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Influence of Exercise Order on the Number of Repetitions Performed and Perceived Exertion During Resistance Exercises

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Abstract. Simão, R., P.T.V. Farinatti, M.D. Polito, A.S. Maior, and S.J. Fleck. Influence of exercise order on the number of repetitions performed and perceived exertion during resistance exercises. *J. Strength Cond. Res. 19(1):152–156. 2005.*—This study examined the performance effects of exercise order during a resistance-training session composed of only upper-body exercises. The 10 repetition maxmimum of 14 men and 4 women with at least 6 months of previous weight-training experience was determined for 5 upper-body exercises. Each subject then completed 2 training sessions separated by 48 hours in a counterbalanced crossover design. One session began with exercises of the large-muscle group and progressed to exercises of the small-muscle group (sequence A), whereas the other session was performed with the opposite exercise sequence (sequence B). The exercise order for sequence A was free-weight bench press (BP), machine lat pull-down (LPD), seated machine shoulder press (SP), standing free-weight biceps curl (BC) with a straight bar, and seated machine triceps extension (TE). The exercise order for sequence B was TE, BC, SP, LPD, and BP. During both sequences, 3 sets of each exercise were performed to concentric failure, with 2-minute recovery intervals between sets and exercises. Performing exercises of both the large- and the small-muscle groups at the end of an exercise sequence resulted in significantly fewer repetitions in the 3 sets of an exercise. This decrease in the number of repetitions performed was especially apparent in the third set when an exercise was performed last in an exercise sequence.

Key Words. strength, strength training, exercise, Borg scale

Introduction

Exercise order refers to the sequence of resistance exercises in a training session. Exercises involving large-muscle groups have been recommended to be placed at the beginning of training sessions (14), because this exercise sequence results in the ability to use the heaviest resistances possible when performing the exercises of the large-muscle group and may result in the greatest long-term strength gains (1, 4, 11). Exercises have also been recommended to be sequenced to allow the use of training resistances and volumes that optimize training adaptations (2). The rationale for performing exercises of the large-muscle group first in a training session is that the total force production (repetitions × resistance) with this exercise order is greater than when performing exercises of the small-muscle group or single-joint exercises first (11).

In the recently published "Position Stand on Progression Models in Resistance Training for Healthy Adults," the American College of Sports Medicine (1) recommends that exercises of the large-muscle group generally be performed first in a training session based on the rationale described above. However, although the rationale for performing exercises of the large-muscle group first in a training session is generally believed and followed, little research on exercise sequencing is available. Sforzo and Touey (11) found that performance of exercises of the small-muscle group before exercises of the large-muscle group resulted in significantly less total force production in the exercises of the large-muscle group and in the total training session. These investigators also reported greater total force production in some, but not all, single-joint exercises when the exercises were performed early in a training session that was composed of both upper- and lower-body exercises of the large-muscle (multijoint) and small-muscle (single joint) groups. Results of a previous study (13) by researchers involved in the present study support the conclusion reached by Sforzo and Touey (11). However, information on the effect of exercise sequencing when a session is composed of only upper-body exercises appears to be lacking. Therefore, the purpose of the present study was to examine the effect of exercise order on the number of repetitions performed and ratings of perceived exertion (RPE) in a resistance-training session composed of only upper-body exercises. It is hypothesized that exercises of both the large- and small-muscle groups will be negatively affected in terms of total number of repetitions performed to volitional fatigue when they are performed late in a training session compared with early in a session.

