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*Original Research*

# EPOC Comparison Between Resistance Training and High-Intensity Interval Training in Aerobically Fit Women

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ABSTRACT

***International Journal of Exercise Science 14(2): 1027-1035, 2021.*** Previous research has shown that various modes of exercise may elicit significant increases in resting metabolism for up to 24 hours post-exercise, but typically using untrained or moderately active subjects. The purpose of the present study was to compare excess post-exercise oxygen consumption (EPOC) between circuit-style resistance training (RT) and high-intensity interval training (HIIT) in young, aerobically fit women. During the follicular phase of the menstrual cycle, seven participants reported to the laboratory for evening and morning baseline resting metabolic rate (RMR) measurements via indirect calorimetry. Participants fasted and slept overnight in the laboratory between RMR measurements. Following the morning RMR measurement, participants were randomly assigned to complete either a total-body, circuit-style RT protocol (30 seconds of lifting at 80% 1RM:one minute rest) or treadmill HIIT (30-second run at 90% $VO_2$ max:one minute stationary recovery). RMR was repeated 14 and 24 hours post-exercise. All procedures were replicated during the follicular phase of the next menstrual cycle using the remaining exercise protocol. Resting $VO_2$ was significantly ($p$<0.05) higher 14 hours after RT (3.8±0.3 ml/kg/min) compared to baseline (3.4±0.3 ml/kg/min), however HIIT showed no significant change (3.7±0.3 ml/kg/min). Both RT and HIIT showed significantly higher energy expenditure 14 hours post-exercise (33±5 and 33±4 kcals/30 minutes, respectively) compared to baseline (30±3 kcal). Neither protocol sustained a RMR change at 24 hours. Based on the magnitude and duration of post-exercise energy expenditure, EPOC responses may be a worthwhile consideration when prescribing exercise for weight maintenance in young, fit women.

KEY WORDS: Circuit training, weight control

## INTRODUCTION

The degree to which practitioners should factor the predicted magnitude or duration of excess post-exercise oxygen consumption (EPOC) into exercise programming design for body weight or fat control remains controversial. This may be due to the following factors: 1) a relative lack of long-term training studies investigating the practical importance of EPOC responses on body weight or fat control via exercise program variable manipulation; 2) remaining uncertainty regarding differences between choice of exercise mode and consequent effects on EPOC (7, 12); 3) lack of evidence that chronic resistance training (RT), which generally is considered to have a more pronounced effect on EPOC than aerobic exercise (7, 11), is an effective exercise modality for long-term weight control (17); and 4) the diminishing EPOC returns in trained participants compared to untrained (2, 14, 20).

Higher intensity or longer duration programming typically results in greater EPOC responses than ones of lower intensity or shorter duration (6) in untrained individuals (2, 23). However, since exercise intensity and duration mutually influence the other, the results of many previous investigations may have limited "real-world" application. Additionally, results from exercise mode comparisons (typically RT vs. both continuous and interval-oriented aerobic exercise) have proven difficult to interpret as there is no single accepted strategy (e.g., matching caloric expenditure, oxygen consumption, or heart rate responses) used to equate the intensity between a resistance-based and aerobic exercise session.

More recently, there has been increasing interest in high-intensity interval training (HIIT) due to favorable effects in aerobic capacity and cardiovascular health (5). There is a limited body of research investigating the influence HIIT on EPOC, most of which indicates favorable effects when compared to steady-state aerobic work (23). However, of the 22 investigations that met inclusion criteria for a recent systematic review (23), only three utilized female participants, all of which whom were considered recreationally active.

Since little work has been done to examine the effects of HIIT versus RT on EPOC in trained women, the purpose of the present study was to investigate the influence of two time-matched exercise trials (RT versus HIIT) on EPOC within an aerobically fit and resistance-trained female subject pool. Based on previous research and the aerobically trained profile of the subject pool (11, 12), it was hypothesized that both modes would elevate resting metabolic rate (RMR) at 14 hours post-exercise compared to baseline, and that RMR would remain elevated at 24 hours post-exercise only after RT.

