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Sex specific responses to self-paced, high-intensity interval training with variable recovery periods

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ABSTRACT

This study examined sex-specific responses during self-paced, high-intensity interval training (HIIT). Sixteen (8 male, 8 female) individuals completed a VO_{2peak} test and 3 treadmill HIIT sessions on separate days. The HIIT sessions consisted of 6, 4 minute intervals performed at the highest self-selected intensity individuals felt they could maintain. Recovery between intervals were counterbalanced and consisted of 1-min, 2-min, or 4-min recovery during each trial. Relative measures of intensity including percent of velocity at VO_{2peak} (vVO_{2peak}), percent of VO_{2peak}, percent of HR_{max}, and blood lactate concentration ([La]) were observed during the trials. Perceived readiness was recorded immediately before and ratings of perceived exertion (RPE) were recorded at the end of each interval with session RPE recorded after each trial. Results revealed a significant effect of sex on $\%vVO_{2peak}$ ($p<0.01$) and $\%HR_{max}$ ($p<0.01$). Data show that across trials men self-select higher $\%vVO_{2peak}$ (84.5% vs. 80.7%), whereas, women produce higher $\%HR_{max}$ (96.9% vs. 92.1%) and $\%VO_{2peak}$ (89.6% vs. 86.1%) with no difference in [La] or perceptual responses. These findings support the notion that women may demonstrate improved recovery during high-intensity exercise, as they will self-select intensities resulting in greater cardiovascular strain. Moreover, results confirm previous findings suggesting a 2:1 work-to-rest ratio is optimal during HIIT for both men and women.

Key Words: high-intensity, exercise, performance, female

INTRODUCTION

It is well established that high intensity interval training (HIIT) is a valuable modality in preparation for competition dominated by oxygen-dependent (aerobic) (e.g., distance running/cycling etc.) and oxygen-independent (anaerobic) metabolic pathways (e.g., team-sports, sprinting, etc.) (4, 30, 32, 35, 40). The presumed benefit to this form of training lies primarily in an athlete's ability to maximize time spent at or above physiological thresholds by interspersing high intensity running bouts with less intense recovery periods. Seiler and Sjursen (32) state that there are virtually limitless avenues to manipulate the interval training model to individualize the session. Chief among the variables commonly manipulated are recovery duration and intensity. As would be expected, when these variables are manipulated they manifest varying levels of fatigue relative to physiological (HR, VO_2) and biochemical (blood lactate concentration) responses, and/or levels of perceived strain as evidenced by changes in ratings of perceived exertion (RPE). As Seiler and Sjursen (32) note, the literature has largely focused on the training response when subjects perform at pre-determined physiological thresholds; however, this lacks ecological validity. That is, when training athletes, a prescription of intensity is advised but is ultimately self-regulated by the individual. To that end, there is a continuing need to monitor the impact of variable manipulation on an individual's response during interval training.

Seiler and Hetlelid (31) published a novel study detailing the physiological and perceptual response to manipulating recovery duration during high-intensity interval training in highly trained males (VO_{2peak} = 71±4 $ml \cdot kg \cdot min^{-1}$). In their study, individuals performed 3 bouts of self-selected high-intensity training using 6, 4-minute intervals with 1, 2, or 4-mintues of recovery. Results from that study suggest that the optimal work-to-rest ratio is 2:1, as it elicits an optimal training intensity with little benefit gained by affording extra recovery time. While this study is novel and provides much needed information about HIIT, there are a variety of other populations that routinely employ interval training as a means of training that have not received adequate attention in the literature. Evidence from recent studies identify potential differences in rate of fatigue and/or recovery between bouts of high(er) intensity exercise between men and women (1, 8, 15, 22, 26, 39). However, the possibility of a sex difference during prolonged, high intensity interval-type exercise is not well-understood. Identifying sex specific responses to this mode of exercise is important as the specificity of the exercise prescription should provide an adequate overload to maximize performance as well as minimize predisposition to injury due to an ineffective training stimulus. To provide this stimulus both the optimal intensity and recovery duration deserve adequate attention. Clearly, there is a need for further work delineating the sex-specific responses to high-intensity exercise to more precisely optimize desired adaptations from interval training (3, 14, 15, 19, 20, 22, 24, 25, 33). It seems plausible that if women demonstrate improved resistance to fatigue or improved ability to recover they may self-select higher relative intensities than men during HIIT when presented with longer recovery periods. Therefore, the aim of this study was to examine physiological and performance responses between well-trained men and women during self-paced HIIT with variable recovery periods. Thus, because of the potential impact of sex on fatigability and recovery it was hypothesized that women would manifest higher levels of intensity during the sessions of HIIT when compared to men during self-paced HIIT with variable recovery periods, indicating either lower level of fatigue during the bout or improved recovery between bouts.