Methods

Experimental Approach to the Problem

Subjects performed 2 exercise sessions 48 hours apart by using a counterbalanced crossover design. The 2 sessions were composed of the same exercises performed in a different exercise order. Sequence A began with exercises of the large-muscle group and progressed toward exercises of the small-muscle group. The exercise order for sequence A was free-weight bench press (BP), machine lat pull-down (LPD), seated machine shoulder press (SP), standing free-weight biceps curl (BC) with a straight bar, and seated machine triceps extension (TE). Sequence B began with exercises of the small-muscle group and pro-

gressed toward exercises of the large-muscle group. The exercise order for sequence B was TE, BC, SP, LPD, and BP. The performances of sequence A and B were separated by 48 hours. All exercises in both sequences were performed for 3 sets to volitional fatigue by using the predetermined 10 repetition maximum (10RM) of each subject for each exercise. Sets and exercises in both sequences were separated by 2-minute intervals of passive recovery. The total number of repetitions was determined in each set of each exercise for both sequences. RPEs were assessed immediately after completion of each sequence by using the Borg CR-10 Scale with emphasis on local fatigue (3).

Subjects

Fourteen men and four women (age, 20 ± 2 years; body mass, 71 ± 18 kg; height, 176 ± 10 cm; body mass index, 23 ± 5 $kg \cdot m^{-2}$) with at least 6 months of resistance-training experience participated as subjects in the study. All subjects answered the Physical Activity Readiness Questionnaire–PAR-Q (12) and signed an informed consent form before participation in the study according to the Declaration of Helsinki.

10RM Testing

The mass of all weight plates and bars that were used was determined with a precision scale, and the subjects' weight and height were determined with a medical scale. The actual mass of all plates and bars was then used to calculate the 10RM of each exercise. Data were assessed during 3 nonconsecutive days. The 10RMs of all subjects were determined on the first day. The 2 different exercise sequences were performed on days 2 and 3. The 10RM tests were performed in the following order: BP, LPD, SP, BC, and TE. All machine exercises were performed on Life Fitness equipment (Franklin Park, IL). To minimize possible errors in the 10RM tests, the following strategies were adopted: (a) all subjects received standard instructions on the general routine of data assessment and the exercise performance techniques before testing, (b) the exercise technique of subjects during all testing sessions was monitored and corrected as needed, and (c) all subjects received verbal encouragement during testing.

During the 10RM tests, each subject had a maximum of 5 attempts on each exercise with 2- to 5-minute intervals between attempts. After the 10RM load in a specific exercise was determined, an interval no shorter than 10 minutes was allowed before the 10RM determination of the next exercise. Standard exercise techniques were followed for each exercise. No pause was allowed between the eccentric and the concentric phase of a repetition or between repetitions. For a repetition to be successful, a complete range of motion as is normally defined for the exercise had to be completed. Excellent day-to-day 10RM reliability for each exercise was shown by this protocol on a subset of the subjects (7 men and 2 women). This subset performed 10RM testing on 2 occasions 24 hours apart. The data were analyzed by Pearson product moment correlations (BP, $r = 0.98$; LPD, $r = 0.99$; SP, $r = 0.96$; BC, $r = 0.98$; TE, $r = 0.97$).

A brief description of the range of motion used to define a successful repetition was as follows: (a) BP, moving the bar from a chest touch to a fully extended elbow position; (b) LPD, starting with the elbows fully extended and touching the bar to the manubrium; (c) SP, starting with the bar slightly above shoulder height and moving the bar to a fully extended elbow position; (d) BC, starting with the elbows fully extended and flexing the elbow as completely as possible; and (e) TE, staring with the elbows at a 90° angle and fully extending the elbow.

Exercise Sessions

Forty-eight hours after the 10RMs were determined for each exercise, subjects performed 1 of the 2 exercise sequences in a counterbalanced crossover design. The second session was performed 48 hours after the first session. Nine subjects (7 men and 2 women) performed sequence A first and 9 subjects (7 men and 2 women) performed sequence B first. Warm-up before each exercise sequence consisted of 12 repetitions of the first exercise of the session (BP for sequence A and TE for sequence B) at 40% of the 10RM load. A 2-minute rest interval was allowed after the warm-up before subjects performed the assigned exercise sequence. Both exercise sequences consisted of 3 sets of each exercise (10RM load) with 2-minute intervals between sets and exercises. The exercise order for sequence A was BP, LPD, SP, BC, and TE. The exercise order for sequence B was TE, BC, SP, LPD, and BP.

