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Title

Comparison of sprint interval and endurance training in team sport athletes

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Abstract

Purpose: High volume endurance training (ET) has traditionally been used to improve aerobic capacity but is extremely time-consuming in contrast to low volume short duration sprint interval training (SIT) that improves maximal oxygen uptake ($\dot{V}O_2max$) to a similar extent. Few studies have compared the effects of SIT versus ET using running-based protocols, or in team sport athletes. **Methods:** Club level male Gaelic football players were randomly assigned to SIT (n=7; 21.6 ± 2.1 yr) or ET (n=8; 21.9 ± 3.5 yr) for six sessions over two weeks. $\dot{V}O_2max$, muscle mitochondrial enzyme activity, running economy (RE), and high intensity endurance capacity (HEC) were measured before and after training. **Results:** An increase in $\dot{V}O_2max$ ($P<0.05$) following two weeks of both SIT and ET was observed. Performance in HEC increased by 31.0% and 17.2% after SIT and ET, respectively ($P<0.05$). RE assessed at 8, 9, 10 and 11 $km \cdot h^{-1}$, lactate threshold and $v\dot{V}O_2max$ were unchanged following both SIT and ET. Maximal activity of 3-β-hydroxylacyl coenzyme A dehydrogenase (β-HAD) was increased in response to both SIT and ET ($P<0.05$), whereas the maximal activity of citrate synthase remained unchanged following training ($p=0.07$). **Conclusion:** A running-based protocol of SIT is a time-efficient training method for improving aerobic capacity and HEC, and maintaining indices of running economy and lactate threshold in team sport athletes.

Key words

Gaelic football; maximal oxygen uptake; mitochondrial enzyme activity; running;

INTRODUCTION

Field-based invasion team-sports such as soccer, Australian football and rugby involve irregular changes of pace and high-intensity efforts interspersed with periods of light to moderate aerobic activity. While performance in these sports is dominated by technical and tactical proficiencies, players must also develop a number of fitness components including aerobic capacity, running speed and power. The aerobic energy system contributes significantly to energy provision during low to moderate intensity level activities whereas the phosphagen system and anaerobic glycolysis are major contributors to energy provision during high intensity activities. A high maximal oxygen uptake ($\dot{V}O_2max$) is also associated with a higher playing intensity, increased number of repeated sprints, increased involvement with the ball and greater distance covered during soccer (20).

Sport-specific training strategies that mimic the demands of the sport while eliciting improvements in $\dot{V}O_2max$ and associated performance parameters are of great interest to coaches and players. High volume endurance training (ET), characterised by repeated sessions of continuous moderate intensity exercise, induces numerous physiological and biochemical adaptations that facilitate improved exercise capacity (27). Although this type of training offers significant training adaptations it requires a large time commitment and lacks specificity in relation to the movement patterns of match play. Low volume short duration sprint interval training (SIT) consists of alternating brief bouts (<30 sec) of high intensity exercise interspersed with periods of active or passive recovery. This type of training allows players to undertake a greater volume of high intensity activities and can elicit similar or even superior physiological adaptations and improvements in exercise performance normally associated with traditional ET

(26,37). SIT is now considered one of the most effective forms of exercise for improving physical performance in athletes (4).

Many previous studies that have compared high intensity interval training to ET have been matched for total work or caloric expenditure (11,31). Sprint interval protocols are normally not matched for energy expenditure, and therefore involve a substantially lower time commitment and reduced total exercise volume than ET. For example, brief repeated sessions of SIT over as little as two weeks, induces changes in skeletal muscle energy metabolism that resemble endurance type training (8,30). Gibala *et al*., (2006) found that six sessions of either SIT or ET induced similar improvements in muscle oxidative capacity, muscle buffering capacity and exercise performance. The total volume of training was 90% lower in the SIT group than the ET group indicating that SIT is a time-efficient strategy to produce physiological adaptations similar to endurance training (14).

