Effects of Standard Set and Circuit Weight Training on Excess Post-exercise Oxygen Consumption

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Abstract
Murphy, E. and R. Schwarzkopf. Effects of standard set and circuit weight training on excess post-exercise oxygen consumption. J. App. Sport Sci. Res. 6(2):88-91. 1992. — The purpose of this study was to compare the effects of standard set weight training (SWT) and circuit weight training (CWT) on excess post-exercise oxygen consumption (EPOC). The type and order of exercises were the same for both programs. The programs differed in three respects: a circuit approach as opposed to three sets of the same exercise; the percent of maximum weight used was 80 percent in SWT and 50 percent CWT; and rest periods were shorter for CWT (30 seconds) than SWT (120 seconds). This longer rest period resulted in a longer SWT program (50 minutes) than the CWT program (19 minutes). Ten untrained college men performed both weight-training programs. Resting metabolic rate (RMR) was determined before each weight program, followed by a determination of EPOC.

The magnitude and duration of EPOC produced by CWT were significantly (p < 0.01) greater than those produced by SWT. The EPOC produced by CWT was 20 minutes in duration with a net caloric cost estimated at 24.9 kilocalories, while that produced by SWT was 15 minutes in duration with an estimated net caloric cost of 13.5 kilocalories. The intensity of CWT (289 kilograms per minute) was also greater than that of SWT (106 kilograms per minute).

It was concluded that the magnitude and duration of EPOC is greater for CWT in comparison to SWT and the EPOC produced by weight training is somewhat less than that found for aerobic exercise.

Introduction
Excess post-exercise oxygen consumption (EPOC) is the additional energy expenditure after exercise due to a metabolic rate elevated above the resting level (3). Estimates of the duration of EPOC range from 10 minutes to 48 hours (1, 4, 6, 7, 10).

Some studies have suggested EPOC may have a greater role in weight control than has been previously recognized (7, 10). Because the caloric cost of EPOC is not normally included in energy expenditure estimates, a knowledge of the added caloric cost related to the type, intensity and duration of exercise, might be useful to individuals concerned with reducing body fat. Previous research regarding EPOC has employed cycling, walking or jogging as the mode of exercise. A comparison of EPOC obtained from various types of weight-training programs can add to the knowledge of post-exercise energy expenditure.

The purpose of this investigation was to compare the effects of standard set weight training (SWT) and circuit weight training (CWT) on excess post-exercise oxygen consumption (EPOC) in men.

Methods
Subjects
Ten untrained, volunteer college men signed an informed consent approved by the Human Subjects Committee at Montana State University, which also approved the protocol for the study. The subjects’ average (± standard deviation) age was 23.6 (± 3.9) years, while their average height and weight were 1.79 (± 0.05) meters and 80.5 (± 10.7) kilograms, respectively.

Protocol
A randomized crossover design was used in which each subject performed both the CWT and SWT programs, with one week between programs. Subjects arrived at the laboratory where all testing was performed at approximately 3 p.m. on each test day. Subjects were instructed not to eat after noon, to refrain from caffeine, tobacco and alcohol after 10 a.m and to refrain from vigorous physical activity on the day of testing. After a 10-minute rest period, resting...
metabolic rate (RMR) was determined by a five-minute measurement before each weight-training program. Ventilatory measurements were made by open-circuit spirometry. A Modified Otis-McKerrow valve conducted air into a Collins Chain Compensated Tissot. Ventilatory samples were passed through a paramagnetic oxygen (Beckman E-2) analyzer and an infrared carbon dioxide (Beckman LB-2) analyzer. Standardized methods of oxygen consumption determinations were used (5). EPOC was determined from one-minute VO₂ samples taken during the first minute of six consecutive five-minute intervals (minutes 1, 6, 11, 16 etc., until RMR was reached). Total EPOC was determined from the area beneath the curve (Figure 1). EPOC duration was defined as the length of time necessary for oxygen consumption to return to resting levels. Energy cost during CWT exercise was estimated from a similar program reported by Wilmore et al. (11).

The CWT and SWT programs consisted of the same six exercises conducted in the following order: power clean, bench press, squat, biceps curl, seated military press and bent knee sit-ups. The programs differed in three respects: a circuit approach as opposed to three sets of the same exercise; the percent of 1 RM was 80 percent in SWT and 50 percent in CWT; and the work:rest ratio was 1:1 for CWT and 1:5 for SWT. In the CWT program, the subjects performed 12 repetitions for the first set, 10 for the second and 8 for the final set. As many repetitions as possible

<table>
<thead>
<tr>
<th>RMR and Sampling Minutes Post-exercise</th>
<th>CWT</th>
<th>SWT</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMR</td>
<td>0.31 (± 0.04)</td>
<td>0.30 (± 0.04)</td>
</tr>
<tr>
<td>1</td>
<td>1.45 (± 0.24)</td>
<td>0.97 (± 0.16)</td>
</tr>
<tr>
<td>6</td>
<td>0.58 (± 0.07)</td>
<td>0.45 (± 0.03)</td>
</tr>
<tr>
<td>11</td>
<td>0.43 (± 0.06)</td>
<td>0.36 (± 0.04)</td>
</tr>
<tr>
<td>16</td>
<td>0.39 (± 0.05)</td>
<td>0.31 (± 0.06)</td>
</tr>
<tr>
<td>21</td>
<td>0.34 (± 0.07)</td>
<td>0.29 (± 0.07)</td>
</tr>
<tr>
<td>26</td>
<td>0.31 (± 0.04)</td>
<td>0.27 (± 0.06)</td>
</tr>
</tbody>
</table>

