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ScienceDirect
Journal of Exercise Science & Fitness 14 (2016) 41–46
www.elsevier.com/locate/jesf

Original article

Supersets do not change energy expenditure during strength training sessions in physically active individuals

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Received 21 December 2015; revised 28 April 2016; accepted 10 May 2016
Available online 22 September 2016

Abstract

Background/Objective: The energy expenditure (EE) in strength training (ST) is analyzed both during and after each training session. However, little information exists about the influence of strength exercises supersets on EE. We aimed to determine whether supersets of ST exercises influenced EE during and after one strength exercise session.
Methods: Twenty men were randomly divided to perform either a session with grouped exercises for the same muscle (GE: 26.6 ± 3.4 years; 17.4 ± 3.4 body fat) or a session with separated exercises (SE: 24.9 ± 2.6 years; 15.4 ± 5.9 body fat). Four exercises (5 sets of 8–10 maximum repetitions) for knee extensor muscles and shoulder horizontal flexor muscles were executed in both training sessions. The EE of each experimental session was obtained through the analysis of oxygen uptake during and after exercise (60 minutes postsession).
Results: Total work during the session and increases in lactate concentrations were similar between the GE and SE Groups. During exercise, EE was greater in the SE Group when compared with the GE Group (GE: 123.8 ± 14.36 kcal vs. SE: 131.77 ± 20.91 kcal). During the postexercise period, GE induced greater EE when compared with SE (GE: 25.12 ± 7.86 kcal vs. SE: 19.76 ± 5.53 kcal). However, the exercise sequence did not influence overall EE (GE: 148.92 ± 18.72 kcal vs. SE: 151.53 ± 17.97 kcal, $p = 0.920$).
Conclusion: Our findings indicate that, in physically active men, ST supersets do not influence total EE during and 60 minutes after a single session.

Keywords: excess postexercise oxygen consumption; lactate; pre-exhaustion

Introduction

The energy expenditure (EE) of strength training (ST) has been studied both during as well as after (excess postexercise oxygen consumption; EPOC) exercise.[1–9] Although EE (kcal) is typically obtained by gas analysis (oxygen uptake – VO_2), the variation in lactate concentration has also been used to quantify EE.[10–14] Interestingly, different ST sessions may generate EE ranging from 2.4 kcal/min to 7.9 kcal/min.

Previous studies involving the responses of EE induced by ST usually manipulated the exercise intensity by modifying weight loads,[2,4,15] while the volume has been modified through the number of repetitions of each set and the number of sets performed.[2,4,15,16] The training intensity and explosive movements are crucial to reach greater total EE in ST,[15,17] while higher volumes promote greater EE only during the exercise session.[16]

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http://dx.doi.org/10.1016/j.jesf.2016.05.003

However, another way to increase the training intensity involves the manipulation of the rest between sets/exercises for the same muscle group. In this context, the supersets (grouping of exercises for the same muscle group) are cited as valid in increasing exercise intensity.[18] Such variations in rest period between exercises for the same muscle group have been consistently investigated from the neuromuscular perspective.[19–24]

As mentioned above, the weight loads, and number of sets and repetitions are the ST variables with greater focus in studies on EE. Although supersets are widely used, studies showing the effects of supersets on EE are scarce, and involve only women[25,26]; and, interestingly, some studies have reported a greater relative EE (due to aerobic energy sources) in women compared with men during traditional sets of ST.[9,27]

Accordingly, this study aimed to examine the effects of supersets in EE during and after (EPOC) single ST sessions. More intense exercise promotes greater muscular fatigue, therefore, we hypothesized that greater EE would occur when the strength exercises for the same muscle group were performed in a grouped order (superset), because there is a shorter rest between them.

Participants and Methods

Participants

The sample consisted of 22 men. The inclusion criteria were being physically active and familiarized with strength exercises, but not on a competitive basis. The following exclusion criteria were adopted: (1) use of drugs that could affect cardiorespiratory responses; and (2) history of neuromuscular injury that could limit exercise performance.