METHODS

Experimental Approach to the Problem

This study aimed to identify sex-specific physiological and perceptual responses to self-paced, high-intensity interval running. Methods were a replication of Seiler and Hetelid (31) that tested only highly trained male runners. Each subject in our study completed four trials; a peak oxygen uptake (VO_{2peak}) treadmill test and 3 subsequent trials of interval training. Each interval training trial had subjects perform 6, 4-minute intervals on a treadmill at a self-regulated speed. The recovery duration between each 4-minute interval was either 1, 2, or 4 minutes and was assigned in a counterbalanced order. That is, the first subject performed the 1-, then 2-, then 4-minute recovery session, the second subject performed the 2-, then 4-, 1-minute recovery, etc. and this repeated throughout. The intervals were performed at a self-regulated pace, with subjects instructed to perform at the highest intensity they felt they could maintain knowing they were to perform 6 intervals and with consideration of the amount of recovery they would be afforded between each interval.

Subjects

All procedures were approved by and conducted in accordance with the local university institutional review board for the use of human subjects. Sixteen subjects (8 men and 8 women) between 19 and 30 years of age (data shown in Table 1) provided written, informed consent prior to participation.

Insert Table 1 about here

All subjects self-reported at least a moderate fitness level and participation in at least one session of interval training per week. Prior to the experimental trials, subjects were assessed for height (m) and total body mass (kg) using a calibrated physicians beam scale and stadiometer (Detecto, Webb City, MO) with body fat percentage estimated using skinfold calipers (Lange, Cambridge, MA) and a three-site skinfold method (men: chest, abdomen, thigh; women: tricep, iliac, thigh) (27). Criteria for exclusion included a reported or demonstrated behavior of any medical or orthopedic problem severe enough to disrupt performance or endanger health or if an individual provided a self-reported fitness classification below moderately active. Subjects were told to report to the laboratory well-hydrated and at least 4 hours post-ingestion of a meal and to have abstained from alcohol 24 hours prior and caffeine 4 hours prior. In addition, all subjects were instructed to replicate their diet on days before the trials and to have abstained from training activities the day before a testing session. All subjects were given a minimum of 72 hours but no more than 10 days of rest between sessions.

Procedures

VO_{2peak} testing. The first session for all subjects involved a maximal treadmill test to determine VO_{2peak} and HR_{max}. Subjects were fitted with a heart rate monitor and belt (Polar, Stamford, CT) worn around the chest. Maximal testing was performed on a motorized treadmill (TrueFitness, O'Fallon, MO) with

metabolic data measured via an automated metabolic measurement system (Parvo TrueOne, ParvoMedics, Sandy, UT). Prior to data collection, the metabolic system was calibrated in accordance with manufacturer's suggestion using gases of a known concentration and a 3-L Hans-Rudolph calibration syringe. The protocol incorporated a 3-minute warm-up with subjects walking at 4.8 $km \cdot h^{-1}$ whereupon the speed of the belt was increased by 0.8 $km \cdot h^{-1}$ every minute until subjects reached volitional fatigue. Throughout testing, the treadmill grade was set at a constant 5% incline. At the end of each minute, subjects provided their RPE using Borg's 6-20 scale. Heart rate and metabolic data were recorded at the conclusion of every minute. The criteria for VO_{2peak} were confirmed by achievement of at least three of the following criteria: an RER value ≥ 1.15, VO_2 plateau with increasing intensity, HR ± 10 bpm of age-predicted maximum, and an RPE of 18 or higher (2). Data from the maximal test was used to identify each subject's velocity at VO_{2peak} (vVO_{2peak}), determined as the speed at which the individual attained VO_{2peak} as long as the speed was maintained for a full minute in accordance with Billat et al. (5).