Figure 1. Excess post-exercise oxygen consumption (EPOC) of circuit weight training (CWT) and standard weight training (SWT)
Table 2. EPOC Duration Comparisons of Weight Training and Aerobic Exercise

<table>
<thead>
<tr>
<th>Mode</th>
<th>Duration (min)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWT</td>
<td>20</td>
<td>Present study</td>
</tr>
<tr>
<td>SWT</td>
<td>15</td>
<td>Present study</td>
</tr>
<tr>
<td>Cycling</td>
<td>&lt;33</td>
<td>Sedlock et al. (10)</td>
</tr>
<tr>
<td>Walking/running</td>
<td>&lt;20</td>
<td>Kaminsky et al. (6)</td>
</tr>
<tr>
<td>Running</td>
<td>&lt;40</td>
<td>Freedman-Akabas et al. (2)</td>
</tr>
</tbody>
</table>

were performed for each set during SWT. The two-minute rest resulted in a longer program for SWT (50.2 ± 1.1 minutes) than CWT (19.4 ± 0.8 minutes).

Statistical Analyses

Dependent tests, at a level of significance of 0.01, were used for comparisons within groups and between groups.

RESULTS

The magnitude of EPOC produced by CWT was significantly (p < 0.01) greater than that produced by SWT during the first four sample periods (Figure 1). The duration of EPOC for CWT (20 minutes) was significantly longer (p < 0.01) than that for SWT (15 minutes) (Figure 1). The net oxygen consumption estimated from the area beneath the curve in Figure 1 was 4.95 liters for CWT and 2.70 liters for SWT. Therefore, the net caloric expenditure, converted at 5 kilocalories per liter, as a result of EPOC, was greater for the CWT program (24.9 kilocalories) than the SWT program (13.5 kilocalories).

The amount of weight lifted for the two programs was very similar. The average (± standard deviation) total weight lifted during the CWT program, not including sit-ups, was 5510 (± 488) kilograms, while a corresponding average during the SWT program was 5293 (± 1113) kilograms. However, the intensity (weight lifted per unit of time) of CWT (289 ± 28 kilograms per minute) was substantially greater than SWT (106 ± 22 kilograms per minute).

DISCUSSION

SWT and CWT as described herein failed to elicit prolonged EPOC, and their durations were similar to those reported for other forms of exercise (Table 2). EPOC in excess of 24 hours has been reported. However, it is noteworthy that three meals were consumed during the 24 hours after exercise in two previously mentioned studies, which may have contributed to the prolonged EPOC. In fact, Sedlock et al. stated that dietary-induced thermogenesis (DIT) may account for a prolonged EPOC (10). Another factor possibly contributing to a prolonged EPOC is the protocol used for establishing a baseline value. Bahr et al. (1) used subjects who had fasted for 12 hours. This study, as well as others (2, 6), measured RMR shortly before exercise testing.

The EPOC produced by weight training was found to be somewhat shorter in duration than that produced by aerobic exercise (Table 2).

Wilmore et al. found a net energy expenditure of 5.73 kilocalories per minute during exercise for a circuit program, similar to that used in this study (11). If this value was used to estimate the end energy expenditure in this study, CWT would have resulted in the expenditure of 109 kilocalories. Interestingly, the CWT EPOC would then be approximately 23 percent of the estimated net values. This estimate is higher than the 10 percent that Sedlock et al. found for cycling 20 minutes at 75 percent of VO₂ max (10). In part, the higher intensity of CWT may be responsible for the larger EPOC.

The differences in EPOC magnitude and duration between CWT and SWT may be related to the work:rest ratios of 1:1 and 1:5, respectively. A longer rest interval would allow lactate, ATP and CP, and core temperature to return partially or totally to a pre-exercise value. A longer rest would also allow greater muscle lactate dissipation, which increases during all forms of interval exercise (9). ATP and CP, which have a half-time of approximately 20 to 25 seconds (8), would be almost entirely restored, and greater heat dissipation would reduce elevated core temperature, which increases with the intensity of exercise (4). Greater core heat could be expected from a 19-minute (CWT) versus a 50-minute (SWT) exercise time with approximately the same weight lifted. Hagberg et al. estimated the effect of increased core temperature to account for 60 to 70 percent of EPOC during the latter stage of recovery (4). Therefore, it appears that rest time and EPOC are inversely related.

PRACTICAL APPLICATIONS

Weight trainers using the CWT methods of this study can expect to obtain a larger and longer EPOC in comparison to SWT. The additional caloric use of CWT over SWT amounted to approximately 11 calories or an additional 83 percent.

The duration of the EPOC from weight training will
generally be somewhat less than from aerobic exercise.
CWT enabled the exerciser to lift approximately the same total weight in much less time (19 minutes, versus 50 minutes for SWT). The higher exercise intensity could be viewed in terms of time efficiency if the amount of weight lifted was the criteria for evaluation.

REFERENCES