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Effect of continuous and intermittent bouts of isocaloric cycling and running exercise on excess postexercise oxygen consumption

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ABSTRACT

Objectives: The purpose of this study was to investigate excess postexercise oxygen consumption (EPOC) induced by isocaloric bouts of continuous and intermittent running and cycling exercise.
Design: This was a counterbalanced randomized cross-over study.
Methods: Ten healthy men, aged 23–34 yr, performed six bouts of exercise: (a) two maximal cardiopulmonary exercise tests for running and cycling to determine exercise modality-specific peak oxygen uptake (VO_{2peak}); and (b) four isocaloric exercise bouts (two continuous bouts expending 400 kcal and two intermittent bouts split into 2 × 200 kcal) performed at 75% of the running and cycling oxygen uptake reserve. Exercise bouts were separated by 72 h and performed in a randomized, counter-balanced order. The VO_2 was monitored for 60-min postexercise and for 60-min during a control non-exercise day.
Results: The VO_2 was significantly greater in all exercise conditions compared to the control session ($P < 0.001$). The combined magnitude of the EPOC from the two intermittent bouts was significantly greater than that of the continuous cycling (mean difference = 3.5 L, $P = 0.001$) and running (mean difference = 6.4 L, $P < 0.001$). The exercise modality had a significant effect on net EPOC, where running elicited a higher net EPOC than cycling (mean difference = 2.2 L, $P < 0.001$).
Conclusions: Intermittent exercise increased the EPOC compared to a continuous exercise bout of equivalent energy expenditure. Furthermore, the magnitude of EPOC was influenced by exercise modality, with the greatest EPOC occurring with isocaloric exercise involving larger muscle mass (i.e., treadmill running vs. cycling).

1. Introduction

Aerobic training has been applied in weight management programs to increase daily energy expenditure (EE).[1–3] The American College of Sports Medicine (ACSM) recommends for health promotion an exercise intensity of 40–85% heart rate reserve (HRR) or oxygen uptake reserve (VO_2R), and a target EE of 150–400 kcal (or 20–60 min) per exercise bout performed continuously or intermittently.[1,3] Given the time constraints, exercise intolerance, or monotony that might be associated with continuous exercise, multiple short bouts of exercise have been recommended as an approach to increasing the leisure time allocated to physical activity and enhancing exercise adherence among sedentary individuals.[4,5] This approach has also has been recommended within the context of weight management programs,[4] since previous studies suggest that the increased metabolic demand during recovery, expressed by the excess postexercise oxygen consumption (EPOC), seems to be greater following intermittent compared to continuous exercise.[6–8]

Although previous research investigating the effects of intermittent vs. continuous exercise upon EPOC superficially matched the exercise bouts for external work (same intensity and duration), the exercise volume was not matched by the actual EE [e.g., 2 × 25-min vs. 50-min of treadmill running at 70% VO_{2peak} [7]; 2 × 15-min vs. 30-min of cycle ergometry at 70% VO_{2max} [6]; or 3 × 10-min vs. 30-min of arm ergometry at 60% VO_{2max} [8]]. Taking into account that the oxygen uptake (VO_2) kinetics at the onset of exercise, which reflect the adjustment of both systemic oxygen transport and muscle metabolism, is dependent on exercise intensity and cardiorespiratory fitness levels,[9] it is possible that the exercise

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volume performed may not have been properly controlled by previous studies.[6–8] This is an important methodological issue that confounds the interpretation of studies that compared the effects of continuous and intermittent exercise on the magnitude of EPOC.[10]

Another issue relates to the assessment of resting VO_2. With one exception,[6] previous studies defined baseline VO_2 as the average VO_2 determined during the final 5 or 10 min of a 30-min resting period in a seated position.[7,8] This has been criticized by Børsheim and Bahr[2] in a systematic review, since it can lead to falsely high baseline VO_2 values that compromise the accuracy of the estimates of the magnitude of EPOC. Recently our group investigated the accuracy and test–retest reliability of the assessment of resting VO_2 in thirty healthy men (e.g., two trials of 60-min rest in a supine position) and reported that the largest decrease in VO_2 occurred during the first 30-min, followed by a small, but significant decrease in VO_2 in the final 30-min ($P = 0.007$). From a practical perspective, a control session where resting VO_2 is determined on a separate day under identical conditions applied in the exercise days should be considered when investigating the EPOC phenomenon.

It also is not clear to what extent the mode of exercise affects the magnitude of EPOC,[2] and previous studies have shown conflicting results.[11,12] Considering that the physiological strain seems to be significantly greater during treadmill running than during cycle ergometry,[13,14] it is plausible that EPOC may be affected by exercise modality. In brief, it would be important to investigate possible differences in EPOC induced by running and cycling bouts performed continuously and intermittently, since the EPOC may affect the total EE associated with exercise.

Thus, the main purpose of the present study was to compare the EPOC induced by continuous and intermittent isocaloric exercise bouts using two different exercise modalities (i.e., running vs. cycling) in healthy men. We hypothesized that isocaloric exercise performed continuously or intermittently, but recruiting different amount of muscle mass (i.e., cycling vs. running), would affect the magnitude of EPOC.

2. Methods

Ten healthy men (mean ± SD: age, 28 ± 4 yr; body mass, 78 ± 9 kg; body mass index, $26 \pm 1\ \mathrm{kg\,m^{-2}}$; resting heart rate, 68 ± 5 beats $\mathrm{min^{-1}}$; and resting VO_2, $3.0 \pm 0.4\ \mathrm{mL\,kg^{-1}\,min^{-1}}$) participated in this study. All participants were involved in moderate-to-vigorous intensity aerobic activities (e.g., treadmill running and/or cycling) lasting 30 min or more, three times per week, for at least six months prior to the study. The study was approved by the University of Rio de Janeiro State (UERJ) Human Research Ethics Committee. All participants provided written informed consent.