During the exercise sessions, subjects were verbally encouraged to perform all sets to concentric failure, and the same definitions of a complete range of motion used during the 10RM testing were used to define completion of a successful repetition. No attempt was made to control the velocity with which repetitions were performed. The total number of repetitions for each set of each exercise was determined. Immediately after completion of each exercise sequence, the Borg CR-10 Scale was used to assess RPE with emphasis on local fatigue (3).

Statistical Analyses

Two-way analyses of variance (ANOVAs) were used to test differences in total number of repetitions and repetitions per set between sequences. A 1-way ANOVA was used to compare the number of repetitions per set within each sequence. A Scheffé post hoc test was performed where indicated. RPE at the end of the sequences was analyzed by a paired Student's t-test. The level of significance was set at $p \leq 0.05$ for all statistical procedures. Statistical software was used for all analyses (version 6.0, Statsoft, Tulsa, OK).

RESULTS

Number of Repetitions of Each Exercise in Both Sequences

The mean number of repetitions of each exercise for the 3 sets varied significantly between sequences: except for the SP, all exercises presented significant differences. Total BP and LPD repetitions (sum of all sets) were lower in sequence B, whereas total BC and TE repetitions were significantly higher in sequence B (Figure 1).

Number of Repetitions in Each Sequence

Comparison between sequence A and corresponding sequence B sets demonstrated no significant differences in the number of repetitions between the first and the second sets for all exercises. Except for the BC, no significant differences were between sequences in the third set (Table 1). However, significant differences were apparent

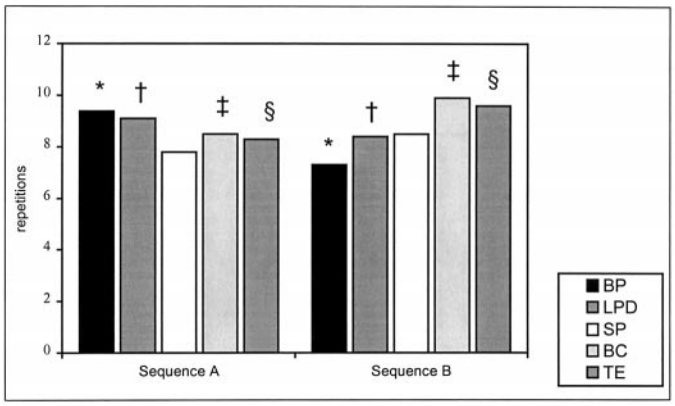

Figure 1. Number of repetitions of each exercise (mean for the 3 sets) in both sequences. * $p < 0.05$ *SD* in bench press (BP); † $p < 0.05$ *SD* in lat pull down (LPD); ‡ $p < 0.05$ *SD* in biceps curl (BC); § $p < 0.05$ *SD* in triceps extension (TE). SP = shoulder press.

when sets within sequences were examined. In sequence A, the third set demonstrated significantly fewer repetitions than did the first and second sets for all exercises, except for TE. In sequence B, the third set demonstrated fewer repetitions than in the first set for the SP and than in the first and second sets for the LPD (Table 2).

RPE

Comparison between sequences showed no significant differences for RPE (sequence A, 8.5 ± 1.6; sequence B, 7.6 ± 1.8), suggesting that exercise order did not influence RPE, at least when considering the present exercise orders.

Discussion

The major finding of the present study was that exercise order in an upper-body–only session does affect the number of repetitions to volitional fatigue in exercises of both the large- and small-muscle groups. When an exercise is performed last or late in a training session, the number of repetitions to volitional fatigue is decreased. The number of repetitions possible in an exercise (SP in the present study) performed in the middle of an upper-body session is not significantly affected.

