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# Comparison of Excess Post-Exercise Oxygen Consumption (EPOC) With Two Mode of Exercise in the Active Females

*Mahsa Mohsenzadeh and Jaleh Bagherli*

Depatment of Physical Education and Sport Sciences, Islamic Azad University, Karaj Branch, Iran

**Abstract:** We examined aerobic exercise energy expenditure and excess post-exercise oxygen consumption (EPOC) between two mode of exercise, cycling and uphill treadmill running.Twenty active females volunteered for the investigation ($VO_2$max: 45.0 ± 10.9 ml kg $min^{-1}$ cycle; 47.3 ± 11.7 ml kg $min^{-1}$ run). Perceived exertion did not differ between exercise bouts (12.0 ± 0.3 cycle; 11.2 ± 0.1 run). Exercise oxygen uptake was significantly greater for running (39.4 ± 4.9 kJ) compared to cycling (29.7 ± 5.7 kJ). EPOC was not different between cycling and runnin so that exercise oxygen uptake + EPOC was greater for running (101.0 ± 11.5 kJ) as compared to cycling (83.4 ± 18.2 kJ). Oxygen-only measures reveal discrepancy in energy expenditure between cycling and uphill running. Measurements of exercise oxygen uptake and a modified EPOC promote the hypothesis of a similarity in exercise and energy expenditure between cycling and uphill running.

**Key words:** Energy expenditure · Excess post-exercise oxygen consumption · Incremental exercise · Active females

## INTRODUCTION

The conversion of oxygen uptake into an estimate of metabolic heat production is the most widely used method of determining the energy expenditure of steady-rate exercise. Yet the presence of an oxygen deficit during brief, intense, non-steady state work suggests that this type of activity can not be accurately quantified with a measurement of exercise oxygen uptake. Likewise, the excess post-exercise oxygen consumption (EPOC) does not provide a valid representation of rapid glycolytic ATP re-synthesis during intense exercise [1, 2]. Thus, oxygen-only measurements have the potential to underestimate energy expenditure for brief, heavy to severe exercise that contains a significant anaerobic energy expenditure component. Cycling and running are described as aerobic activities because they both utilize the large muscle groups of the lower body in repeated and rhythmic contractions. It is apparent however that differences in muscle recruitment patterns between these two activities can invoke different aerobic and anaerobic contributions to exercise energy expenditure. For example, oxygen uptake measurements taken over 15-30 minutes of exercise revealed that treadmill running had significantly greater oxygen uptake and, presumably, greater energy expenditure as compared to cycling [3, 4]. Even so it has also has been shown that the post-exercise energy expenditure after 30 minutes of running and cycling were not different suggesting that the metabolic demands of these discrepant exercises may have been similar [5]. A standardized means of comparison among diverse exercise modes is an area of concern. Previous studies that have examined energy expenditure among different exercise modes have attempted comparisons that promote "similarity" in work intensity. For example, exercise intensity has been based on self-selection [3, 4], perceived exertion [6], percentage of maximum heart rate [7] or a predetermined percentage of $VO_2$max [5, 6]. In the current investigation an attempt was made to equate work output between non-steady state cycling and uphill running. We hypothesized that estimates of aerobic ATP turnover, as opposed to oxygen-only measurements, would indicate no difference in exercise and aerobic exercise energy expenditure between work-equivalent bouts of intense cycling and uphill running.

## MATERIALS AND METHODS

This study was conducted on all the available (n=20) healthy active female who were aged between 19 and 25 years with no known history of cardiopulmonary, metabolic or musculoskeletal disease. All subjects

**Corresponding Author:** Mahsa Mohsenzadeh, Depatment of Physical Education and Sport Sciences, Islamic Azad University, Karaj Branch, Iran.

Table 1: Anthropometry and Body Composition Profile (n=20)

| Subjects | Age [yr] | Weight [kg] | Height [cm] | % Fat | Fat Mass[kg] | Fat Free Mass[kg]] | BMI |
|---|---|---|---|---|---|---|---|
| Treadmill n=10 | 22±3 | 52.31±2.44 | 165±4.50 | 18.3±2.3 | 12.2±2.1 | 44.8±2.7 | 19.8±1.72 |
| Cycle Ergometer n=10 | 22±3 | 53.43±4.19 | 165±3.77 | 19.6±2.7 | 11.0±2.2 | 48.2±3.3 | 20.3±0.65 |

demonstrated a normal menstrual cycle during the previous 4 months as determined by the medical history form and were not currently using birth control medications. The participants were randomly classified in two equal groups and performed an incremental exercise on Treadmill (Technogym) and Cycle Eegometer (Technogym) during their early follicular and luteal phases until they were exhausted. Early follicular was in the fourth day of menstrual cycle and The luteal phase was determined by the level of Progesterone, Prolactin, FSH and LH hormones in serum blood samples (RIA-method). Heart rate and rhythm was monitored continuously throughout the incremental graded exercise test. Lean body mass (LBM) was estimated from skin fold measures and body weight [8]. Body mass index (BMI) was measured by Bio-Electric Impedance Analysis using a Tanita body fat monitor/scale (Model TBF-350, 4-contact electrodes with two on each foot, Tanita Corp, Tokyo, Japan). Anthropometry and Body Composition Profile are shown in Table 1. Energy expenditure was estimated from breath-by-breath metabolic measurements using portable metabolic assessment equipment (Cosmed K4b2, Italy). HR was monitored continuously using a wireless HR monitor (Polar, Kempele, Finland).