Each participant visited the laboratory seven times. On the first visit (control non-exercise day) resting VO_2 was determined, anthropometric measurements were taken, and participants were familiarized with equipment and test protocols. No participant presented difficulty or limitation of movement, as all had previous experience with treadmill and cycling exercise. On the second and third visits a maximal cardiopulmonary exercise test (CPET) for determining the maximal values of heart rate and VO_2 was performed. Seventy-two hours after performing the maximal CPETs, four isocaloric exercise bouts were performed at 75% VO_2R. The two continuous bouts expended each a total of 400 kcal. The two intermittent bouts were each split into 2 × 200 kcal sessions, separated by 1 h of passive rest during which VO_2 was assessed. Rehydration was not allowed between intermittent exercise sessions. The four isocaloric exercise bouts were performed in a randomized counter-balanced order, on different days separated by 24–48 h. All the visits were scheduled between 07:00 and 11:00 a.m., to negate confounding by time-of-day. The running tests were performed on the same motorized treadmill (Inbramed™ Super ATL, Porto Alegre, RS, Brazil) and the cycling tests were performed on a cycle ergometer (Cateye EC-1600, Cateye™, Tokyo, Japan). The seat height of the cycle ergometer was individually set before each of the cycling exercise bouts.

For the control non-exercise day, the resting VO_2 was determined in accordance with the recommendations of Compher et al.,[15]: abstention of physical exercise, alcohol, soft drinks and caffeine in the 24 h and fasting for 8 h preceding the assessment, and minimum effort when traveling to the laboratory. In the laboratory, the participants laid in a calm thermoneutral environment (mean ± SD temperature, 22 ± 1 °C) for an acclimation period of 10-min, after which the VO_2 was measured for 60-min in a supine position (control session). The average VO_2 data between 35 and 40 min was used to calculate the $\%VO_2R$ for prescription of the isocaloric exercise bouts, since this time period has been previously shown to elicit VO_2 steady-state and high test–retest reliability.[16]

The HR_{max} and VO_{2max} were determined using a ramp protocol. The workload increments were individualized to elicit the subject's limit of tolerance in 8–12 min.[17] The tests were considered maximal if at least three of the four following criteria were satisfied: (a) maximum voluntary exhaustion defined by attaining a 10 on Borg CR-10 scale; (b) 90% of predicted HR_{max} [220 − age] or presence of heart rate plateau (ΔHR between two consecutive work rates ≤ 4 beats $\mathrm{min^{-1}}$); (c) presence of VO_2 plateau (ΔVO_2 between two consecutive work rates of less than $2.1\ \mathrm{mL\,kg^{-1}\,min^{-1}}$); (d) maximal respiratory exchange ratio (RER_{max}) > 1.10.[18]

Based on VO_{2max} obtained in the running and cycling ramp protocols, and on values of resting VO_2, values corresponding to 75% VO_2R were calculated to determine the intensity of the isocaloric exercise bouts. The absolute VO_2 values obtained from the $\%VO_2R$ equation were used to calculate the associated running speeds and cycling power outputs by applying the ACSM metabolic equations.[1] The grade of the treadmill was set at 1%, which has been found to reflect the energetic cost of outdoor, level overground running.[19] Each running and cycling exercise bout was preceded by a 5-min warm-up at $5.5\ \mathrm{km\,h^{-1}}$ and 1% grade for running and 30 W for cycling. Cycling cadence was maintained at 70 (ranging from 65 to 75) revs $\mathrm{min^{-1}}$ throughout the test. The EE was calculated individually from the net VO_2, which is the VO_2 induced by the exercise bout (i.e., net VO_2 = gross VO_2 − resting VO_2).[20] The net VO_2 values expressed in $\mathrm{mL\,kg\,min^{-1}}$ were converted to $\mathrm{L\,min^{-1}}$ and then to $\mathrm{kcal\,min^{-1}}$. Based on the values obtained for VO_2 and EE, the exercise bouts were terminated when each participant had achieved a total EE of 400 or 200 kcal in continuous or intermittent exercise bouts, respectively. To negate the confounding effects of the initial (fast) VO_2 on-kinetics (i.e., anaerobic EE component of total EE), the first 5-min interval of each exercise bout was omitted from all analyses.[21] The EPOC was calculated by subtracting the baseline VO_2 determined during the control session from the VO_2 determined during the recovery from each exercise bout and was reported as the total EPOC for the 60 min recovery period.

Expired gases were collected during and postexercise using a VO2000 analyzer (Medical Graphics™, Saint Louis, MO, USA) and a silicone face mask (Hans Rudolph™, Kansas, MO, USA). The gas analyzers and pneumotacograph were calibrated according to the manufacturer's instructions. Immediately prior to each exercise bout, the gas analyzers were calibrated using a certified standard mixture of oxygen (17.01%) and carbon dioxide (5.00%), balanced with nitrogen (AGA™, Rio de Janeiro, RJ, Brazil) and the flows and volumes of the pneumotacograph were calibrated using a syringe graduated for a 3 L capacity (Hans Rudolph™, Kansas, MO, USA). During the determination of resting VO_2 participants were instructed to minimize movement and keep as relaxed as possible. For the purpose of statistical analyses, the breath-by-breath