Effect of exercise intensity on postexercise energy expenditure in women*

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This study was designed to examine the effect of exercise intensity on the magnitude and duration of excess postexercise oxygen consumption (EPOC) in women. On separate days and in a counterbalanced order, seven moderately active young adult women performed a 850 kJ cycle ergometer exercise at an intensity of 40 or 60% of their previously determined peak oxygen uptake ($\dot{V}O_2$). Baseline $\dot{V}O_2$ and heart rate (HR) were recorded during the last 10 min of a 45 min seated rest. $\dot{V}O_2$ and HR were measured continuously during recovery until $\dot{V}O_2$ returned to baseline. There was no significant difference noted in the baseline measures between the two exercise programmes. Magnitude of EPOC was comparable ($P > 0.05$) being mean (s.d.) of 30(17) and 36(13) kJ after 40 and 60% exercises respectively. Although the EPOC duration was 53% longer following the 40% exercise than following 60% (27(15) min and 18(8) min, respectively) this difference was not statistically significant. These exercise conditions failed to produce a prolonged EPOC in the women of this study, and values recorded for magnitude of EPOC indicate that it was not significant with regard to the overall energy expenditure of the activity. It was concluded that both magnitude and duration of EPOC seemed to be independent of the chosen exercise intensities used by the women in this study.

Keywords: Recovery metabolism, women, cycle ergometer

One important factor that must be addressed when prescribing exercise is that the programme be designed to meet the specific objectives of the client. Evidence indicates, for example, that many women engage in aerobic exercise to reduce or control their body weight¹. In order to develop the most effective exercise for this particular group, professionals must know how to maximize energy expenditure among women, and be aware of their metabolic responses to exercise.

Energy expenditure associated with physical activity includes that expended during the exercise itself and that consumed in the postexercise or recovery period. Although results reported in the literature concerning the excess postexercise oxygen consump-

tion (EPOC) are equivocal as to both the magnitude and duration of this period²⁻⁷, it has been reported that postexercise energy expenditure may be influenced by manipulating the intensity^{3,7} or duration⁸ of isocaloric exercise. However, our understanding of the overall EPOC response is largely confined to men since many EPOC studies have included male subjects^{2,4,5,7,9-11}, whereas only one study was found that involved women exclusively¹².

The purpose of this study was therefore to examine postexercise energy expenditure in women. Investigations of EPOC duration are critical in attempting to identify the underlying physiological mechanisms, whereas quantifying the consequent magnitude has the greater impact regarding weight control. It has recently been shown that these two issues are not necessarily related, i.e. a longer EPOC duration does not necessarily result in a greater energy expenditure⁷, suggesting that each of these should be addressed independently. Therefore, this study specifically investigated the effect of exercise intensity on both magnitude and duration of EPOC with exercise energy expenditure held constant.

Methods

Subjects. Seven moderately trained women volunteered for the study. Mean (s.d.) age, height, and weight were 25.7 (4.0) years, 165.8 (5.2) cm, and 61.3 (5.9) kg, respectively. All were physically active at the time of the study, although none was engaged in any systematic training. The procedures used in this investigation were reviewed and approved by the institutional committee for research involving human subjects. All subjects expressed their understanding of the procedures and their rights as subjects by signing a statement of informed consent.

Protocol. Subjects performed two submaximal cycle ergometer exercises that elicited an energy expenditure of 850 kJ. One was at an intensity of 40% and the other at 60% of each subject's previously determined peak oxygen uptake ($\dot{V}O_2$). The exercise tests were administered in a counterbalanced order and were separated by a minimum of 2 days.

Test for peak $\dot{V}O_2$. A continuous, incremental exercise test was performed using a mechanically-braked cycle ergometer to determine peak $\dot{V}O_2$. Initial power output (PO) was 60 W at 60 r.p.m., with subsequent

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increases of 30 W every 2 min until termination of the test. Criteria for termination of the test were: (1) an increase in PO with little or no increase in $\dot{V}O_2$; (2) heart rate (HR) at or near the age-predicted maximum; or (3) failure to maintain the prescribed cranking rate due to fatigue. The highest minute value obtained for $\dot{V}O_2$ was recorded as peak $\dot{V}O_2$.