High-intensity interval training. At least 48 hours following maximal testing, subjects reported to the laboratory to perform the first of three bouts of HIIT. Each session consisted of 6, 4-minute intervals interspersed with either 1, 2, or 4 minutes of recovery. The recovery duration was counterbalanced and subjects were informed of the specific work-to-rest ratio prior to performing each session. Each trial began with a 5-minute warm-up that consisted of walking 4.8 $km \cdot h^{-1}$ at 5% incline. Immediately following the warm-up, subjects were asked to begin the session by setting the treadmill to the highest possible speed they felt they could maintain for 4 minutes knowing they were to perform 6 intervals considering their specific work-to-rest ratio. Subjects were told there is no right or wrong speed, rather, just set the belt at the speed they felt was their highest effort given the testing situation. The treadmill remained elevated at 5% incline for the duration of the HIIT session. Prior to each interval, subjects estimated their level of readiness using a perceived readiness scale (11). The perceived readiness scale, shown in Figure 1, is analogous to a RPE scale in that it uses numbers associated with anchors to estimate

Insert Figure 1 about here

perceived readiness to perform. Throughout each interval, VO_2 ($ml \cdot kg \cdot min^{-1}$), HR (bpm), and RPE were measured at the end of each minute. At the conclusion of the fourth minute, the treadmill was slowed to 4.8 $km \cdot h^{-1}$ for an active recovery, the mouthpiece and nose-clip were removed and a blood lactate ([La]) sample was obtained by a capillary draw from a preferred finger and analyzed using an enzymatic portable lactate system (Lactate Pro, Arkray Inc, Kyoto, Japan). The lactate measurement system was calibrated in accordance with manufacturer's instructions prior to each trial. Throughout the recovery period, subjects were allowed to drink water. Within the last 15 seconds of the active recovery, subjects re-inserted the mouthpiece and applied the nose-clip and were given a countdown to initiate the next interval. These procedures were followed identically for each of the 6 intervals and across all 3 trials. At the conclusion of the final interval of each session, subjects were disconnected from the metabolic system and sat quietly in a chair in the laboratory for approximately 15-20 minutes whereupon they provided a session RPE (SRPE) using the OMNI scale (16). All subjects were given at least 72 hours but no more than 10 days of rest between HIIT sessions.

Statistical Analyses

Sex differences between physiological and perceptual responses to self-selected interval training were analyzed using the general linear model with a 2 (sex) x 3 (recovery duration) repeated measures ANOVA to identify any significant main effect. When appropriate, univariate post-hoc follow-ups including 1-way ANOVA and dependent paired t-tests were performed to identify significant differences and 95% confidence interval for real change. All data are presented as mean ± SD unless stated otherwise. Power is reported as N-β and effect size for main effects are reported as partial eta squared (η^2) whereas post-hoc effect sizes are presented as Cohen's *d*. Between subject (i.e., sex) effect sizes are classified in accordance with Cohen (10) with a small effect size $d = 0.20$, a medium effect size $d = 0.50$ and a large effect size $d = 0.80$. Statistical significance was determined a priori at the 0.05 level and all data were analysed using the statistical package for social sciences (SPSS, v 19.0, Chicago, IL).

RESULTS

Tables 2 – 4 present the mean, SD, 95% CIs, level of significance and effect size of the differences between men and women during self-selected HIIT.

Insert Tables 2-4 about here

Percent of HR_{max}, vVO_{2peak}, and VO_{2peak}

As shown in Tables 2 – 4, there was a consistent, significant difference between men and women on %HR_{max} values with women producing significantly higher %HR_{max} values than men across all trials (p = 0.03 – <0.01). Moreover, the effect sizes presented are considered large and suggest that these differences are meaningful.

Results also show men produced significantly higher relative velocities (i.e., %vVO_{2peak}) during the 1-minute recovery trial with the effect size suggesting a large difference. During the 2-minute recovery trial, men still produced higher velocities; however, the difference was not significant but produced a large effect size, suggesting a meaningful difference. This is further demonstrated by the small overlap shown in the 95% confidence limits. During the 4-minute recovery trial, men still produced higher velocities but values were not significantly different and the effect size is considerably low.