## METHODS

*Participants*

Using an expected effect size (Cohen's *d*) of ≈ 0.92 from an investigation with similar participant demographics (i.e., age range, gender), RT protocol, and RMR measurement time course (22), we determined eight participants would provide statistical significance ($\alpha$=0.05) with power > 0.7. Women 18-38 years of age were recruited and screened for the following self-reported inclusion criteria: non-smokers, eumenorrheic, not currently taking any stimulant-containing dietary supplements, and currently engaging in aerobic training (≥3 sessions/week) and RT (≥2 sessions/week) for at least six months prior to starting the study. A secondary inclusion criterion was a maximal oxygen uptake ($VO_2$ max) > 45.0 ml/kg/min (> 75% percentile for gender and age range) (18), which was measured at the initial laboratory visit. A trained population was chosen to ensure that the planned study protocol could be executed without points of volitional exhaustion and to avoid the unusually high degree of muscle damage observed in novice lifters (8). All participants provided written informed consent, and all study methodology was approved by the Florida State University Institutional Review Board. Additionally, all procedures are in accordance with the ethical guidelines set by the Editorial Board of the *International Journal of Exercise Science* (21).

*Protocol*

Participants initially reported to the laboratory 5-10 days prior to the expected beginning of their menstrual cycle (i.e., first day of menses). Time periods in relation to menses were fixed to control for any metabolic fluctuations due to hormonal variation throughout the menstrual cycle. Body height and mass measurements were made using a wall-mounted stadiometer and Seca digital scale (Seca Corp., Columbia, MD), respectively. A three-site skinfold body composition measurement (triceps, iliac crest, thigh) was also taken using Lange skinfold calipers and followed standard procedures (Beta Technology, Inc., Santa Cruz, CA) to estimate body fat percentage (1).

A continuous, graded exercise test (modified Bruce protocol) on a Quinton treadmill (Burdick, Ventura, CA) was used to determine $VO_2$ max. All metabolic measurements throughout this study were made via open-circuit, indirect calorimetry (Parvo Medics Truemax 2400 Metabolic Measurement System, Sandy, UT). The highest $VO_2$ collected was considered maximal if three of the four following criteria were met: 1) $VO_2$ plateau (<2.0 ml/kg/min increase) with an increase in workload; 2) respiratory exchange ratio ≥1.15; 3) heart rate within ± 10 beats/min of age-predicted maximal heart rate (220-age beats/min); and 4) volitional exhaustion as indicated by a rating of perceived exertion ≥18 on Borg's scale (15). If criteria were not met, the test was repeated within two days.

One-repetition maximum (1RM) muscular strength testing was performed 2-3 days following the $VO_2$ max test. Chest press, squat, latissimus pull-down, and shoulder press were tested using previously described methods (2) on a non-counterbalanced Smith Machine. Stationary lunges were also tested on the Smith Machine using an eight-repetition maximum (8RM) protocol for each leg. Following all baseline data collection, participants were randomly assigned to the order in which they would perform the two exercise trials.

Figure 1 shows the flow of the study protocol inclusive of RMR measurements and the exercise trials. Prior to recorded metabolic baseline measures, participants spent one night in the laboratory and performed a morning RMR measurement to familiarize them to the procedures and surroundings, with the goal of reducing intrasubject variability. Food logs were kept for 24 hours prior to baseline metabolic measures and for three, 24-hour periods following this measurement so that diets could be replicated prior to measurements during the subsequent menstrual cycle. Participants were asked to refrain from RT for 48 hours and aerobic training for 24 hours prior to baseline measures.