To date, the majority of studies that have compared the physiological and performance changes in response to SIT and ET have involved cycle ergometer exercise performed by untrained or recreationally-active participants (37), with a paucity of studies examining performance in trained athletes using running-based interventions (34,36). Given that the principle of specificity states that the training effect that occurs in response to an exercise overload is specific to the way the load was applied, cycling-based protocols lack the specificity to develop the physical, physiological and metabolic indices that are required for field based invasion team sport. Furthermore, the time-course and magnitude of the adaptive training response to exercise training is not only influenced by the intensity, volume and frequency of

the training stimulus but also the initial fitness level of the participant (32,36)**.** Therefore, compared to ET it is unclear whether SIT can induce similar physiological and biochemical adaptations when undertaken by trained athletes. Previous SIT studies have focused primarily on the changes to $\dot{V}O_2$max and mitochondrial enzyme activity, with no studies examining the effect of SIT on parameters such as running economy (RE), velocity at $\dot{V}O_2$max ($v\dot{V}O_2$max) (1), lactate responses and high-intensity endurance capacity (HEC), specifically in athletes involved in team sports. The novel aim of the present study was to investigate the effect of two weeks of SIT, using a shuttle-based, bidirectional running protocol, compared to ET on physiological, biochemical and performance parameters in field-based intermittent team sport athletes, specifically, Gaelic football players. Gaelic football, much like other intermittent team sport involves weight bearing short-duration, high-intensity sprints interspersed with periods of light to moderate aerobic activity consisting primarily of walking and jogging (3).

METHODS

Experimental Approach to the Problem

The study was approved by the Dublin City Research Ethics Committee at University (DCUREC 148). Participants were randomly assigned to the ET or SIT group that involved six training sessions over a two week period, with assessment of physiological and biochemical parameters before and after training. Participants were instructed to refrain from any additional strenuous physical activity during the study. Participants were also instructed to continue their normal dietary practices throughout the study but refrain from alcohol and caffeine 24 h prior to each laboratory visit for assessments.

Participants

Fifteen male club level Gaelic football players (mean ± SD; age 21.7 ± 2.8 y; BMI 24.2 ± 1.8 $kg \cdot m^{2}$; $\dot{V}O_2max$ 55.5 ± 3.4 $ml \cdot min^{-1} \cdot kg^{-1}$) participated in the study during the competitive phase of the season. Each player had a minimum of 3 years playing experience in Gaelic football. During the season participants trained, on average, 2 $d \cdot week^{-1}$ on the field, played a game on the majority of weekends, and supplemented this field-based activity with at least one resistance training session per week. Participants were fully informed of the experimental procedures, benefits and possible discomforts associated with the study before giving their written informed consent to participate.

Procedures

Prior to starting the training phase, participants made three separate visits to the Human Performance Laboratory with each visit separated by 24 to 48 h. The first visit assessed anthropometric characteristics, running economy (RE), blood lactate responses and $\dot{V}O_2max$ using a treadmill (Woodway ELG 55, Waukesha, WI) protocol. Briefly, height and body mass were measured to the nearest 0.1 cm and 0.1 kg respectively, using a portable scale (Seca 707 Balance Scales, GmbH, Hamburg, Germany). Participants were instructed to wear a light top and shorts, and to remove their shoes prior to the measurement. The cardio-pulmonary exercise test (CPET) involved participants warming-up at 8 $km \cdot h^{-1}$ for 3 min at 1% gradient, after which the speed was increased by 1 $km \cdot h^{-1}$ every 3 min. At the end of each 3 min stage, participants straddled the moving treadmill and a 5 µL blood sample was taken from the earlobe to determine whole blood lactate concentration. When blood lactate concentration reached 4 mM, the treadmill velocity was then kept constant and the gradient increased by 1% every 60 s until the

participant reached volitional fatigue. RE was examined in $ml \cdot kg^{-1} \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot km^{-1}$ and $kcal \cdot kg^{-1} \cdot km^{-1}$ at submaximal speeds of 8, 9, 10 and 11 $km \cdot h^{-1}$. $v\dot{V}O_2max$ was determined by extrapolating from the sub-maximal velocity-$\dot{V}O_2$ relation during the CPET. Heart rate and RPE were recorded during the final 10 s of each minute of exercise.