A unique aspect of the present study was the performance of 5 upper-body exercises in 2 different orders and the performance of the exercises in an order such that no single muscle group was a primary mover in 2 successive exercises. Thus, the sequences resembled common exercise orders used by many strength and conditioning professionals. A previous study by Sforzo and Touey (11) indicates that both upper- and lower-body exercises of the large- and small-muscle groups are affected by exercise order. Their data show that whenever an exercise of a large-muscle (squat, bench press) or small-muscle (leg extension, triceps pushdown) group is performed before an exercise of the other exercise type that uses a muscle involved in both groups, exercise performance (total force) in the exercise that is performed second decreases. Their data also indicate this effect may be greater for the lower body than for the upper body. However, it is important to note that the exercise order they used resulted in the use of a muscle group as a primary mover in successive exercises (i.e., triceps push-down, military press, and BP all involving the triceps were performed in succession).

The present study demonstrates that a negative performance effect (number of repetitions to volitional fatigue) of exercises of large- and small-muscle groups occurs in exercises performed late in a session even when a muscle group is not a primary mover in successive exercises. For example, in sequence B when the BP and LPD were performed last in the exercise sequence, 28 and 8% fewer mean number of repetitions, respectively, were performed compared with sequence A when they were performed first in the exercise sequence. In sequence B

Table 1. Descriptive and inferential statistics for the number of repetitions—intersequence comparison (mean ± *SD*).

	First set		Second set		Third set	
Exercise	Sequence A	Sequence B	Sequence A	Sequence B	Sequence A	Sequence B
Bench press	9.9 ± 0.3	8.3 ± 2.0	9.7 ± 0.7	6.9 ± 3.0	8.5 ± 1.8	6.7 ± 2.6
Lat pull-down	10 ± 0.0	9.8 ± 0.6	9.5 ± 0.8	8.3 ± 2.0	7.8 ± 2.0	7.1 ± 2.2
Shoulder press	9.4 ± 1.5	9.8 ± 0.6	8.1 ± 1.3	8.6 ± 1.6	5.6 ± 2.3	7.1 ± 1.5
Biceps curl	10 ± 0.0	10 ± 0.0	9.0 ± 1.5	10 ± 0.0	6.5 ± 2.5*	9.6 ± 0.8
Triceps extension	9.3 ± 1.6	9.5 ± 1.7	7.9 ± 2.4	9.9 ± 0.3	7.8 ± 1.9	9.5 ± 0.9

* Significant difference ($p < 0.05$).

Table 2. Descriptive and inferential statistics for the number of repetitions—intrasequence comparison (mean ± *SD*).

	First set		Second set		Third set	
Exercise	Sequence A	Sequence B	Sequence A	Sequence B	Sequence A	Sequence B
Bench press	9.9 ± 0.3	8.3 ± 2.0	9.7 ± 0.7	6.9 ± 3.0	8.5 ± 1.8*	6.7 ± 2.6
Lat pull-down	10 ± 0.0	9.8 ± 0.6	9.5 ± 0.8	8.3 ± 2.0	7.8 ± 2.0*	7.1 ± 2.2†
Shoulder press	9.4 ± 1.5	9.8 ± 0.6	8.1 ± 1.3	8.6 ± 1.6	5.6 ± 2.3*	7.1 ± 1.5‡
Biceps curl	10 ± 0.0	10 ± 0.0	9.0 ± 1.5	10 ± 0.0	6.5 ± 2.5*	9.6 ± 0.8
Triceps extension	9.3 ± 1.6	9.5 ± 1.7	7.9 ± 2.4	9.9 ± 0.3	7.8 ± 1.9	9.5 ± 0.9

* Significant difference ($p < 0.05$) between sets for bench press, lat pull-down, shoulder press, and biceps curl (first and second sets).

† Significant difference ($p < 0.05$) between sets for lat pull-down (first and second sets).