Submaximal exercise test. Subjects reported to the laboratory at approximately 6.00 hours following an overnight fast and having refrained from any strenuous physical activity for 24–36 h. After applying surface electrodes to monitor HR, the subjects sat quietly in a chair for 45 min. Baseline $\dot{V}O_2$ and HR were measured during the last 15 min of this period. The exercise was then performed at the prescribed intensity, with subjects again seated quietly in a chair immediately after termination of the exercise. $\dot{V}O_2$ and HR were monitored continuously during the recovery period until $\dot{V}O_2$ returned to the baseline value.

Measurements. $\dot{V}O_2$ was measured by open circuit spirometry. Subjects inspired room air, and expired air was metered and analysed for fractional oxygen and carbon dioxide using an automated system (Quinton Q-Plex I, Seattle, WA, USA). $\dot{V}O_2$ was converted to energy expenditure (kJ) using the caloric equivalent of 1 litre of oxygen based on the non-protein respiratory exchange ratio (RER).

Baseline $\dot{V}O_2$ and HR were determined by averaging the minute values for these variables obtained during the last 10 min of the 15 min baseline measurement period. Duration of EPOC was determined by continuously averaging five consecutive 1 min values of $\dot{V}O_2$ during the postexercise period. When this average was equal to the baseline value, duration was recorded as the elapsed time (min) from termination of the exercise to the first minute of this 5 min average. Magnitude of EPOC was obtained by summing the net energy expenditure for each minute of the EPOC period.

Results

Mean baseline values obtained before exercise at 40 and 60% of peak $\dot{V}O_2$ are shown in Table 1. No significant difference was noted for any of the variables, indicating that the subjects were in a comparable resting state before both experiments.

Table 2 includes data obtained during the exercises. The target intensities were 40 and 60% peak $\dot{V}O_2$. Actual values were 41.1 and 61.8%, respectively. As expected, a significantly higher $\dot{V}O_2$ ($t = 22.6$, $P < 0.01$) and HR ($t = 10.1$, $P < 0.01$) response was elicited during the 60% exercise compared with the 40% exercise. Energy expenditure for the two exercises was similar, and therefore required a significantly longer duration ($t = -21.8$, $P < 0.01$) when exercising at 40% peak $\dot{V}O_2$.

Data obtained during the EPOC period are shown in Table 3. There was no significant difference in duration of EPOC; however, the mean value following exercise at 40% peak $\dot{V}O_2$ was 53% longer than

Table 1. Mean (s.d.) values measured during the baseline period

Variable	Before 40% exercise	Before 60% exercise	t^*
$\dot{V}O_2$ (litre min^{-1})	0.22 (0.03)	0.23 (0.03)	0.21
$\dot{V}O_2$ ($\text{ml kg}^{-1} \text{min}^{-1}$)	3.67 (0.45)	3.68 (0.20)	0.13
Heart rate (b min^{-1})	62 (6)	59 (5)	-1.38
Energy expenditure (kJ min^{-1})	4.62 (0.59)	4.70 (0.59)	0.51

* $P > 0.05$

Table 2. Mean (s.d.) values obtained during the two exercises

Variable	40% peak $\dot{V}O_2$	60% peak $\dot{V}O_2$	t
% Peak $\dot{V}O_2$	41.1 (0.89)	61.8 (1.83)	36.92*
$\dot{V}O_2$ (litre min^{-1})	1.03 (0.13)	1.54 (0.19)	22.61*
Heart rate (b min^{-1})	108 (9)	137 (3)	10.16*
Energy expenditure (kJ)	871.1 (26.0)	879.5 (31.9)	1.70
Duration (min)	41.1 (5.2)	27.3 (3.6)	-21.87*

* $P < 0.05$

Table 3. Mean (s.d.) values measured during the postexercise period for the two experiments

Variable	After 40% exercise	After 60% exercise	t^*
Duration (min)	27.7 (15.5)	18.1 (8.4)	-1.65
EPOC (kJ)	29.8 (17.2)	36.1 (12.6)	0.78
Heart rate (b min^{-1})†	62 (4)	67 (5)	2.25

* $P > 0.05$

† Heart rate recorded at the end of the period of excess postexercise oxygen consumption. Value following exercise at 60% peak $\dot{V}O_2$ was significantly higher ($P < 0.05$) than baseline.

the EPOC duration following the 60% exercise. This lack of statistical significance was probably due to the relatively large interindividual variation recorded for both conditions. On the other hand, magnitude of EPOC was similar following the two exercises.