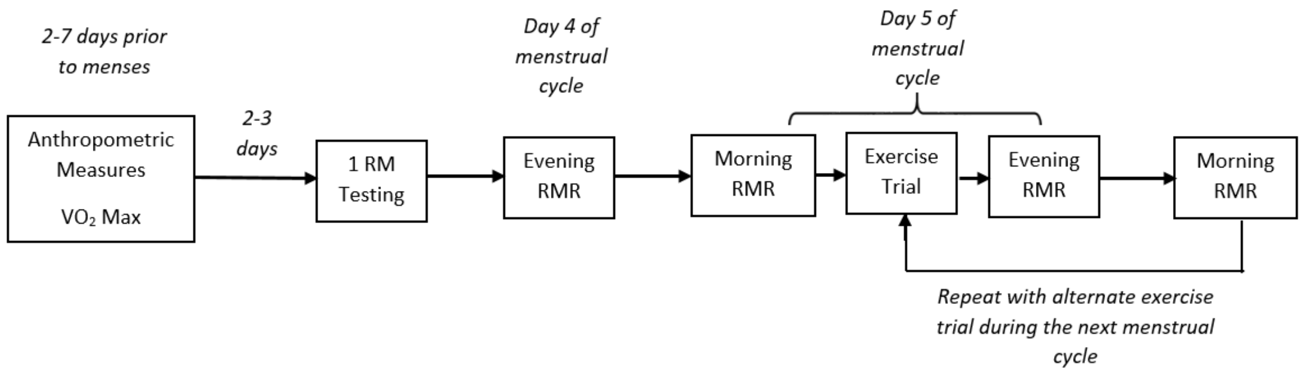


**Figure 1.** Study design.

Participants reported back to the laboratory at 1800 hours on day four of their menstrual cycle. Both evening (2130 hours) and morning (0630 hours, after sleeping in the laboratory) RMR measurements were made to account for circadian rhythm shifts. All RMR measurements were made after a minimum four-hour fast and included 30 minutes of lying in a supine position while wearing the ventilation mouthpiece. RMR was recorded as both the mean $VO_2$ (ml/kg/min) over 30 minutes and total caloric expenditure. Total caloric expenditure was calculated using nonprotein respiratory quotients (27).

Immediately following morning RMR measures (day five of menstrual cycle), participants performed one of the two time-matched (30 minutes total) exercise trials. The two trials were also matched for exercise:recovery time (30 seconds:one minute), and indirect calorimetry was utilized throughout the trials for metabolic data acquisition. The RT protocol consisted of each of the five aforementioned resistance exercises performed at 80% 1RM for 30 seconds. While participants were not paced by a metronome, they were instructed to maintain a 2 second eccentric contraction and immediately perform the concentric portion of the lift as fast as possible, with a 1-2 second rest between repetitions. This protocol results in 6-7 repetitions performed per set. Rest periods were set at 1 minute between exercises, and the entire circuit was completed 4 times (i.e., 4 sets per exercise). The HIIT protocol consisted of twenty, 30-second intervals on the treadmill with one minute of stationary rest between. Treadmill speed and grade for the work interval was calculated to ensure an intensity ≥ 90% $VO_2$ max. Stationary recovery was used to replicate the rest interval of the RT protocol. RMR measures were repeated at 14 and 24 hours post-exercise with identical procedures as baseline testing.

*Statistical Analysis*
Data collected during the exercise bouts were compared with paired-samples t-tests. All RMR data were analyzed via repeated measures analysis of variance (ANOVA) using a Fisher's Least Significant Difference test for post-hoc analyses. A $p$ value of 0.05 was set *a priori*, and Cohen's $d$ was used to describe effect size. All statistical analyses were conducted using SPSS Statistics software, version 23.0 (IBM, Armonk, NY).

## RESULTS

Out of 19 initial recruits, only seven participants completed all testing procedures. Three did not qualify due to $VO_2$ max values < 45.0 ml/kg/min. One developed an orthopedic injury during the study, five withdrew due to scheduling conflicts, and two had irregular menstrual cycles, preventing them from completing the protocol. Participant characteristics and baseline testing results are presented in Table 1.