During the second visit, a test of HEC was performed. The test consisted of a 5 min warm-up at 50% $v\dot{V}O_2max$. Treadmill velocity was then increased to 110% $v\dot{V}O_2max$ and participants ran to volitional exhaustion. Estimated $v\dot{V}O_2$ values were calculated once more by extrapolating from the submaximal velocity-$\dot{V}O_2$ relation from the participants CPET on visit 1. A muscle biopsy (pre-training) was taken from the vastus lateralis muscle during the third visit. After completing the training protocol, participants performed the same physiological assessments, starting with the muscle biopsy (48 h after the last training session), anthropometric and physiological fitness assessment, and the performance test.

Lactate analysis

Blood samples were drawn from the earlobe and measured for lactate. Prior to each sample, the earlobe was wiped with alcohol and allowed to dry thoroughly. The base of the earlobe was pierced with a lancet (Accu-ChekSoftclix, UK), and the first drop of blood was wiped away. Pressure was applied to the earlobe with the thumb and forefinger in order to provide an adequate sample. A 5 μL sample of whole blood was automatically aspirated into a single use, enzyme-coated electrode test strip and analysed using a hand-held portable analyser (Lactate Pro, Akray, Japan). Plots of blood lactate against treadmill velocity and $\dot{V}O_2$ were provided to two independent reviewers who determined the lactate threshold as the first

sustained increase in blood lactate above baseline (9). Blood lactate markers at 2.0 mmol.L^{-1} and 4.0 mmol.L^{-1} were also identified from the treadmill velocity vs. blood lactate and $\dot{V}O_2$ plots.

(*Table 1 about here)

Muscle biopsies

A resting muscle biopsy sample was taken during the third assessment visit prior to commencing training, and another biopsy was taken 48 h after the last exercise training session. Each muscle biopsy was obtained from the m. vastus lateralis under local anaesthesia. An area of the skin was anaesthetized with 2% lidocaine and a small (0.5 cm) incision made. The biopsy needle was inserted into the muscle with suction applied (13). Muscle samples were snap-frozen in liquid nitrogen and stored at -80°C until analysis. Each biopsy was obtained from a separate incision site, with incision sites spaced 2 to 3 cm apart.

Muscle enzyme activity

Frozen wet muscle (~15 mg) was dissected from each biopsy under liquid nitrogen for the spectrophotometric determination of maximal enzyme activities of mitochondrial citrate synthase (CS) and β-3-hydroxyacyl coenzyme A dehydrogenase (β-HAD) as described previously (33).

(*Table 2 about here)

Training intervention

Participants commenced the training protocol 48 h following the final pre-training assessment visit. Training involved three sessions of ET or SIT per week on alternate days (i.e., Monday, Wednesday, Friday) for two weeks. Endurance training consisted of 50 min of continuous treadmill running at a velocity corresponding to 75% v$\dot{V}O_2$max. Before and after each ET session, a 5 µL blood sample was taken from the earlobe to determine whole blood lactate concentration. The SIT protocol involved three sets of high intensity sprints interspersed with short recovery periods. Each interval run was 110 m in total distance, and involved forward and backward sprints over distances ranging from 5 to 20 m with multiple changes of direction (COD) (Figure 1). A set consisted of 3 x 110 runs with a 20 s recovery period between each run, and a 5 min recovery period between sets. Before exercise commenced and at the end of each run, a 5 µL blood sample was taken from the earlobe to determine whole blood lactate concentration. Participants were verbally encouraged throughout both exercise protocols. All training sessions for both groups were supervised by one of the study investigators.

(*Figure 1 about here)

Statistical Analysis

SPSS 21 (Statistical Package for Social Science, Chicago, IL) was used to perform the statistical analysis. The data were checked for normality using the Shapiro-Wilk test. The data was analysed using mixed design ANOVA. With the exception of blood lactate, time (pre and post training) was treated as the within group effect and training condition (SIT or ET) as the between group effect for all other response variables.

Time and training session were treated as the within group effect and training condition as the between group effect for blood lactate analysis. Post-hoc analysis was conducted using a Bonferroni correction factor. All values are reported as mean ± standard deviation.

RESULTS

Over the two weeks of training, compliance was 100% in both SIT and ET groups. Body mass was unchanged following the two week training intervention (SIT: pre, 74.80 ± 7.30 kg, post, 75.05 ± 6.87 kg; ET, pre, 75.14 ± 6.82 kg, post, 75.30 ± 6.64 kg). Blood lactate concentrations for each training session are summarized in Table 1. Circulating blood lactate levels increased significantly during each SIT and ET session, and the levels were significantly higher after each SIT than ET session.