The characteristics of the participants are shown in Table 1. Before taking part, all participants were informed about the procedures, risks, and benefits of the study and signed a consent form approved by the Ethics Committee of the Hospital de Clínicas de Porto Alegre (CEP/HCPA 08–474). The sample was obtained through the dissemination of posters placed in the School of Physical Education of the Federal University of Rio Grande do Sul and surroundings. Based on the effect size of 1, alpha level of 0.05, and power (1−β) of 0.80, with an expected difference of 10% for the VO_2 between two groups, it was shown that eight participants per group were necessary.[17,28] After the selection of individuals, they were randomly divided into two groups, according to the muscle groups involved in each experimental sessions: grouped exercises (GE: 26.6 ± 3.4 years) or separated exercises (SE: 24.9 ± 2.6 years). We chose to study two parallel groups in order to avoid interference from a protective effect that reduces the responses of muscle damage markers (and consequently EE) in successive workouts, with similar characteristics.[29]

Procedures

Prior to data collection, the reproducibility of gas analyzer and lactimeter was evaluated on two separate days, with intraclass correlation coefficient values of $r = 0.954$ and $r = 0.937$, respectively; $p < 0.05$. Moreover, the coefficient of variation ranged between 15.2% and 18.9%. The steps of the data acquisition can be viewed in Figure 1.

Table 1
Sample characterization of grouped exercises (GE) and split exercises (SE). Results presented as mean and standard deviation ($p > 0.05$). RM = maximum repetitions; VO_2 ST = maximal oxygen consumption during each strength training session.

	Groups	
	GE	SE
Age (y)	26.6 ± 3.4	24.9 ± 2.6
Height (cm)	178.0 ± 7.0	177.0 ± 6.0
Body mass (kg)	77.2 ± 6.0	76.1 ± 10.0
Fat mass (%)	17.4 ± 4.0	15.4 ± 5.9
VO_2 ST mL/kg/min	34.9 ± 3.3	36.2 ± 4.7
10 RM bench press (kg)	52.6 ± 12.3	47.0 ± 12.0
10 RM peck deck (kg)	25.5 ± 7.5	28.0 ± 6.7
10 RM leg press (kg)	157.9 ± 33.0	164.0 ± 36.3
10 RM knee extension (kg)	34.7 ± 4.5	38.4 ± 3.5

Strength training sessions

The participants performed a total of four exercises: (1) bench press with free weights; (2) pec deck (Taurus, Brazil); (3) leg-press 45° (Top Line, Brazil); and (4) knee extension (Taurus, Brazil). These four exercises were conducted in two training sessions: one with exercises for the same muscle group in sequence (GE – exercise order a, b, c, and d); and one with exercises for the same muscle group performed separately (SE – exercise order c, b, a, and d). Based on the characteristics of physically active individuals and targeting a typical session for muscle hypertrophy,[30,31] participants performed five sets with 8–10 maximum repetitions (RM) in each of the four exercises. All exercises were performed at the load obtained during the 10 RM tests; therefore, both sessions were conducted with loads equivalent to 85% of 10 RM.

During GE, the participants performed one set of the leg-press exercise, immediately followed by one set of the knee extension exercise, with no rest between each exercise. After five sets, the participants performed one set of the bench press exercise, immediately followed by one set of the pec deck exercise, with no rest between each exercise. During SE, the participants performed one set of the bench press exercise, immediately followed by one set of the knee extension exercise, with no rest between each exercise. After five sets, the participants performed one set of the leg-press exercise, immediately followed by one set of the pec deck exercise, with no rest between each exercise. In both GE and SE, there were 3 minutes of rest between every two exercises (superset) to minimize the decrease in total work for subsequent sets.[32–34]

10 maximum repetitions test

The modulation of loads was performed using the 10 RM test, as previously described.[35] Therefore, the sequence of exercises was as follows: leg-press, bench press, knee extension, and pec deck. There were up to three attempts in each

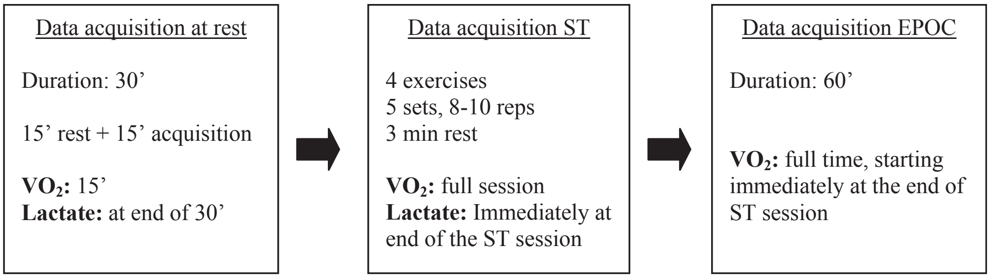

Figure 1. Illustration of energy expenditure data acquisition. EPOC = excess postexercise oxygen consumption; ST: strength training; VO_2: oxygen uptake.

exercise, with an interval of 5 minutes between each one. At the end of an exercise test, an interval of at least 10 minutes was given prior to the subsequent test.