As shown in Tables 2 - 4, women produced higher %VO_{2peak} values than men across all three recovery trials with values reaching significance during the 4-minute recovery. The effect sizes for the 1- and 2-minute trials were moderate despite no statistical significance and the effect size for the 4-mintue recovery condition was large.

Blood Lactate Concentration

There were no significant differences between men and women with respect to [La] during any of the trials. During the 1-minute recovery trial [La] is nearly identical between men and women but during the 2-minute recovery trial women presented slightly lower [La] and then higher [La] during the 4-minute recovery trial. The effect sizes of the differences found between sexes ranged from small to moderate.

Perceived Readiness, RPE and Session RPE

During the sessions, women report higher PR, indicating less readiness, than men during all three trials. However, there were no significant differences between these values and the corresponding effect sizes associated with the differences were considered to be small.

Across all trials, women consistently reported higher RPE values. The values between sexes were very similar in the 1-minute recovery trial and the associated effect size was small with larger, albeit non-significant, differences in RPE with increasing durations of recovery. The 2-minute recovery trial, while not significant, produced a moderate effect size. During the 4-mintue recovery, differences produced a large effect size, suggesting the differences, despite not reaching $p < 0.05$, were meaningful.

The differences between men and women in SRPE were not significant. In general, women reported lower SRPE values when compared to men and the difference approached significance in the 4-minute recovery trial. Moreover, the effect size associated with the difference is considered large. The effect sizes for the 1- and 2-minute recovery trials were small and moderate, respectively.

DISCUSSION

In general, the goal of HIIT is to enhance physiological, psychological and metabolic overload by maximizing time spent performing high-intensity exercise. During HIIT, the ability to maintain adequate overload without critical disruption of homeostasis leading to premature fatigue is controlled by either duration of the interval and/or the duration of the recovery period (36). While the importance of intensity is fairly well-established and generally ranges between 75–100% of VO_{2peak} or 85-100% of HR_{max}, less is known about optimal recovery duration. Indeed, Bishop and colleagues (9) state that recovery is a critical component of training, albeit not well understood. This is true not only between training sessions, but in recovery periods during sessions of repeated exercise. Results from the current study support the notion that a 2:1 work-to-rest ratio, in this case 4 minutes of exercise with 2 minutes of recovery, during extended HIIT tends to yield an appropriate training stimulus and is perceived as less difficult. In addition, results suggest that women undertaking self-paced HIIT may produce disparate running velocities as well as different physiological and perceptual responses when compared to men despite similar instructions relative to performance expectation.

The notion of a sex difference during high-intensity exercise has gained increased attention in the literature (6, 7, 17, 22, 24, 25). In general, men possess higher total and lean body mass and produce higher absolute and relative power. However, recent studies show that women may demonstrate higher resistance to fatigue and/or improved recovery during bouts of repeated exercise despite men's ability to produce greater power (1, 8, 22, 26). While studies fail to provide overwhelming support of a true sex difference with respect to high-intensity exercise (3, 6, 17), evidence indicates that, at the very least, sex-specific training considerations are appropriate (22, 24, 34). Results from the current study provide evidence that sex-specific considerations are appropriate during self-paced HIIT. As expected, there were anthropometric and capacity differences between men and women (Table 1). Interestingly, data indicate distinct sex differences with respect to high-intensity exercise. Specifically, women demonstrate lower $\%vVO_{2peak}$ values during each recovery condition, reaching significant and meaningful levels during the 1- and 2-minute recovery trials (see Tables 2-4). Despite lower relative velocities, women produce significantly higher $\%HR_{max}$ and $\%VO_{2peak}$ response. This is observed despite near identical metabolic strain, as reflected by [La], during shorter recovery periods with marked differences, although not statistically significant, during longer recovery trials.

