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

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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

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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. Such variations in rest period between exercises for the same muscle group have been consistently investigated from the neuromuscular perspective. 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; 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.

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. 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.

### 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, 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.

### 10 maximum repetitions test

The modulation of loads was performed using the 10 RM test, as previously described. 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
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. The sum of skinfolds was used to estimate body density and, posteriorly, body fat of individuals.

Energetic expenditure

The EE in each training session was obtained through the analysis of VO₂ 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 VO₂ at rest during 15 minutes; (3) acquisition of VO₂ during each ST session (GE or SE); and (4) postexercise acquisition of VO₂ (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°C and 50–70%, respectively.

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

Obtaining the value of VO₂ (L/min) during rest, using the following formula:

\[ VO_{2R} (L/min) = \Sigma VO_{2R} (L/min)/t_R (min) \]  

where

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

Obtaining the total value of VO₂ during exercise (2) and postexercise (3), using the following formulas:

\[ VO_{2TE} (L) = \Sigma VO_{2E} (L/min) \]  

\[ VO_{2TEPOC} (L) = \Sigma VO_{2EPOC} (L/min) \]  

where

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

From VO₂TE and VO₂TEPOC we obtained the absolute values of VO₂ during exercise (4) and during postexercise (5), by subtracting the resting values:

\[ VO_{2E} (L) = VO_{2TE} (L) - (VO_{2R} (L/min) \times t_E (min)) \]  

\[ VO_{2EPOC} (L) = VO_{2TEPOC} (L) - (VO_{2R} (L/min) \times t_{EPOC} (min)) \]  

where

\[ VO_{2E} (L) = \text{oxygen uptake during exercise} \]
\[ VO_{2EPOC} (L) = \text{oxygen uptake during postexercise} \]
\[ t_E = \text{duration of exercise session} \]
\[ t_{EPOC} = \text{duration of postexercise period (60 min)} \]

The total VO₂, considering the exercise and the postexercise period, was obtained with the formula (6):

\[ VO_{2T} = VO_{2E} (L) + VO_{2EPOC} (L) \]  

where

\[ VO_{2T} = \text{total oxygen uptake} \]

The total EE was estimated multiplying the VO₂T values for 4.82 kcal.

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, VO₂, 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 VO₂ 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
values of VO₂, 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. 26,30 Farinatti et al 30 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 (VO₂ 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 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 ( ≏ 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.

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References

1. Melby CL, Tincknell T, Schmidt WD. Energy expenditure following a bout of non-steady state resistance exercise. J Sports Med Phys Fitness. 1992;32:128–135.
2. Pichon CE, Hunter GR, Morris M, et al. Blood pressure and heart rate response and metabolic cost of circuit versus traditional weight training. J Strength Cond Res. 1996;10:153–156.
3. Burleson Ma Jr., O’Bryant HS, Stone MH, et al. Effect of weight training exercise and treadmill exercise on post-exercise oxygen consumption. Med Sci Sports Exerc. 1998;30:518–522.
4. Paulsen G, Myklestad D, Raastad T. The influence of volume of exercise on early adaptations to strength training. J Strength Cond Res. 2003;17: 115–120.
5. Sedlock DA, Fissinger JA, Melby CL. Effect of exercise intensity and duration on postexercise energy expenditure. Med Sci Sports Exerc. 1989; 21:662–666.
6. Sedlock DA. Effect of exercise intensity on post-exercise energy expenditure in women. Br J Sports Med. 1990;25:38–40.
7. Halton RW, Kraemer RR, Sloan RA, et al. Circuit weight training and its effects on excess postexercise oxygen consumption. Med Sci Sports Exerc. 2009;31:1613–1618.

8. Binzen CA, Swan PD, Manore MM. Post-exercise oxygen consumption and substrate use after resistance exercise in woman. Med Sci Sports Exerc. 2001;33:932–938.

9. Morgan B, Woodruff SJ, Tidus PM. Aerobic energy expenditure during recreational weight training in females and males. J Sports Sci Med. 2003; 2:117–122.

10. Scott CB. Re-interpreting anaerobic metabolism: an argument for the application of both anaerobic glycolysis and excess postexercise oxygen consumption (EPOC) as independent sources of energy expenditure. Eur J Appl Physiol Occup Physiol. 1998;77:200–205.

11. Hunter GR, Selkhorst D, Snyder S. Comparison of metabolic and heart rate responses to super slow vs. traditional resistance training. J Strength Cond Res. 2003;17:76–81.

12. Scott CB. Contribution of anaerobic energy expenditure to whole body thermogenesis. Nutr Metab. 2005;2:14–22.

13. Scott CB, Kemp RB. Direct and indirect calorimetry of lactate oxidation: implications for whole-body energy expenditure. J Sports Sci. 2005;23: 15–19.

14. Scott CB. Contribution of blood lactate to the energy expenditure of weight training. J Strength Cond Res. 2006;20:404–411.