After a 5-min warm up at 50 W, the subjects rode a progressive exercise test (25 W/min), until they were unable to continue, in the treadmill group, subjects were allowed to walk for 5 min at 2.5 miles/h (mph) and 0% grade and data were collected in the last minute of this workload. Subjects then warmed up for 5 min at a treadmill speed of 4.5-5.0 mph and 0% grade and data were collected in the last minute of this workload. Next, the treadmill speed was increased to a comfortable running speed (determined during a prior visit), which ranged from 5.0 to 7.0 mph. After 1 min at this speed and 0% grade, the treadmill grade was increased 2% every minute until volitional fatigue [9]. We estimated aerobic exercise energy expenditure and EPOC between work-equivalent bouts of intense cycling and uphill running. Exercise energy expenditure for aerobic metabolism was converted as 1 liter of $O_2$ = 21.1 kJ. Upon completion of the work period, subjects were immediately seated in a chair next to the cycle or treadmill and EPOC was recorded until it fell below the respective 5-min resting $O_2$ uptake measurement. EPOC was calculated as 1 liter of $O_2$ = 19.6 kJ to exclude rapid glycolytic ATP re-synthesis as part of the conversion of oxygen uptake into energy expenditure; in this regard EPOC represented aerobic energy expenditure only [2, 10]. Aerobic exercise energy expenditure and EPOC were compared between cycling and uphill treadmill running with a standard 2-tailed paired t-test.

## RESULTS AND DISCUSSION

All measurements are reported as mean ± SD. $VO_2$ max did not differ between cycle and treadmill testing (55.0 ± 10.9 ml kg $min^{-1}$ cycle; 57.3 ± 11.7 ml kg $min^{-1}$ run). Absolute energy expenditure values are shown in Table 2. Aerobic exercise energy expenditure was significantly lower for cycling as compared to running (29.7 kJ vs 39.4 kJ, respectively). EPOC values were not statistically different (51.7 kJ cycle vs 59.5 kJ run). Aerobic exercise energy expenditure and EPOC values were significantly less for cycling as compared to running (83.4 kJ vs 101.0 kJ, respectively). Percent aerobic contributions (exercise $O_2$ uptake + EPOC) were significantly lower for cycling compared to running (70.1% vs 80.8%, respectively). Percent aerobic exercise energy expenditure was significantly less for cycling as compared to running (25.7% vs 32.0%, respectively). Percent energy expenditure contributions for EPOC were not statistically different between tests (42.4% cycle vs 46.8% run).

As with previous investigations using longer duration exercise and various standards of comparison [3, 11], our data reveal that exercise oxygen uptake is lower bout of intense non-steady state cycling as compared to uphill running. Previous research also has shown that excess post-exercise oxygen consumption (EPOC) is not different between comparable bouts of longer duration cycling and uphill running even though running had greater aerobic exercise energy expenditure [5]; this also was true for the current study. In agreement with our hypothesis, the data suggest that when a measure of aerobic energy expenditure used to independently interpret energy transfer, then exercise and exercise energy expenditure between work-equivalent 1-minute bouts of cycling and uphill running are similar. Additional studies are needed to determine if this finding

Table 2: Absolute energy expenditure between cycling and uphill running

| Mode of exercise | VO2 ml•kg•min$^{-1}$ | EE (KJ) | EPOC (KJ) | EE + EPOC (KJ) |
|---|---|---|---|---|
| Treadmill | 57.3±11.7 | 39.4 | 59.5 | 101.0 |
| Cycle Ergometer | 55.0±10.9 | 29.7 | 51.7 | 83.4 |

extends to lower intensity, longer duration exercise. Heavy to severe exercise promotes rapid glycolytic ATP re-synthesis [12, 13]. Even so, investigations that estimate rapid glycolytic ATP re-synthesis rarely add this component to a measure of EPOC to obtain a measurement of total energy expenditure; this may be because of the reluctance of researchers to dismiss the traditional practice of having rapid glycolytic ATP re-synthesis quantified as part of an oxygen uptake measurement, as the oxygen debt hypothesis proposed [2, 10]. If oxygen uptake were the only means of measuring energy expenditure for the brief, intense and equivalent work in the current study then it would be falsely concluded that cycling was the more efficient and running the more "expensive" exercise. However, cycling appears to recruit a different muscle mass as compared to running that can result in an accelerated glycogenolysis with lactate production that plays a significant role in total ATP re-synthesis [11]. Our data suggest that the difference in motor unit recruitment patterns between equivalent bouts of cycling and uphill running are more likely to influence the extent of aerobic energy transfer rather than exercise and total energy expenditure. We propose that a measurement of exercise oxygen uptake (i.e., aerobic energy expenditure)may provide a better comparison of energy expenditure between unlike exercise modes. In terms of work efficiency it has been shown that cycling and treadmill walking can be similar but caution should be applied as comparisons are heavily influenced by speed and incline [14]. Treadmill running also contains a horizontal along with a vertical power output component that may increase the total work output as compared to cycling; we did not account for this horizontal work component. While potential differences in the horizontal and vertical components of power output along with metabolic and work efficiency are certainly possible between an intense bout of cycling and uphill running, it did not promote significant discrepancy in perceived exertion or recovery energy expenditure (EPOC) between the work bouts so that subjects also appeared to have worked at the same relative exercise intensity. We therefore argue that work output along with the metabolic and work efficiencies were not significantly different between cycling and uphill treadmill running in the current investigation, though exercise oxygen uptake indicated the opposite. Oxygen-only measures reveal discrepancy in energy expenditure between cycling and uphill running. Measurements of exercise $O_2$ uptake, a modified EPOC promote the hypothesis of a similarity in exercise and total energy expenditure between work-equivalent bouts of cycling and uphill running.

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