Seiler and Hetlelid (31) found that aerobically elite males produce $\%vVO_{2peak}$ ranging from 83-85%, increasing as recovery duration increased. Interestingly, the men in the current study demonstrate comparable values of $\%vVO_{2peak}$ ranging from 82.5-86.1%. These are significantly higher than velocities produced by the women in our study, which range from 77.6-83.6%. Despite self-selecting a lower $\%vVO_{2peak}$, women did, indeed, produce at the very least similar and, in most cases, higher physiological strain. As shown in Tables 2 – 4, women achieve higher $\%HR_{max}$ and $\%VO_{2peak}$ with most reaching significance but all being meaningful differences with respect to effect size. Whilst the response of both men and women are within accepted ranges of HIIT (40) they are lower than two previous studies utilizing similar work-to-rest durations. Studies by Seiler and Hetlelid (31) and Seiler and Sjursen (32) report values of 90-100% of VO_{2peak} during 4-minute HIIT whereas our subjects show an average VO_2 response between 85–90% of VO_{2peak}, with women producing consistently higher values than the men.

It seems plausible, then, that in order for women to maintain the requisite “high-intensity” prescription, a greater proportion of their aerobic capacity is necessary (when compared to men). This may explain why the average $\%HR_{max}$ values for women are 4-5% higher in women vs. men in this study. That is, in order to maintain aerobic energy production via oxidative pathways, a greater strain is placed on the cardiovascular system. This, when examined concurrently with the higher $\%VO_{2peak}$ values, may suggest that in order to maintain what women perceive as high-intensity there is greater reliance on aerobic mechanisms vs. anaerobic pathways. Overall, though, the response of men and women tends to show that both are able to produce an appropriate stimulus during self-paced HIIT.

A possible factor that may influence increased resistance to fatigue during exercise and sport performance in women is estrogen level. Indeed, studies have shown that estrogen may exert a protective effect on skeletal muscle mediating strength, endurance, resistance to fatigue and inflammation during and following exercise (12, 20, 37). Studies, though, have produced only equivocal evidence in determining the degree to which either estrogen or menstrual cycle and its resultant effect on hormone levels has on exercise or sport performance (12, 28). Also, and specific to our study, Hunter (20) notes that despite the potential protective and positive effects of estrogen, the impact of estrogen levels in younger women (vs. older) is negligible. That notwithstanding, it does seem plausible that estrogen may play at least some contributory role to explain higher levels of relative intensity during the repeated bouts of high-intensity running with lower recovery periods in women versus men in the current study. However, this should be interpreted with some caution as levels of estrogen or menstrual cycle were not measured or controlled for in this study.

With regard to perceptual responses during self-paced HIIT, Tables 2–4 show a relatively uniform response. This finding is consistent with previous research suggesting the relative stability of RPE during high-intensity exercise (13, 21, 23, 36, 38). However, there was a new measure of perception, the perceived readiness scale, used to determine if recovery duration influenced level of readiness during HIIT (11). In the only other study using the perceived readiness scale, Edwards et al. (11) found individuals were able to gauge readiness to perform 1,000-meter time trials at a RPE anchored intensity of "16" on the Borg scale. Those individuals were instructed to begin the time trial when they reached a perceived readiness value of "4" (adequately recovered) and results suggest that perceived readiness is as accurate as HR recovery or traditional work-to-rest recommendations. In our study, we aimed to evaluate if individuals would report variable levels of perceived readiness with increased or decreased recovery durations. Results reveal that individuals seem to adjust physiological and metabolic strain in such a manner that perceptual strain during *and* between intervals is stable. This finding, along with the finding of stable RPE response, despite variable recovery periods may suggest that individuals will more likely negotiate physiological strain vs. perceptual strain during self-paced HIIT.

