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original article

Effect of exercise order on the resistance training performance during a circuit training session

Efeito da ordem dos exercícios sobre o desempenho durante uma sessão de treinamento resistido no método circuito

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Abstract – The aim of this study was to compare total work volume, number of repetitions and rate of perceived effort performed in two different sequences of circuit training sessions. Eleven recreationally trained men (24.0 ± 4.8 years, 76.1 ± 8.5 kg, 1.75 ± 0.06 m) performed two different sequences of circuit training sessions. All sessions consisted of eight stations (exercises) of three sets in circuit, performed to volitional fatigue, alternating upper and lower body exercises, with 1-minute rest interval between exercises. Sequence A began with multiple joint exercises and progressed to single joint exercises, whereas sequence B was performed with the opposite exercise order. Number of repetitions and rating of perceived exertion (RPE) were compared by repeated measures multivariate analysis of variance (repeated measures MANOVA). Total work volume (TWV) was compared by paired t-test. There were no differences between exercise order for TWV ($p=0.47$) and RPE of all exercises ($p>0.05$). For both sequences, number of repetitions was greater when exercise was performed first ($p<0.05$). These results indicate that during a circuit training session, exercises order influenced the number of repetition, but did not influence TWV and RPE. These findings may suggest that for those who aim overall muscular gains, similar results will be obtained with single and multiple joint, upper and lower body circuit training exercise orders. Similarly, exercise intensity will be similarly perceived regardless of exercise sequences. For those who aim specific muscle group gains, priority exercises must be performed first.

Key words: Exercise order; Rating of perceived exertion; Repetition; Strength training; Volume.

Resumo – *O objetivo deste estudo foi comparar o Volume Total de Trabalho (VTT), o Número de Repetições (NR), e a Percepção Subjetiva de Esforço (PSE) de duas sequências de exercícios executadas no método circuito. Onze homens treinados recreacionalmente (24.0 ± 4.8 years, 76.1 ± 8.5 kg, 1.75 ± 0.06 m) realizaram duas sequências diferentes de exercícios contra a resistência no método circuito. As sessões foram compostas por três passagens em oito estações (exercícios), executadas até a fadiga, alternados membros superiores e inferiores, com 1 minuto de intervalo entre os exercícios. A sequência A foi iniciada por exercícios multiarticulares e progrediu para exercícios monoarticulares, enquanto a sequência B foi executada na ordem inversa. O NR e a PSE foram comparadas pela MANOVA com medidas repetidas. O VTT foi comparado por meio do teste t pareado. Não houve diferenças significativas entre as ordens de exercícios para o VTT ($p=0.47$) e PSE ($p>0.05$). Para ambas as sequências, o NR foi maior quando os exercícios foram realizados no início das sequências ($p<0,05$). Esses resultados indicaram que a ordem dos exercícios afetou o número de repetições, mas não afetou o VTT e a PSE. Esses achados sugerem que, para aqueles que objetivam ganhos musculares gerais, resultados similares podem ser obtidos com exercícios mono e multiarticulares, para membros superiores e inferiores em diferentes ordens no método circuito. Da mesma forma, a intensidade do exercício será percebida de forma similar independente da sequência. Para aqueles que objetivam ganhos musculares específicos, exercícios prioritários devem ser executados no início da sessão.*

Palavras-chave: *Ordem dos exercícios; Percepção subjetiva de esforço; Repetição; Treinamento de força; Volume.*

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INTRODUCTION

Resistance training (RT) promotes direct and indirect health gains and performance benefits related to muscular strength[1-3], hypertrophy, endurance[4,5] and power[6]. Its successful achievement depends on the combination of training variables (volume, intensity and order)[7-9], and the knowledge on the outcomes of each variable in a training session is important to achieve health and fitness goals[10].

Initially, according to Sforzo and Touey[11], exercise order (EO) refers to the execution sequence of the exercises that compose the training session[12]. EO has been pointed out as an important variable when prescribed, since some studies have shown that the sequence of resistance exercises significantly influences performance[9,13-16].

Studies involving OE have reported that the exercise sequence acutely influences the number of repetitions and the total work volume (TWV) of RT exercises performed late in the session[8,13,17-19]. Therefore, the authors recommend that priority exercises must be performed first in the session[8,9,17,18,20].

The studies mentioned above were conducted using simple or consecutive sets of the same exercise. No previous study has evaluated the effect of exercise order on a complete training session or tested training methods or systems. These training methods are different combinations of training variables (number of series, rest interval, exercise order and so on) empirically established[21], which have been widely applied in practical context [22] (i.e., traditional, circuit, and superset).