Physiological parameters and high intensity exercise capacity

Following two weeks of training, there was a significant time effect for $\dot{V}O_2max$ ($p=0.008$, $F_{(1,12)}=9.989$) in response to six sessions of SIT and ET (Figure 2). There was also a significant time effect ($p<0.001$, $F_{(1,12)}=31.919$) for performance in the test of HEC with increases ($p<0.001$) of 31.0% and 17.2% in SIT and ET, respectively (Figure 3). There was a significant group*time interaction effect, ($p= 0.013$, $F_{(1,12)}=8.494$) for HRmax with the maximal value decreasing significantly after ET. There was no significant change in $v\dot{V}O_2max$, velocity, %HR and $\%\dot{V}O_2$ at 2 $mmol \cdot L^{-1}$, 4 $mmol \cdot L^{-1}$ and LT (Table 2) or RE at 8, 9, 10 and 11 $km \cdot h^{-1}$ (data not shown).

(*figure 2 and figure 3 about here)

Mitochondrial enzyme activity

Maximal activity of β-HAD increased significantly ($p=0.008$, $F_{(1,12)}=9.981$) in response to training in both SIT (pre, 6.33±1.90 vs. post, 9.20±4.41 $mM \cdot min^{-1} \cdot kg\ ww^{-1}$) and ET (pre, 5.87±3.24 vs. post, 7.06±3.15 $mM \cdot min^{-1} \cdot kg\ ww^{-1}$), (Figure 4A). There was no significant change ($p=0.069$) in the maximal activity of CS in response to SIT (pre, 13.19±3.32 vs. post, 16.66±2.92 $mM \cdot min^{-1} \cdot kg\ ww^{-1}$), or ET (pre, 13.69±3.74 vs. post, 14.16±2.16 $mM \cdot min^{-1} \cdot kg\ ww^{-1}$) (Figure 4B).

(*figure 4 about here)

DISCUSSION

The present study examined the effects of two weeks of running-based SIT or ET on physiological, biochemical and performance indices in field-based intermittent team sport athletes. The primary finding was that six sessions of SIT or ET over a two week period is adequate to induce significant improvements in $\dot{V}O_2max$ in previously-trained athletes. Additionally, we observed comparable improvements in HEC and the maximal activity of mitochondrial enzymes of the β-oxidation pathway i.e. β-HAD after both SIT and ET.

Pre-training $\dot{V}O_2max$ values in SIT and ET were similar to values previously reported for club level Gaelic football players (40). In addition to supplying the energy requirements for low to moderate intensity activities during field-based intermittent team sport, a high $\dot{V}O_2max$ also helps to ensure the provision of ATP for the replenishment of phosphagen stores following short-duration bouts of high-intensity activities, and decreases reliance on anaerobic glycolysis during periods of play that involve repeated high-intensity sprints, with relatively short recovery

intervals (39). Despite SIT being 90% less in terms of total active exercise time, $\dot{V}O_2$max increased significantly compared to pre-training in response to both SIT (7.2%) and ET (5.4%). Previous studies have also found similar increases in $\dot{V}O_2$max following two weeks of SIT (7,19), but the present study demonstrates this effect specifically in previously-trained team sport athletes employing a novel, running-based protocol. Moreover, time to exhaustion in the test of HEC improved in both SIT and ET.

ET has traditionally been used to develop aerobic fitness in team sport athletes. In general, an average improvement of between 5% and 25% can be anticipated for healthy young adults in response to ET ranging from 2 to 25 weeks in duration (21,24). This form of training is known to induce both central and peripheral adaptations that result in an increased $\dot{V}O_2$max (12,16). Therefore the 5.5% increase in $\dot{V}O_2$max following ET is not surprising and may have been sufficient for the consequent increase in HEC. However, many other factors may influence endurance performance other than an individual's $\dot{V}O_2$max (10). Other potential mediators of the change in HEC may include an increase in skeletal muscle blood flow (35), lactate transport capacity (2), ionic regulation and sarcoplasmic reticulum function (18), but were beyond the scope of the present study.