**Table 1.** Subject characteristics and baseline testing results.

| | *Mean ± SD* | *Range* |
|---|---|---|
| Age (yr) | 23 ± 3 | 20-27 |
| Height (cm) | 163.3 ± 11.0 | 152.4-182.9 |
| Weight (kg) | 60.2 ± 7.3 | 51.8-70.9 |
| BMI (kg/m$^2$) | 22.6 ± 2.4 | 20.0-27.0 |
| Body Fat Percentage (%) | 18.0 ± 3.5 | 13.0-23.2 |
| Lean Body Mass (kg) | 49.4 ± 6.5 | 43.3-61.7 |
| $VO_2$ max (ml/kg/min) | 50.9 ± 4.1 | 46.3-57.8 |
| 1RM Bench Press (kg) | 43 ± 9 | 31-56 |
| 1RM Squat (kg) | 71 ± 17 | 47-91 |
| 1RM Lat Pulldown (kg) | 34 ± 11 | 21-46 |
| 1RM Shoulder Press (kg) | 28 ± 5 | 22-33 |

N=7. Values are mean ± standard deviation. BMI=body mass index, $VO_2$ max = maximal oxygen uptake, 1RM = one-repetition maximum; Lat = Latissimus Dorsi

Metabolic measurements from the two exercise trials are presented in Table 2. Energy expenditure and heart rate were significantly higher, and respiratory exchange rate significantly lower, during the HITT protocol compared to RT. Significant ($p<0.05$) elevations in energy expenditure as compared to time-matched baseline measures were present at 14 hours post-exercise, but not 24 hours, for both exercise trials (Table 3). There were no significant differences between the two exercise protocols in energy expenditure at 14 and 24 hours.

**Table 2.** Performance variables during exercise trials.

| | *HIIT* | *RT* |
|---|---|---|
| $VO_2$ (ml/kg/min) | 32.4 ± 4.0* | 13.4 ± 1.6 |
| EE (kcals) | 298 ± 49* | 129 ± 29 |
| RER | 0.99 ± 0.06* | 1.09 ± 0.06 |
| HR (beats/min) | 169 ± 11* | 134 ± 18 |

Values are mean ± standard deviation over the 30-minute trial. * Significantly different than RT ($p < 0.05$). HIIT = high-intensity interval trial, RT = resistance training trial, $VO_2$ = oxygen uptake, EE = energy expenditure, RER = respiratory exchange ratio, HR = heart rate.

## DISCUSSION

The primary finding of the present study is that both a 30-minute, circuit-style RT session and a 30-minute HIIT treadmill session stimulate a significant increase in energy expenditure that is still detectable 14 hours post-exercise in moderately trained women. The present results are consistent with a similar investigation in young, untrained males in which elevations in RMR post-RT and HIIT were present at 12-hours post-exercise (12), but only the RT trial resulted in a significant elevation 21 hours post-exercise.

**Table 3.** Resting metabolic measurements across trials.

| | Baseline | HIIT | HIIT-d | RT | RT-d |
|---|---|---|---|---|---|
| | 14-hrs post-exercise (evening) | | | | |
| VO2 (ml/kg/min) | 3.4 ± 0.3 | 3.7 ± 0.3* | 1.00 | 3.8 ± 0.3* | 1.33 |
| 30 min. EE (kcals) | 30 ± 3 | 33 ± 4* | 0.85 | 33 ± 5* | 0.73 |
| RER | 0.86 ± 0.04 | 0.85 ± 0.03 | 0.28 | 0.86 ± 0.06 | 0.00 |
| | 24-hrs post-exercise (morning) | | | | |
| VO2 (ml/kg/min) | 3.2 ± 0.3 | 3.2 ± 0.3 | 0.00 | 3.4 ± 0.4 | 0.93 |
| 30 min. EE (kcals) | 28 ± 2 | 29 ± 2 | 0.50 | 30 ± 3 | 0.78 |
| RER | 0.90 ± 0.03 | 0.91 ± .04 | 0.28 | 0.90 ± 0.06 | 0.00 |

Values are mean ± standard deviation. * Significantly different than baseline ($p < 0.05$). HIIT = high-intensity interval training trial, RT = resistance training trial, $d$ = Cohen's $d$ (as compared to baseline values), $VO_2$ = oxygen uptake, EE = energy expenditure, RER = respiratory exchange ratio.