Among training methods, the single-set circuit is the most widely used, which is generally recommended for controlling and/or reducing weight[23]. The circuit of resistance exercises consists of exercises, or stations, performed in simple sets, alternating upper- and lower-body exercises, with multiple passages at stations[22]. In this method, the time between sets of the same station is extended, compared with traditional methods. This improves the recovery time, which can lead to performance maintenance during the training session. Thus, it is hypothesized that, during a circuit session, the exercises order does not affect performance. Therefore, the aim of this study was to compare total work volume, number of repetitions and rate of perceived effort performed in two different sequences of circuit training sessions.

METHODOLOGICAL PROCEDURES

Experimental Approach to the Problem

A within-subject randomized and counterbalanced repeated measures design was used to examine the effect of EO on performance during a circuit training session. Participants participated in one habituation/strength testing session, and two experimental sessions, with a 7-day interval between them. On day 1, anthropometric measures were collected,

a familiarization was performed and the 1-RM was determined. On days 2 and 3, two different exercise sequences were performed.

The sessions were composed of the same exercises, performed in two opposite exercises orders. Sequence A (SEQA) began with multi-joint exercises and progressed to single joint exercises. The exercise order for SEQA was bench press (BP), 45º Leg press (LP), Seated Rows (SR), Hack machine (HM), pulley triceps extension (TE), hamstring cur (HC), biceps curl (BC) and hip adduction (HA). Sequence B (SEQB) was performed in the opposite order: HA, BC, HC, TE, HM, SR, LP and BP. Eight stations (exercises) of 3 sets to volitional fatigue were performed in both sequences using 60% of predetermined 1-RM. Sets and stations were separated by a 1-minute rest interval of passive recovery. Number of repetitions, RPE and TWV were determined for SEQA and SEQB.

Subjects

Eleven men (24.0 ± 4.8 yr; 76.1 ± 8.5 kg; 175 ± 5cm) with at least 6 months of uninterrupted recreational resistance training experience participated as volunteers in this study. The experimental approach had institutional ethical board approval, and all subjects signed the informed consent form before participation in the study. The inclusion criteria for participation were the following: (a) being male between 18 and 28 years of age, (b) being classified as able to practice physical activities by the Physical Activity Readiness Questionnaire–PAR-Q[24], and (c) being free of clinical problems that could be aggravated by the protocol, not smoker, and with at least 6 months of uninterrupted resistance training experience, practicing one hour at least three times a week, and with no experiences on the circuit training method. Subjects were excluded from the study if they (a) did any type of exercise 48h prior to the experimental session, (b) used drugs or nutritional supplements during the experimental period, (c) consumed alcohol 48h prior to any session, or (d) missed any session. Subjects' characteristics are presented in Table 1.

According to norm 196/96 of the Brazilian National Health Council, all participants read and signed the informed consent form before undergoing the study procedures, and the study protocol was approved by the Ethics Committee of the Federal University of Pernambuco.

Procedures

One Repetition Maximum Test: Seven days before the first experimental sessions, the load used for 1RM was determined for each subject in each exercise of the circuit training session. The test followed the American Society of Exercise Physiologists protocol[25]. All participants started the test with a set of 5 repetitions using 50% of the self-reported maximum load and a set of 3 repetitions using 80% of the self-reported maximum load, with a 2-minute rest interval between sets. Three minutes after warm-up exercise, the 1RM test was started. The subjects had a maximum of 5 1-RM attempts of each exercise with 2 5-minute rest intervals between successive

attempts. For a repetition to be successful, the eccentric and concentric phase, as normally defined for the exercise, had to be completed. During the training sessions, 60% of 1RM of each exercise was used.

Table 1. Sample characteristics and 1 Repetition Maximal (1-RM) values.

Characteristics	Mean	Standard deviation
Age (years)	24.0	4.8
Height (centimeters)	175	5.0
Body mass (kilograms)	76.1	8.5
Body mass index	24,8	3.2
Body fat	12,1	4.1
1RM (kilograms)		
Bench press	94	13.8
Leg press	284	78.5
Seated role	96	7.4
Hack machine	170	24.1
Pulley triceps extension	83	9.0
Hamstring curl	89	13.6
Biceps curl	44	4.6
Hip adduction	125	14.3

Exercise Sessions: Seven days after the 1-RM test, subjects performed 1 of the 2 exercise sequences in a counterbalanced crossover design, and the other was performed seven days after. All exercise sessions were preceded by a 5-minute warm-up treadmill exercise at speed from 5 to 7km/h. Both exercise sequences consisted of 3 sets of each exercise performed in circuit to failure with 1-minute rest intervals between sets and stations. During the exercise sessions, subjects were encouraged to perform all sets to concentric failure, and the same motion range limits used during the 1-RM test were used to define completion of a successful repetition. During the training sessions, a metronome, adjusted for 60 bpm was used to facilitate control of movement speed. Hands and feet spacing was recorded and maintained during both training sessions. At the end of each set, the number of repetitions was recorded. Immediately after completion of each set, the Omni-Res Scale was used to assess RPE with emphasis on local fatigue[10]. TWV was calculated based on the number of repetitions, number of sets and training load.

