.5     | 81.8 ± 15.4     | 17.2 ± 6.1      |
| CG (n = 9)      | 25.8 ± 3.6      | 171.1 ± 6.3     | 73.9 ± 9.9      | 15.3 ± 6.9      |

*CG = control group.
<table>
<thead>
<tr>
<th>Group</th>
<th>BP Lat pull-down</th>
<th>TE</th>
<th>BC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline 12 wks</td>
<td>Baseline 12 wks</td>
<td>Baseline 12 wks</td>
</tr>
<tr>
<td>LG-SM (n = 11)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1RM, kg</td>
<td>76.1 ± 9.7</td>
<td>92.0 ± 15.5</td>
<td>38.5 ± 5.7</td>
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<td>Kilograms/body mass</td>
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<td>1.16 ± 0.14</td>
<td>0.49 ± 0.09</td>
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<tr>
<td>CV, %</td>
<td>12.8 ± 11.2</td>
<td>16.8 ± 10.5</td>
<td>14.8 ± 14.2</td>
</tr>
<tr>
<td>SM-LG (n = 10)</td>
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<tr>
<td>1RM, kg</td>
<td>70.0 ± 16.1</td>
<td>82.5 ± 13.0</td>
<td>32.7 ± 4.4</td>
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<td>1.04 ± 0.2</td>
<td>0.41 ± 0.06</td>
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<tr>
<td>CV, %</td>
<td>21.8 ± 16.6</td>
<td>13.0 ± 9.6</td>
<td>10.0 ± 13.9</td>
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<tr>
<td>CG (n = 9)</td>
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<tr>
<td>1RM, kg</td>
<td>71.6 ± 9.4</td>
<td>86.6 ± 11</td>
<td>34.7 ± 3.1</td>
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<tr>
<td>Kilograms/body mass</td>
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<td>1.19 ± 0.23</td>
<td>0.48 ± 0.08</td>
</tr>
<tr>
<td>CV, %</td>
<td>13.1 ± 12.3</td>
<td>12.7 ± 11.2</td>
<td>13.0 ± 10.2</td>
</tr>
</tbody>
</table>

*CV = coefficient of variation; 1RM = 1 repetition maximum.
†Values of 1RM tests are expressed in kilograms.
‡Significant difference from baseline.
§Significant difference from CG.
normality test and by the homoscedasticity test (Bartlett’s criterion). All variables presented normal distribution and homoscedasticity. After a 2 (pre–post) by 3- (groups) way analysis of variance (ANOVA) (time [baseline vs. 12 weeks training] × group [SM-LG vs. LG-SM vs. CG]) was used to analyze differences among the groups in the 1RM load and kilogram of body mass (1RM load/body mass). A 3 (pre–middle–post) by 3- (groups) way ANOVA (time [baseline vs. six vs. 12 weeks training] × group [SM-LG vs. LG-SM vs. CG]) was used to analyze differences among the groups in the MVs. The calculation of percentage increases by the effect size in strength and MV (the difference between pretest and posttest scores divided by the pretest standard deviation), and the scale proposed by Rhea (9) was used. A 1 by 3- (groups) way ANOVA (time [baseline to 12 weeks % difference] × group [SM-LG vs. LG-SM vs. CG]) was used to analyze differences among the groups in 1RM tests and MV effect sizes. When appropriate, follow-up analyses were performed using Fisher’s post hoc tests. The t-tests were used to analyze differences between 1RM test and retest, pre and post training, and between the total work (session × sets × load) and total volume (sets × repetitions) in both training programs. An alpha level of $p \leq 0.05$ was considered statistically significant for all comparisons. Statistica version 7.0 (Statsoft, Inc., Tulsa, OK) statistical software was used for all statistical analyses.

**RESULTS**

**Total Volume and Total Work**

There was no difference between total volumes; however, the total work performed by LG-SM (499,571.8 kg) was...
significantly higher than the total work performed by SM-LG (369,025.7 kg).

1 Repetition Movement Tests
The 1RM test-retest reliability showed high ICC at baseline (BP, r = 0.94; LPD, r = 0.96; TE, r = 0.94; BC, r = 0.95) and after 12 weeks of training (BP, r = 0.96; LPD, r = 0.93; TE, r = 0.95; BC, r = 0.96). There were no differences (p > 0.05) between groups in 1RM tests at baseline, and after 12 weeks, both trained groups showed a significant 1RM improvement for all exercises and differences in relation to CG (Table 2) but not between them. After the normalization per kilogram of body mass, the results were very similar.