Osterberg and Melby reported a 4.2% increase in RMR ($VO_2$) 16 hours after a RT protocol in trained female participants (22). Subsequent measurements of RMR were not made, so it remains unclear if elevations would have been present 24 hours post-exercise. This observed increase in $VO_2$ was lower than in the present study (11.8%). This discrepancy may be explained by the lower intensity and longer rest periods used in the Osterberg and Melby protocol, or the fact that RMR was measured at 16 hours as opposed to 12 hours post-exercise. However, the RT results contrast with an investigation of resistance trained men who displayed no increase in RMR at the 12-hour post-exercise time point (2) despite an extremely high volume-load prescribed. This may be a reflection of gender differentials in RT responses, or may represent a training effect as inclusion criteria were stricter for RT experience in the alternate study.

While the current study did not investigate mechanisms, there are plausible explanations for the elevated post-exercise RMRs for both RT and HIIT workouts. The majority of slow component oxygen debt post-RT is hypothesized to be related to muscular damage and the consequent protein synthesis required for repair (25); we examined trained women in an effort to limit this effect. While early upregulation of metabolic rate post-aerobically oriented exercise may be explained by continued elevations in ventilation, heart rate, and other variables related to sympathetic output (4), slow component elevations are likely due to the creation of additional mitochondria and muscle cell remodeling (10).

Previous investigations have led to questioning the practical importance of energy expended during the post-exercise period (2, 12). As metabolic data were not recorded immediately post-exercise, a line of best fit for energy expenditure between exercise cessation and the 14-hour mark could not be accurately formulated. However, based on the 14-hour post-exercise measures, both the RT and HIIT trials resulted in at least 168 additional kcals expended from the time that exercise ended. This suggests that either workout would have a practically important effect for caloric/weight control. Irving et al. (2008) reported significant reductions in abdominal fat over 16 weeks in middle aged, obese women with a continuous, high-intensity aerobic exercise protocol whereas no reduction was observed during a low-intensity protocol matched for energy expenditure. While metabolic data were not recorded post-exercise, these results suggest either a practically important effect of higher intensity work on EPOC, the attenuation of appetite, or a purposeful decrease in energy intake (which was not measured) (16, 28).

It would be illogical to discuss exercise-based strategies for weight control without considering the consequent effects said protocols have on appetite. However, these effects have been inconsistent in the literature. Multiple investigations have reported short-term attenuations in appetite markers following higher intensity aerobic exercise (9, 26), although this did not always result in decreased food consumption. Conversely, high-intensity aerobic exercise was shown to increase appetite markers and caloric consumption in women (24), whereas no gender effect was present in an alternate investigation after steady-state aerobic exercise (3). It should be noted that the majority of evidence related to exercise and appetite has used steady-state aerobic work as the independent variable, and therefore it is less predictable what effects HIIT may have. However, no differences in appetite responses have been reported between chronic HIIT or steady-state moderate intensity aerobic training (19).

There are several limitations to the present study. Investigators were unable to fully control all environmental influences on metabolism including chronic dietary habits, physical activity outside of the study-related exercise trials, and sleep duration as participants operated in a free-living environment throughout the study. Attempts at delimitation included the standardization of diet immediately prior to the exercise trials by use of food logs, as well as aforementioned limitations placed on physical activity within 48 hours of training.

When considering the 24-hour effect sizes in the present study, EPOC remained elevated, albeit non-statistically significantly, for a longer period post-RT training than post-HIIT, which is consistent with previous findings (12). But considering that aerobic exercise has been associated with upregulated satiety and RT has not (13), the non-significant increases in energy expenditure post-exercise due to RT may be negated by higher appetites than post-HIIT. Future researchers should consider collecting markers of appetite in the post-workout period, as well as actual food consumption data.

In conclusion, both HIIT and RT result in elevated metabolic demands for at least 14 hours, but less than 24 hours, post-exercise in aerobically fit and resistance trained young women. Based on EPOC effect size and magnitude of duration, these data justify the consideration of expected EPOC responses into exercise prescriptions for weight control and body composition improvement in similar populations. Given the higher energy expenditure during the HIIT trial but similar EPOC responses between trials, HIIT may provide greater utility for females focusing on weight management. However, RT may provide unique benefits related to body composition and bone density (1), although these were not assessed in this investigation.

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