The possibility of a sex difference in perceptual response is not well understood with studies yielding overall equivocal results. Some have suggested that when exercise is performed at relative intensity anchors there appear to be no sex difference (18). Others, however, show that when exercise is performed using absolute anchors perceptual differences may exist (29). Our results suggest that there are meaningful sex differences in perceptual strain both during and following self-paced HIIT as evidenced by RPE and SRPE, respectively. Interestingly, there appear to be no differences, either statistically or practically, on level of perceived readiness to perform during self-paced HIIT. It seems that both perceived readiness and perception of effort during high-intensity bouts are stable within-sex regardless of recovery duration but may occur at different relative points between men and women. That is, women may incur greater cardiovascular and/or metabolic strain at a similar level of perceptual level of strain. As shown in Tables 2-4, during the 1-minute recovery men and women generally report the same average RPE and SRPE values, however, during the 2-minute and 4-minute recovery bouts, there was increasing disparity. Women typically report higher perceptual strain during a bout but lower global values of perceptual strain following a bout. While these values did not reach statistical significance (p = 0.23–0.10), the effect size for both the 2-minute recovery bout and the 4-minute recovery bout were considered moderate and large, respectively. This finding is in line with other research noting that women report higher RPE values during and lower SRPE values following a bout of high-intensity exercise (22). Reasons to explain this finding are not clear in the literature but is worthy of future research.

In conclusion, results from our study tend to suggest that women will produce higher physiological, perceptual, and metabolic strain during bouts of self-paced HIIT compared to men when given standard instructions and prescribed a designated recovery duration between intervals. Moreover, our results support previous findings showing that during extended bouts of HIIT, a 2:1 work-to-rest ratio is perhaps the optimal prescription to ensure adequate overload while concomitantly reducing the total time in an exercise session. This is demonstrated by the similarity in responses during the 4-minute recovery bout vs. the 2-minute recovery bout.

PRACTICAL APPLICATIONS

Current results provide application to strength and conditioning professionals as well as individuals taking part in training and program design that utilize HIIT. In most cases, athletes undergoing HIIT training are directed to produce target cardiovascular and metabolic strain using prescribed effort levels provided by their coaches. For example, a strength coach may ask an individual to perform a 4-min "hard run" and hope that the athlete will self-pace themselves to reach the desired intensity to elicit stimuli that are known to precipitate functional adaptations. Findings from this study show that trained, but not necessarily aerobically elite, individuals produce optimal intensity levels during extended self-paced HIIT sessions using verbal instructions. Moreover, it seems that during these extended periods of HIIT a 2:1 work-to-rest ratio provides adequate recovery between intervals and will minimize training time as no benefit is gained by increasing recovery periods between intervals.

Another point-of-application from this study is that men and women will demonstrate variable levels of performance as well as physiological and perceptual responses to self-paced HIIT. Specifically, women, given similar instructions to self-paced HIIT, tend to produce lower relative intensities with respect to velocity of running but produce greater cardiovascular strain as well as slightly increased perceptions of effort. However, the increased strain does not demand increased recovery times, suggesting that women may demonstrate improved recovery when afforded similar rest periods. Finally, strength and conditioning personnel should be cautious instructing or encouraging female athletes to increase relative speeds to intensities similar to those of men as it may magnify the overload and, if performed regularly, may lead to non-functional overreaching if sub-optimal recovery is afforded between intervals. Results indicate female athletes warrant unique considerations compared to male athletes with regard to training and acute recovery.

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Figure Captions

Figure 1. The Perceived Readiness Scale (from Edwards et al., 2011).

Tables

Table 1. Descriptive characteristics of the subjects (*n* = 8 men, 8 women).

Variable	Men	Women
Age (yrs)	20.8 ± 2.1	21.9 ± 3.6
Height (m)	1.80 ± 0.03	1.67 ± 0.10*
Total Body Mass (kg)	74.6 ± 5.0	61.3 ± 8.3*
Body Fat (%)	6.8 ± 2.2	18.8 ± 2.2*
Maximal Heart Rate (bpm)	192 ± 11	187 ± 9
VO_{2peak} ($ml \cdot kg \cdot min^{-1}$)	60.8 ± 5.3	47.5 ± 3.0*
Velocity at Peak ($km \cdot h^{-1}$)	15.4 ± 1.6	12.7 ± 1.1*

* Values significantly different at $p < 0.05$.