Muscle Volumes
Table 3 shows the MV at baseline, at 6 and 12 weeks post training in the 3 groups. There were no differences (p > 0.05) between groups in MVs at baseline, and after 12 weeks, both trained groups showed a significant improvement in triceps and biceps volumes in relation to the CG but not between them.

Effect Sizes
Effect size data (Table 4) demonstrated that differences in strength and MV were exhibited based on exercise order. Although both training groups demonstrated greater strength improvements than the CG, which actually decreased in strength, only BP strength increased to a greater magnitude in the LG-SM group as compared with the SM-LG, 1.74 vs. 0.90, respectively. In all other strength measures (LP, TE, and BC), the SM-LG group showed significantly greater strength increases. Triceps MV increased greater in the SM-LG group (1.08 compared with 0.40); however, biceps MV did not differ significantly between the training groups.

Discussion
The purpose of this study was to examine the effects of exercise order on muscle strength and volume. Despite the significant gains across both training groups, the present results revealed no statistically significant differences of strength gains or muscle accretion between the different exercise order training groups. However, effect size calculations present an interesting alteration in strength improvement based on exercise order. The only exercise in which the LG-SM group demonstrated greater magnitudes of strength gains was the BP. All other exercises, including the lat pulldown, which is often considered an exercise targeting large muscle groups, showed greater magnitudes of strength improvements in the SM-LG exercise order. The absolute strength gains did not differ statistically; however, it is important to examine treatment effects independent of statistical probability, especially in small group studies (9). With such large differences in treatment effects, yet no statistical difference between the absolute strength data, variability within each group and the lack of statistical power may hamper conclusions based solely on statistical probability.

Therefore, the effect size data suggest that an exercise order beginning with small muscle groups and progressing to large groups would be more appropriate if greater gains were desired/sought in small muscle groups. However, this conclusion should be examined in subsequent research with larger sample sizes. Muscle volume in the triceps was shown to increase to a greater extent, based on effect size data, in the SM-LG group; however, this trend was not demonstrated in the biceps MV data. Little can be drawn from these conflicting data with regard to muscle hypertrophy, and additional investigation would be needed for further evaluation of this variable.

In previous research, Simão et al. (15) examined the influence of exercise order on strength and muscle thickness in untrained men after 12 weeks of linear periodized resistance training. The participants were randomly assigned into 3 groups differing in exercise order. One group began with large muscle group exercises and progressed toward small muscle group exercises (LG-SM), whereas another group started with small muscle group exercises and advanced to large muscle group exercises (SM-LG). The exercise order for LG-SM was BP, LPD, TE, and BC. The order for the SM-LG was BC, TE, LPD, and BP. The third group did not exercise and served as a CG. Training frequency was 2 sessions per week with at least 72 hours of rest between sessions. Muscle thickness was assessed at baseline and 12 weeks of training by US techniques. The 1RM strength for all exercises was assessed at baseline and after 12 weeks of training. The results showed no significant differences in 1RM between training groups for the selected exercises after 12 weeks of training. However, when compared with CG, all exercises for both training groups presented significant 1RM strength gains with the exception of BC in LG-SM. Furthermore, between baseline and post 12 weeks of training, all exercises for both training groups presented significant strength gains with the exception of BC in LG-SM and BP in SM-LG. The analysis of 1RM loads per kilogram of body mass normalization demonstrated significant 1RM strength gains between baseline and 12 weeks for all exercises. After 12 weeks, the normalized 1RM loads of BP for both training groups were significantly different from CG, whereas the normalized 1RM loads for TE and BC were significantly different only between SM-LG and CG. Triceps muscle thickness for both training groups was significantly higher when compared with the CG, but with no significant differences between then, whereas the biceps muscle thickness presented significant differences only between LG-SM and CG. Effect size data demonstrated that differences in strength and muscle thickness were exhibited based on exercise order. Although both training groups demonstrated greater strength improvements than the CG, which actually decreased in strength, only TE strength increased to a greater magnitude in the LG-SM group as compared with the LG-SM, 2.07 vs. 0.75, respectively. In BP, the same magnitude was observed for both training groups. For LPD,
Exercise Order in Nonlinear Periodized Training

LG-SM group showed little greater strength increases and the opposite occurred in BC, where little greater strength increases were observed in SM-LG. Triceps muscle thickness increased greater in the SM-LG group (0.51 compared with 0.20); however, biceps muscle thickness did not differ significantly between the training groups.