Body composition

Body weight and height were obtained on a scale with a stadiometer (Asimed, Barcelona, Spain), following previous recommendations.[36] The sum of skinfolds was used to estimate body density and, posteriorly, body fat of individuals.[37,38]

Energetic expenditure

The EE in each training session was obtained through the analysis of VO_2, and the total value was used to estimate total EE (kcal). We used a gas analyzer (Cardiopulmonary Exercise System Cpx; Medical Graphics Corporation, St. Paul, MN, USA), calibrated before each data acquisition. Data acquisition (breath by breath) was conducted using the following steps: (1) preexercise resting for 15 minutes in the supine position until the respiratory exchange ratio fell below 0.85; (2) baseline acquisition of VO_2 at rest during 15 minutes; (3) acquisition of VO_2 during each ST session (GE or SE); and (4) postexercise acquisition of VO_2 (EPOC) during 60 minutes, immediately after the end of each ST session. All procedures were conducted in an environmental chamber (Russells Technical Products, WMD-1350-5S, Holland, MI, EUA), with controlled temperature and humidity of 20–23° and 50–70%, respectively.

The total EE of each of the ST sessions was obtained through the following steps.

Obtaining the value of VO_2 (L/min) during rest, using the following formula:

$$VO_{2R}\ (\text{L/min}) = \Sigma VO_{2R}\ (\text{L/min})/t_R\ (\text{min}) \quad (1)$$

where

VO_{2R} (L/min) = oxygen uptake per minute, during rest
ΣVO_{2R} (L/min) = sum of the oxygen uptake per minute, during rest
t_R (min) = duration of rest (15 min)

Obtaining the total value of VO_2 during exercise (2) and postexercise (3), using the following formulas:

$$VO_{2TE}\ (\text{L}) = \Sigma\ VO_{2E}\ (\text{L/min}) \quad (2)$$

$$VO_{2TEPOC}\ (\text{L}) = \Sigma\ VO_{2EPOC}\ (\text{L/min}) \quad (3)$$

where

VO_{2TE} (L) = total oxygen uptake during exercise
VO_{2TEPOC} (L) = total oxygen uptake postexercise
ΣVO_{2E} (L/min) = sum of the oxygen uptake per minute during exercise
ΣVO_{2EPOC} (L/min) = sum of the oxygen uptake per minute during postexercise period

From VO_{2TE} and VO_{2TEPOC} we obtained the absolute values of VO_2 during exercise (4) and during postexercise (5), by subtracting the resting values:

$$VO_{2E}\ (\text{L}) = VO_{2TE}\ (\text{L}) - (VO_{2R}\ (\text{L/min}) \times t_E\ (\text{min})) \quad (4)$$

$$VO_{2EPOC}\ (\text{L}) = VO_{2TEPOC}\ (\text{L}) - (VO_{2R}\ (\text{L/min}) \times t_{EPOC}\ (\text{min})) \quad (5)$$

where

VO_{2E} (L) = oxygen uptake during exercise
VO_{2EPOC} (L) = oxygen uptake during postexercise
T_E = duration of exercise session
t_{EPOC} = duration of postexercise period (60 min)

The total VO_2, considering the exercise and the postexercise period, was obtained with the formula (6):

$$VO_{2T} = VO_{2E}\ (\text{L}) + VO_{2EPOC}\ (\text{L}) \quad (6)$$

where

VO_{2T} = total oxygen uptake

The total EE was estimated multiplying the VO_{2T} values for 4.82 kcal.[3,4,9]

Statistical procedures

Data are expressed as means and standard deviations. The normality and homogeneity were verified by Shapiro–Wilk and Levene tests, respectively. The reproducibility of all variables was verified with the intraclass correlation coefficient and coefficient of variation. Whenever normality assumptions were warranted, comparisons of numerical means between groups (workout time, total work, VO_2, kcal and lactate) were made through an independent *t* test. For all analyses significance was considered as $p \leq 0.05$. Analyses were conducted by using the Statistical Package for the Social Sciences (SPSS), version 18.0.

Results

Twenty participants completed the study, with 10 in each training group (SE and GE). One individual from each group was excluded due to the impossibility of using the VO_2 data.