15. Thornton MK, Potteiger JA. Effects of resistance exercise bouts of different intensities but equal work on EPOC. Med Sci Sports Exerc. 2002;34:715–722.

16. Haddock BL, Wilkin LD. Resistance training volume and post exercise energy expenditure. Int J Sports Med. 2006;27:143–148.

17. Melanson EL, Sharp TA, Seagle HM, et al. Resistance and aerobic exercise have similar effects on 24-h nutrient oxidation. Med Sci Sports Exerc. 2002;34:1793–1800.

18. Brennecke A, Guimarães TM, Leone R, et al. Neuromuscular activity during bench press exercise performed with and without the preexhaustion method. J Strength Cond Res. 2009;23:1933–1940.

19. Garfinkel S, Cafarelli E. Relative changes in maximal force, EMG, and muscle cross-sectional area after isometric training. Med Sci Sports Exerc. 1992;24:1220–1227.

20. Kellis E, Baltzopoulos V. Agonist and antagonist EMG-angle relationship during isokinetic eccentric and concentric exercise. Isokin Exerc Sci. 1996a;6:79–87.

21. Kellis E, Baltzopoulos V. The effects of normalization method on antagonist activity during concentric and eccentric isokinetic knee extension and flexion. J Electromyogr Kinesiol. 1996b;6:235–245.

22. Augustsson J, Thomeé R, Hornstedt P, et al. Effect of pre-exhaustion exercise on lower-extremity muscle activation during a lift press exercise. J Strength Cond Res. 2003;17:411–416.

23. Hassani A, Patikas D, Bassa E, et al. Agonist and antagonist muscle activation during maximal and submaximal isokinetic fatiguing tests of knee extensors. J Electromyogr Kinesiol. 2006;16:661–668.

24. Garrandes F, Colson SS, Pensini M, et al. Neuromuscular fatigue profile in endurance-trained and power-trained athletes. Med Sci Sports Exerc. 2007;39:149–158.

25. Benton MJ, Swan PD. Influence of resistance exercise volume on recovery energy expenditure in women. Eur J Sport Sci. 2009;9:213–218.

26. Da Silva RL, Brentano MA, Kruel LFM. Effects of different strength training methods on postexercise energetic expenditure. J Strength Cond Res. 2010;24:2255–2260.

27. Kent-Braun JA, Ng AV, Doyle JW, Towe T. Human skeletal muscle responses vary with age and gender during fatigue due to incremental isometric exercise. J Appl Physiol. 2002;93:1813–1823.

28. Zafeiridis A, Smilos I, Considine RV. Serum leptin responses after acute resistance exercise protocols. J Appl Physiol. 2003;94:591–597.

29. Nosaka K, Sakamoto K, Newton M, et al. How long does the protective effect on eccentric exercise-induced muscle damage last? Med Sci Sports Exerc. 2001;33:1490–1495.

30. Pincivero DM, Campy RM. The effects of rest interval length and training on quadriceps femoris muscle. Part I: knee extensor torque and muscle fatigue. J Sports Med Phys Fitness. 2004;44:111–118.

31. Campos GER, Luecke TJ, Wendeln HK, et al. Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones. Eur J Appl Physiol. 2002;88:50–60.

32. Willardson JM, Burkett LN. A comparison of different rest intervals on the exercise volume completed during a workout. J Strength Cond Res. 2005;19:23–26.

33. Willardson JM, Burkett LN. The effect of rest interval length on bench press performance with heavy vs. light loads. J Strength Cond Res. 2006;20:396–399.

34. Willardson JM, Burkett LN. The effect of rest interval length on the sustainability of squat and bench press repetitions. J Strength Cond Res. 2006;20:400–403.

35. Simão R, Farinatti PT, Polito MD, et al. Influence of exercise order on the number of repetitions performed and perceived exertion during resistance exercises. J Strength Cond Res. 2005;19:152–156.

36. Costa RF. Composição Corporal Teoria e Prática da Avaliação. São Paulo: Manole; 2001.

37. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. Br J Nutr. 1978;40:497–504.

38. Siri WE. Body composition from fluid spaces and density: analysis of methods. In: Brozek J, Henschel A, eds. Techniques for Measuring Body Composition. Washington, DC: National Academy of Sciences; 1961:223–244.

39. Farinatti PTV, Simão R, Monteiro WB, et al. Influence of exercise order on oxygen uptake during strength training in young women. J Strength Cond Res. 2009;23:1037–1044.

40. Ratamess NA, Falvo MJ, Mangine GT, et al. The effect of rest interval length on metabolic responses to the bench press exercise. Eur J Appl Physiol. 2007;100:1–17.

41. Scott CB, Earnest CP. Resistance exercise energy expenditure is greater with compared to non-fatigue. J Exerc Physiol. 2011;14:1–10.