Although there was no significant difference in mean HR measured at the end of the EPOC period between the two conditions ($P < 0.07$), end-EPOC HR was significantly elevated ($P < 0.05$) above baseline following the 60% exercise.

Discussion

This investigation was designed to examine the effect of exercise intensity on postexercise energy expenditure in women when exercise energy expenditure was held constant. Only one other EPOC study was located that included women as subjects¹². However, that study compared the recovery response to exercise with and without a caffeine challenge, with the exercise performed at a constant intensity (55% $\dot{V}O_{2, \text{max}}$) and duration (90 min) for both experiments.

Moreover, $\dot{V}O_2$ was still elevated at the time the measurements were terminated. Therefore, neither magnitude nor duration of EPOC were reported. Results in this study indicate that a 850 kJ exercise at 40 and 60% peak $\dot{V}O_2$ had no differential effect on either the magnitude or duration of EPOC. Further, energy expenditure measured during the postexercise period was relatively low following both exercise experiments.

It is commonly believed that the elevated metabolic rate during recovery from exercise exists for several hours. This tenet is based on several reports of this phenomenon spanning 50 years^{2,4,9,13,14}. In contrast to those studies, which included males as subjects, the results of this study using women did not show a prolonged elevated metabolic rate during recovery from exercise.

Although a prolonged EPOC has been demonstrated in the above-mentioned studies, results of other investigations have not supported this finding^{3,5,7,15}. Reasons for these discrepant findings are unclear, although exercise intensity and duration have been suggested as a possibility¹⁶. With regard to exercise intensity, Brehm and Gutin³ have proposed a model for postexercise energy expenditure after exercise of moderate duration, such as that used in the present study. The authors suggest that recovery energy expenditure is only minimally affected when exercise intensity is within 'the low to moderate range (30–50% $\dot{V}O_{2,max}$). At higher exercise intensities, the slope of the curve may increase sharply' (Reference 3, page 209). Results of the present study on women do not seem to support this model. Since little is known about the EPOC response in women, it is difficult to speculate why this had occurred. However, there are several possibilities. First, the study of Brehm and Gutin³ included both males and females, suggesting that perhaps differences in the sex of the subject groups between the latter study and the present study may have influenced the results. Second, the subjects of Brehm and Gutin³ were relatively exercise-trained whereas subjects of the present study were not engaged in any systematic training. Third, although one of the exercise intensities used in this study was above and the other below the implied threshold value of 50% $\dot{V}O_{2,max}$, it could be that they were not sufficiently different from this threshold to show the EPOC response.

Although no threshold value for duration of exercise has been identified as producing the EPOC response, evidence suggests that a minimum of 1 h of moderate intensity exercise is necessary to affect the duration of EPOC. For example, a prolonged EPOC period has been reported following exercise durations of 180 min⁹, 150 min¹³, and 90 min^{6,12}. Additionally, Sedlock *et al.*⁷ reported that a 60 min exercise gave a significantly longer EPOC than a 30 min

exercise. In contrast, the exercise durations of the present study were less than 1 h (i.e. 27 and 41 min) and resulted in relatively short EPOC durations that were not significantly different from each other.

In summary, this study employed exercise intensities that are similar to what is often used by women for purposes of weight control, i.e. 850 kJ exercise energy expenditure at 40 and 60% peak $\dot{V}O_2$. These conditions failed to elicit a prolonged elevated metabolic rate during the postexercise period, and the magnitude of EPOC suggests that the postexercise energy expenditure was not significant in relation to the total energy expenditure. Moreover, with the energy cost of the exercise held constant, both magnitude and duration of EPOC seemed to be independent of exercise intensity.

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