‡ Significant difference ($p < 0.05$) between sets for shoulder press (first set).

when the BC and TE were performed first in the sequence, 14 and 6% greater mean number of repetitions, respectively, were performed compared with sequence A when they were performed last in the order. Thus, whether exercises are large-muscle group or multijoint (BP, LPD) or small-muscle group or single joint (BC, TE), performance (number of repetitions) decreases if they are performed last in an exercise sequence. However, the SP, which was in the middle of the session for both sequences, showed no significant difference between sequences for the mean number of repetitions performed.

Figure 1 suggests differences may be in the mean number of repetitions in the intersequence comparison with exercises last in the exercise order showing a decrease in performance. Moreover, the intraset comparisons (Table 2) demonstrate significant decreases in the number of repetitions in the third set of some exercises, indicating fatigue. Collectively, these results indicate that cumulative fatigue causes a decrease in exercise performance, resulting in decreased performance in the exercises that are performed last in an exercise sequence, which is expressed especially in the last set of the last exercises performed. The effect of cumulative fatigue during a session affecting the last sets of an exercise is supported by data showing fatigue rates ranging from 12.8 to 58.2% in 4 successive sets of an exercise (11).

RPE is often used as an intensity indicator in continuous aerobic activities but is infrequently used in conjunction with resistance-training exercise. Some data suggest that RPE could reflect resistance-exercise intensity (7, 15), for RPE is particularly susceptible to the fatigue of muscle groups activated during exercise (6). Therefore, RPE was adopted to verify the influence of exercise order on local fatigue and was assessed immediately after completion of the 2 exercise sequences. No significant differences were observed between sequences, although a slightly lower RPE was found after completion of sequence B. These results tend to confirm data from a previous study demonstrating that resistance-exercise sequences progressing from exercises of large-muscle groups to exercises of small-muscle groups possibly contribute to a higher RPE (13).

Another factor that could determine whether exercise order influences exercise performance is the length of the rest intervals between sets and exercises. In the present study, 2-minute rest intervals were allowed between sets and exercises. In the study by Sforzo and Touey (11), rest intervals were 2 minutes between sets of the same exercise, 3 minutes between different exercises, and 5 minutes between upper- and lower-body exercises. Shorter rest intervals between sets and exercises result in higher blood lactate concentrations than produced by longer rest intervals (5). Thus, the present study's use of 2-minute rest intervals throughout the exercise sequence may have resulted in increased fatigue compared with the study by Sforzo and Touey (11). On the other hand, some authors suggest that 1- to 5-minute rest intervals have no differential influence on fatigue (8–10, 16). Despite the use of slightly different rest-interval lengths, the present study and the study by Sforzo and Touey (11) agree that exercise performance decreases as an exercise sequence progresses. The possible effect of rest-interval length on exercise performance as a session progresses needs further study.

Exercise order in an all upper-body training sessions does affect exercise performance. Exercise performance later in a session is negatively affected even when muscle groups are not used in successive exercises. This is true for exercises of both large- and small-muscle groups. However, an exercise performed in the middle of a resistance-exercise session is minimally affected by exercise order. No significant difference in RPE was shown between the 2 exercise sequences, suggesting that exercise order does not influence fatigue at the end of a session.

PRACTICAL APPLICATIONS

The implications of this study are relevant to the design of training sessions with the goal of maximizing muscle strength and hypertrophy. Performing exercises of large-muscle groups first in a training session will meet the training goals of many individuals. However, this study's results suggest that whenever an exercise is performed last in an exercise sequence or training session, performance of that exercise will be negatively affected. This is true whether the exercise is from the large- or small-muscle group. This negative effect on exercises performed late in a training session needs to be considered when designing programs for both athletes and fitness enthusiasts. This study's results indicate that an exercise should be performed early in a training session if the exercise is important to meet the training goals of a program. This is true for exercises of both large- and small-muscle groups.

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