Table 2. Overall average, SD, 95% confidence limits, level of significance and effect size of the observed response between men and women during a bout of 6, 4-min bouts of self-selected, high-intensity interval training utilizing 1-min of recovery between intervals. (*n* = 8 men, 8 women)

	Mean	**SD**	**95% CI**	***p***	**Cohen's *d***
$\%HR_{max}$					
Men	92.2	3.0	89.7 – 94.6	0.03	1.17
Women	96.2	3.8	92.9 – 99.4		
$\%vVO2_{peak}$					
Men	82.5	4.0	79.0 – 85.8	0.03	1.24
Women	77.6	3.9	74.4 – 80.9		
$\%VO_{2peak}$					
Men	85.6	5.1	81.4 – 89.8	0.21	0.65
Women	88.4	3.4	85.5 – 91.3		
[La] (mmol)					
Men	9.7	2.1	7.9 – 11.4	0.99	0.00
Women	9.7	2.9	7.3 – 12.0		
PR (a/u)					
Men	2.9	0.9	2.1 – 3.7	0.48	0.37
Women	3.2	0.7	2.6 – 3.8		
RPE (a/u)					
Men	13.4	1.6	12.1 – 14.7	0.68	0.24
Women	13.8	1.8	12.2 – 15.2		
SRPE (a/u)					
Men	7.6	0.8	7.0 – 8.2	0.23	0.12
Women	7.2	0.7	6.4 – 7.8		

Table 3. Overall average, SD, 95% confidence limits, level of significance and effect size of the observed response between men and women during a bout of 6, 4-min bouts of self-selected, high-intensity interval training utilizing 2-min of recovery between intervals. (n = 8 men, 8 women)

	Mean	SD	95% CI	*p*	Cohen's *d*
%HR_{max}					
Men	92.1	4.1	89.3 – 94.9	0.01	1.47
Women	97.4	3.4	95.0 – 99.8		
%vVO_{2peak}					
Men	84.9	6.4	80.5 – 89.3	0.08	0.95
Women	80.2	4.1	77.4 – 83.0		
%VO_{2peak}					
Men	86.7	5.8	82.7 – 90.7	0.21	0.66
Women	89.8	4.2	86.9 – 92.7		
[La] (mmol)					
Men	10.0	3.1	7.9 – 12.1	0.90	0.03
Women	9.9	4.6	6.7 – 13.1		
PR (a/u)					
Men	2.9	0.9	2.1 – 3.7	0.79	0.13
Women	3.2	0.7	2.6 – 3.8		
RPE (a/u)					
Men	12.8	1.4	11.8 – 13.8	0.14	0.74
Women	12.9	1.8	11.1 – 14.7		
SRPE (a/u)					
Men	7.5	0.8	6.9 – 8.1	0.30	0.54
Women	6.8	1.5	5.7 – 8.1		

Table 4. Overall average, SD, 95% confidence limits, level of significance and effect size of the observed response between men and women during a bout of 6, 4-min bouts of self-selected, high-intensity interval training utilizing 4-min of recovery between intervals. (n = 8 men, 8 women)

	Mean	SD	95% CI	*p*	Cohen's *d*
%HR_{max}					
Men	92.0	1.6	90.7 – 93.3	<0.01	0.91
Women	97.2	3.2	94.4 – 99.9		
%vVO_{2peak}					
Men	86.1	4.9	82.1 – 90.2	0.28	0.56
Women	83.6	4.0	80.2 – 87.0		
%VO_{2peak}					
Men	85.9	4.2	82.3 – 89.4	0.03	1.22
Women	90.8	3.8	87.6 – 93.9		
[La] (mmol)					
Men	9.9	2.4	7.9 – 12.0	0.27	0.59
Women	11.8	4.0	8.5 – 15.2		
PR (a/u)					
Men	3.1	0.4	2.4 – 4.0	0.92	0.15
Women	3.2	0.9	2.8 – 3.6		
RPE (a/u)					
Men	13.1	1.1	12.2 – 14.0	0.06	1.36
Women	14.3	1.4	13.2 – 15.5		
SRPE (a/u)					
Men	8.0	0.5	7.6 – 8.4	0.10	1.0

Women	7.0	1.4	5.7 – 8.3

Figure 1.

7 – Exhausted	(unable to exercise)
6 – Very tired	(unable to exercise at the required intensity)
5 – Tired	(not yet able to exercise at the required intensity)
4 – Adequately recovered	(able to exercise at the required intensity)
3 – Well recovered	(able to exercise above the required intensity)
2 – Very well recovered	(well able to exercise above the required intensity)
1 – Fully recovered	(able to exercise at maximal intensity)