Our methodology was very similar from Simão et al. (15), but with some crucial differences. In our study, we analyzed MV measurements for the same muscles, whereas Simão et al. (15) analyzed only the muscle thickness. Furthermore, this study involved a nonlinear periodized resistance training program; whereas in the study of Simão et al. (15) was utilized a linear training program. In 1-session 4 sets with high intensity (12–15 repetitions) were performed followed by a session of 3 sets with moderate intensity (8–10 repetitions). A third and final session of the cycle involved 2 sets with high intensity (3–5 repetitions). Differences between linear and nonlinear strength improvements have previously been identified (8,10,11). Despite the results of strength gains or muscle accretion having very little differences between studies, the effect size data presented by both studies determined the same major conclusions.

Dias et al. (3) examined the influence of exercise order on strength in untrained young men after 8 weeks of training. One group began with large and progressed toward small muscle group exercises (G1), whereas another started with small group exercises and advanced to large muscle group exercises (G2). The exercise order for the G1 was BP, LPD, seated machine shoulder press (SP), BC, and TE. The order for the G2 was TE, BC, SP, LPD, and BP. The third group did not exercise and served as a CG. Training procedures were 3 sets of 8 to 12RM for each exercise, and frequency of 3 sessions per week with at least 48 hours of rest between sessions for a total of 24 sessions in the 8-week period. In agreement with the present results, both G1 and G2 resulted in significant increases in IRM compared with the CG. The BC and TE revealed significant differences between trained groups, but the BP and LPD did not show the same results, demonstrating that the exercise order to small muscle group exercises may be particularly important during the initial stages of resistance training in untrained young men. Effect size calculations from the Dias et al. (3) study showed that moderate/large treatment effects for BP, lat pull-down, and shoulder press measures (1.89, 2.47, and 3.67, respectively) when exercise order progresses from large to small muscle groups. In the same group, effect sizes in measures of strength in smaller muscle groups were shown to be much lower (BC: 1.45; TE: 1.59). Effect sizes for the group progression from small to large muscle groups during training showed an opposite effect favoring strength development in smaller muscles (BP: 1.26; lat pull-down: 1.30; shoulder press: 2.92; BC: 2.94; TE: 3.82). This study (3) used a constant training program, different training frequency, and young men and did not use the effect size to analyze the results, whereas the present study used nonlinear periodized resistance training and involved predominantly 30-year-old men.

Previous studies from our group (13,14) agree with the present results and suggest that when an exercise is performed last in an exercise sequence or training session, performance of that particular exercise may be negatively affected. This is true whether the exercise involves large or small muscle groups. Both studies by Simão et al. (13,14) indicated that an exercise should be performed early in a resistance training session if the exercise is important to meet the training goals of a resistance training program. Simão et al. (13) investigated the influence of different exercise sequences on the number of repetitions performed in a group composed of both men and women with at least 2 years of recreational resistance training experience. The results demonstrated performing either large or small group exercises for the upper body at the end of an exercise sequence that resulted in significantly fewer repetitions compared with when the same exercises were performed early in an exercise sequence. A more recent study from Simão et al. (14) suggested a similar phenomenon of a decrease in the total number of repetitions performed when both upper- and lower-body exercises were performed in the same exercise sequence by 23 women with a minimum of 2 years of resistance training experience. In agreement with previous results (13), this study (14) demonstrates that an exercise performed last in a training session is negatively affected, whether the exercise involves large or small muscle groups in an acute way.

In conclusion, the present study suggests that different exercise orders during resistance training involving upper-body, single-, and multi-joint exercises have a significant influence in strength and MV during 12 weeks of nonlinear periodized resistance training in untrained men when effect size calculations are examined. Although continued investigation on this topic is warranted, particularly with larger sample sizes, the differences in the magnitude of strength improvements based on exercise order exist and should be considered when designing a resistance training program.

**Practical Applications**

Based on the effect size data in the present study, and reviewing other studies examining this issue, it appears that exercises that are particularly important to the client should be placed at the beginning of an exercise session. Additionally, if an exercise is important for the training goals of a program, then it should be placed at the beginning of the training session, regardless of it being a large or small muscle group exercise. In this approach, the immediate need of the client receives greater emphasis in program design than the traditional large to small muscle exercise sequence. Because weaknesses in smaller supportive muscles can limit the performance of more complex exercises, increased focus on those smaller muscles (if they are found to be a limiting factor) early in an exercise session would be expected to have
a positive impact on the performance of complex exercises over time.

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References