Statistical Analyses

All statistical procedures were conducted using IBM SPSS Statistics (version 20) software for Windows. Once variables presented nonparametric distribution, log transformation was used to ensure parametric analysis. Repeated measures multivariate analysis of variance (repeated measures MANOVA) was used to assess the difference between sequences: 1) sum of number of repetitions of the three sets of each exercise in SEQA and SEQB (statistical power analysis - 88%); 2) mean of the three RPE sets of each exercise in SEQA and SEQB (statistical power analysis - 75%). Paired

t-tests were used to compare TWV in SEQA and SEQB. 2). All results are presented as mean ± standard deviation and Cohen's d effect size, unless otherwise noted. Effect size of 0.2 was considered small, 0.5 medium, and 0.8 large. The alpha level was set at $p \leq 0.05$

RESULTS

Total Work Volume

Figure 1 shows that for TWV, there was no statistically significant difference between SEQA and SEQB ($p = 0.47$; $d = 0.16$).

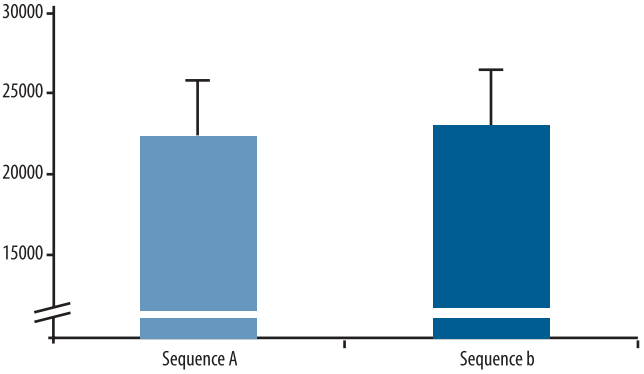

Figure 1. Total work volume on Sequence A and B. Mean values and standard deviation are shown.

Number of Repetitions

Multivariate comparison indicated that there was a statistically significant difference in the Number of Repetitions performance based on different sequences, $F(8,3) = 20.635$; $p < .047$.

Table 2 above shows that the number of repetitions was significantly different from SEQA to SEQB for all exercises, except for HC ($p=0.08$). For BP, LP and SR, more repetitions were executed when performing SEQA, while for HM, TE, BC and HA, more repetitions were executed when performing SEQB.

Table 2. Mean (Standard Deviation –SD), significance values (p) and effect size (d) for comparison (univariate tests) between number of repetitions on Sequence A and B.

Exercise	Mean (SD) Number of repetitions		p	d
	Sequence A	Sequence B		
Bench press	34.54 (4.94)	32.18 (7.89)	0.05*	0.45
Leg press 45º	43.00 (14.38)	33.72 (11.15)	0.01*	0.71
Seated Rows	38.27 (8.22)	34.63 (8.09)	0.02*	0.38
Hack machine	36.27 (9.77)	45.18 (11.40)	0.01*	0.86
Pulley triceps extension	36.45 (10.04)	40.63 (11.24)	0.01*	0.48
Hamstring curl	30.45 (6.37)	29.54 (7.63)	0.08	0.01
Biceps curl	24.18 (6.23)	29.54 (7.28)	0.03*	0.92
Hip adduction	46.18 (12.46)	65.00 (17.21)	0.01*	1.29

*$p \leq 0.05$

Rating of Perceived Exertion

Multivariate comparison with sequences indicated that RPE did not differ from each other (F (8,3) = 6.68; p = 0.073), as Table 3.

Table 3. Mean (Standard Deviation –SD), significance values (p) and effect size (d) for comparison (univariate tests) between ratings of perceived exertion on Sequence A and B.

Exercise	Mean (SD) Rating of Perceived Exertion		p	d
	Sequence A	Sequence B		
Bench press	7.27 (0.90)	7.63 (0.80)	0.23	1.17
Leg press 45º	7.63 (0.67)	7.90 (0.83)	0.42	0.01
Seated Rows	7.54 (0.82)	7.54 (0.93)	0.97	0.01
Hack machine	7.63 (1.02)	7.72 (0.78)	0.76	0.01
Pulley triceps extension	7.63 (0.80)	7.63 (0.80)	1.00	0.01
Hamstring curl	7.63 (0.80)	7.63 (0.67)	0.96	0.01
Biceps curl	7.72 (0.78)	7.54 (0.68)	0.57	0.01
Hip adduction	7.54 (1.03)	7.00 (0.89)	0.10	1.04

DISCUSSION

The initial hypothesis of this study was that, during a circuit training session, the exercises order would not affect performance, once the other stations between sets of the same exercise would enlarge the recovery interval. The major findings of the investigation indicated this hypothesis was partially confirmed.