During the GE and SE sessions, groups did not differ in total work (GE: 11,972.5 ± 2158.94 kg vs. SE: 12,022.88 ± 1812 kg) and session lengths (GE: 35 min 4 s ± 3 min 14 s vs. SE: 34 min 58 s ± 2 min 21 s), between the two protocols. These results are fundamental because only the order of exercises acted as a possible influence on EE.

During exercise, EE was greater in the SE compared with the GE Group (GE: 123.8 ± 14.36 kcal vs. SE: 131.77 ± 20.91 kcal). This pattern was changed during the postexercise period, when GE induced greater EE compared with SE (GE: 25.12 ± 7.86 kcal vs. SE: 19.76 ± 5.53 kcal) (Figure 2, Table 2). However, the exercise sequence did not influence overall EE (GE: 148.92 ± 18.72 kcal vs. SE: 151.53 ± 17.97 kcal, $p = 0.920$) (Table 2).

Discussion

The main finding of this study was the same pattern of EE according to the order of exercises during typical sessions of ST. Nonetheless, contrary to our hypothesis, the overall EE was not different between the two experimental sessions.

Studies have shown that training intensity (i.e., percentage of 1 RM) and explosive movements are crucial to reach greater

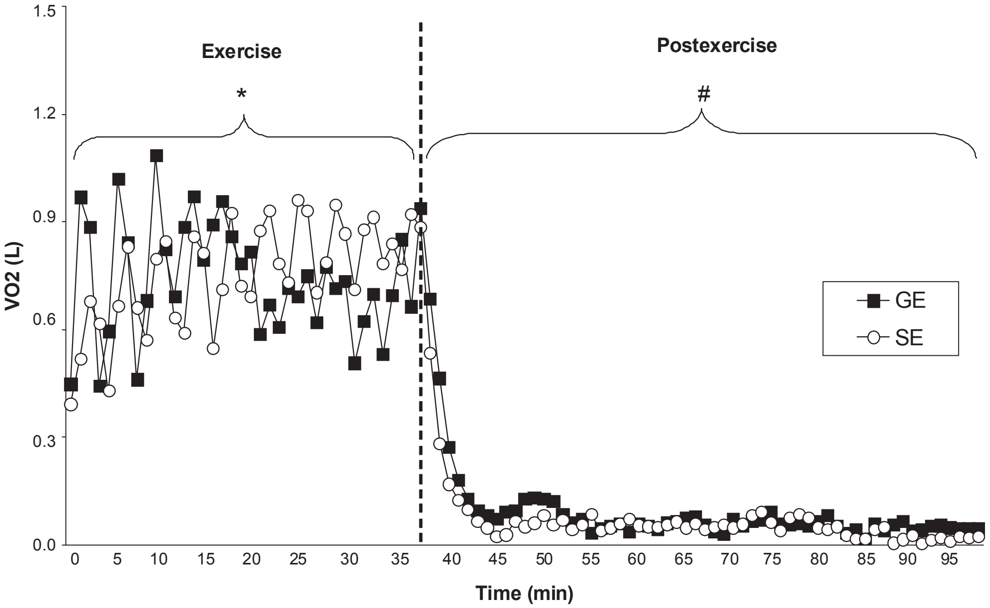

Figure 2. Oxygen consumption exercises performed grouped (GE) and separated (SE). * Values higher in SE compared with GE ($p < 0.05$). # Values lower in SE compared with GE ($p < 0.05$).

Table 2
Variables related to energetic expenditure in groups with grouped exercises (GE) and separated exercises (SE). Results presented as mean ± standard deviation of the variables related to energy expenditure in groups with grouped exercises (GE) and separated exercises (SE). * Values higher in SE compared with GE; # Values lower in SE compared with GE.

Variables	Group	
	GE	SE
Total work (kg)	11,972.5 ± 2158.94	12,022.88 ± 1812
Total time (min:sec)	35:04 ± 03:14	34:58 ± 02:21
VO_2 exercise (L)/(kcal)	25.17 ± 4.10/(121.33 ± 14.36)#	26.55 ± 4.56/(127.98 ± 20.91)
VO_2 exercise/min/(kcal/min)	0.72 ± 0.12/(3.47 ± 0.56)#	0.76 ± 0.13 (3.66 ± 0.63)
EPOC (L)/(kcal)	5.21 ± 1.63/(25.12 ± 7.86)*	4.1 ± 1.15/(19.76 ± 5.53)
VO_2 total (L)/(kcal)	30.90 ± 3.88/(148.92 ± 18.72)	31.44 ± 3.73/(151.53 ± 17.97)
Lactate (mmol/L)/(kcal)	7.05 ± 1.83/(1.37 ± 0.25)	6.52 ± 1.83/(1.27 ± 0.41)