Total Work Volume

The manipulation of exercises order in the circuit training sessions did not influence the TWV. It has been recognized some benefits of TWV on muscular performance. Some studies have reported benefits related to TWV, so that as higher is the TWV, as greater are the strength gains[26], the release of anabolic hormones[27,28] and the muscular hypertrophy[29]. Therefore, based on our results, we can suggest that in the circuit training session, muscular gains related to TWV are similar, regardless of exercise execution order. Even if our study did not investigate chronic effects, it could be speculated that the TWV values for SEQA (mean=22386.45; SD=3426.6) and SEQB (mean=23065.91; SD=3605.16) could have been different if subjects had followed a complete training protocol (with more than one session).

Some studies use TWV as performance measure. The first study was that carried out by Sforzo and Touey[11], which compared two different sequences of six exercises for upper- and lower-body, one starting with groups of large muscles, and the other using groups of smaller muscles at the beginning of the training session.

Slowly, the classification for groups of large and small muscles was replaced by single- and multi-joint exercises. Using this new classification,

Gil et al.[12], observed TWV in one sequence of three upper-body exercises, manipulating the order of the first and the third exercises. The authors verified that TWV was higher when the sequence started with multi-joint exercise and lower when it started with single-joint exercises.

Results from the present study do not support those obtained by Gil et al.[12]. It is important to consider that Gil et al.[12] used 45º *leg press* exercises in the training session. This is a multi-joint exercise, which simultaneously activates both anterior and posterior leg muscles, leading to greater load support. On the other hand, the other two exercises were single-joint, which only the anterior (leg extension) or the posterior leg muscles (hamstring curl) contribute to the movement. Therefore, lower loads were supported in these exercises. Since the TWV calculation considers the number of repetitions, and that generally this variable is affected by exercise order, we can suggest that it is possible that the high load on the 45 leg press, multiplied by the high number of repetitions under the condition that this exercise was performed at the beginning had affected the equation, making VTT to be significantly different between sequences.

Number of repetitions

The number of repetitions was different between the two sequences, indicating that exercises performed first in the session showed greater number of repetitions when compared to those performed later, regardless of muscle size or number of joints involved. This result is supported by other studies that obtained the same result with exercise for groups of large and small muscles[11] and single- and multi-joint exercises[8,9,17,18]. Those results suggest that progressive fatigue throughout the session negatively influences muscle performance.

Only for hamstring curl, there was no significant difference between number of repetitions in SEQA and SEQB. This result can be justified by the specificity of this exercise in the sequence. Hamstring curl was the only station that the posterior portion of the thigh acted like an agonist. Thus, this exercise shows a cumulative fatigue effect compared to other exercises, and thus the recovery interval for these muscles was longer than that for the other lower-body exercises. In this case, the initial hypothesis of the present study was confirmed: the interval between sets for hamstring curl was enough for muscle recovery, leading to similar number of repetitions, regardless of exercise order.

Rating of Perceived Exertion

Our results showed that RPE was not influenced by the manipulation of exercise order, as reported by previous studies[8-10]. The OMNI-RES[16] scale, used in the present study, evaluates the level of perceived exertion on the exercised muscle. In the present study, for the other muscles, the exercises were the same, and so were the worked muscles. So, it could be suggested that if the exercise is the same, the order will not influence RPE.

Another aspect that must be considered is that the RPE measure was collected at the end of a maximal set. At that moment, all subjects were

fatigued, and for this reason, their effort perception was always close to the hardest level. It is possible that if the RPE assessment was made after a resting interval or using submaximal sets, the values could be different.

The results obtained in this study show that the manipulation of exercise order during a resistance training session, including single- and multi-joint exercises, for upper- and lower-body, influence the number of repetitions, but do not influence TWV and RPE. The main limitation of this study was that the 1-RM test was not performed for each sequence, and the training load for both sequences was based on one of the sequences. Further studies on the chronic effect or exercise order should be carried out.

The different orders of exercises in the circuit method did not influence TWV and RPE, but the number of repetitions was greater for exercises performed first in the sequence regardless of the number of joints or size of the muscle group involved in the exercise.

These results indicate that resistance training practitioners that aim general muscular gains should perform single- and multi-joint exercises, alternating upper- and lower- body in different orders in the circuit method to obtain similar results regarding the total work volume in the session, perceiving exercise intensity equally, regardless of exercise order.

For those who aim gains for specific muscle groups, as in case of athletes or for patients under rehabilitation, exercise order should be taken in consideration, once the exercise order manipulation can interfere the prioritized muscle group. In this condition, if an exercise is important for the training goals of a given program, then, it should be performed at the beginning of the training session.

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