values of VO_2, EPOC, and EE in ST.[15,17] The order of exercises, which is also an indicator of exercise intensity, was investigated only in two studies.[26,39] Farinatti et al[39] showed that the within-exercise EE is altered by its order, since a higher EE is observed when the same exercise is performed towards the end of the session. However, the total session EE for upper limbs is not affected by the sequence utilized.[39] Similarly, considering only the EPOC, the order of exercise has no influence in untrained women.[26]

Emphasizing that the two studies cited above included only women, we aimed to extend the knowledge investigating the effect of exercise order in men, both during and after exercise. We expected that the grouped exercises for the same muscle group within the session would induce a higher level of fatigue during exercise, promoting greater increases in the overall EE. In fact, a previous study showed that short rest intervals (30 s and 1 min) produce a greater EE compared to longer intervals (2−5 min) between sets of the same exercise (bench press) performed with five sets of five repetitions (75% 1 RM) or 10 repetitions (85% 1 RM).[40] Furthermore, their findings showed a direct relationship of fatigue rate [expressed by resistance/volume of set 1 − set 5/set 1 (×100)] with the metabolic response and an inverse relationship between the rest interval between sets and the acute metabolic response (VO_2 and EE). Similarly, Scott and Earnest[41] showed that performing exercises with muscle fatigue induced by contraction failure during sets of strength exercises promotes greater EE in the bench press, compared with this exercise performed without fatigue (7−21 repeats with 50% of 1 RM).

The training volume is an important determinant of EE during ST. Higher volumes promote greater EE during the exercise session.[16] However, when EPOC is accounted for in the metabolic response induced by the session, results are controversial.[16,25] Haddock and Wilkin[16] showed no influence of ST volume (1 × 3 sets) on EPOC, whereas Benton and Swan[25] found a positive relationship of the total volume (total work in kg) of supersets with 90 minutes of EPOC. However, the higher volume proposed means higher loads performed with the same repetitions (8−12 RM).[25] Thus, it seems that intensity is the main factor involved with a greater EPOC. Moreover, intervals between the sets of models with multiple sets may promote a decreased contribution of EPOC, due the recovery (rest periods) between the multiple sets.[25] Our study involved 3-minute intervals between sets of exercises performed in the two training sessions, therefore, such a characteristic could have attenuated differences between the GE and SE training sessions.

The type of exercises and speed of execution could affect EE. The latter, however, has been shown not to influence the EE during similar training sessions to those used in our study. Regarding the chosen exercise, it seems that lower-limb exercises promote greater EPOC than upper-limb exercises in sessions where the EE of each exercise is controlled.[41] In our study, we used exercises for large muscle groups of the lower and upper limbs. However, as we have used supersets and not isolated strength exercises, our experimental design does not provide insight into possible specific effects of each exercise in the behavior of EE during or after the training session.

Although the aspects mentioned above may affect EE during ST, there were some limitations to our study that need to be considered. First, oxygen uptake measurements require strict criteria to ensure validity. For example, the participant must be in a resting or low-intensity exercising steady state; must not be rapidly growing or developing; and must reside within a thermoneutral environment.[14] In our study, some of these criteria have been met. However, the ST must be considered as an example where oxygen uptake may not properly interpret the total EE. The occlusion of blood flow during intense muscular contraction, breath holding, the presence of an oxygen deficit due to the brevity of weight training exercises, and the absence of a physiological steady state were all important limitations. Another important limitation of the study was that total work was identical in GE and SE. Although control of this variable is important, it may have eliminated the possibility of differences in EE between GE and SE.

In summary, the present study indicates that the exercise order during a typical ST session does not affect the total EE of physically active men, considering the values obtained during and after exercise ($\cong$ 175 kcal). Our findings indicate that, in physically active men, the ST supersets did not influence the total EE during and 60 minutes after a single session. Thus, the manipulation of that variable appears to have little significance in the prescription when we consider EE induced by ST.

Conflicts of interest

The authors have no conflicts of interest to declare.

Funding/support

Financial support for the work described in this article was provided by FIPE−HCPA (Fundo de Incentivo a Pesquisa e Eventos do Hospital de Clinicas de Porto Alegre), Brazil.

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