An increase in muscle oxidative capacity is commonly reported in response to SIT and ET (5,14,28), and is likely to explain, in part, the improvements in HEC. CS is an enzyme of the TCA cycle that is commonly used as marker of muscle oxidative potential as it exists in constant proportion with other mitochondrial enzymes (17), and reflects mitochondrial content (25). Interestingly, although there was a 26% increase in CS activity in response to SIT, no significant

change ($p=0.07$) was found during analysis, whereas β-HAD activity increased significantly in both groups after training. Peripheral adaptations such as an increase in skeletal muscle enzyme activity are indicated by these changes in β-HAD activity, as it plays an essential role in the mitochondrial beta-oxidation of short chain fatty acids (38). Similarly, maximal activities of glycolytic enzymes such as hexokinase and phosphofructokinase (PFK), and other mitochondrial enzymes such as succinate dehydrogenase and malate dehydrogenase increase in parallel with aerobic fitness following seven weeks of SIT (29), whereas increases in activities of lactate dehydrogenase, PFK, and cytochrome c oxidase (COX) and the protein content of COX subunits II and IV occur after two weeks of SIT (14,34). Based on the observed changes in β-HAD activity, our novel running-based sprint protocol was sufficient to induce similar adaptation to the classic cycle ergometer-based SIT protocols of recent years (8,15).

There was no change in workload, %HR or $\%\dot{V}O_2$ at 2 $mmol \cdot L^{-1}$, 4 $mmol \cdot L^{-1}$ and LT following training in either group. The ET group trained at an average treadmill velocity of 10.3 $km \cdot h^{-1}$, which corresponded to an intensity ~5% above the LT. Our results are in contrast with previous studies that found a period of ET induced a significant decrease in blood lactate concentrations during subsequent exercise bouts (24). Increased capillary density following endurance training increases the exchange area and decreases the distance between the site of lactate production and the capillary wall, leading to improvement in lactate exchange ability (22). In addition, the fact that the workload, relative HR and $\dot{V}O_2$ at LT and fixed blood lactate concentrations did not change following two weeks of SIT, was surprising considering that SIT is also an effective strategy to alter lactate metabolism (7). Compared to straight line or continuous SIT, protocols using changes of direction result in a larger increase in blood lactate

accumulation due to the increased mechanical demands of repeated accelerations inherent with consecutive changes of direction, further manipulating anaerobic glycolytic contribution (4). The stimulus experienced during both training programs may have been too short and that a minimum duration of exercise may be required to induce a significant decrease in blood lactate concentration in trained athletes. Although SIT has been reported to elicit increases in both of the lactate transport proteins MCT1 and MCT4 content in human muscle (6), little is known about the magnitude of the stimulus required to elicit such adaptations.

A major advantage of SIT over ET is the lower total time requirement. In the present study, the total time requirement over the two weeks was almost three times greater in ET than SIT (300 min vs. 102 min, respectively), whereas the actual exercise time was 12.5 times greater for ET (300 min vs. 24 min). In both elite and sub-elite team sports, collective training during the early part of the season is spent undertaking ET to improve $\dot{V}O_2$max and associated performance parameters (23). Surprisingly, few studies have used a running protocol to compare the effects of SIT and ET on $\dot{V}O_2$max and performance parameters in trained athletes. Our findings suggest that as little as six sessions of SIT over a two week period is adequate to induce significant improvements in $\dot{V}O_2$max and HEC in club level Gaelic games players. Future studies should examine the most appropriate work to rest ratio to use during SIT in order to simultaneously improve or maintain aerobic capacity and indices of running speed and power. The cellular and molecular mechanisms underpinning the response to SIT and ET in previously trained team sport athletes also requires further investigation.

PRACTICAL APPLICATION

The present study found that six sessions of SIT performed over a two week period increased maximal oxygen uptake, HEC and markers of muscle oxidative capacity in already-trained, field-based team sport athletes. This represents a more time efficient training method for improving these parameters than ET, and despite a much lower training volume, SIT can rapidly stimulate improvements in aerobic capacity that are comparable to previously employed ET programs of similar duration. The short duration of the SIT sessions could potentially free-up considerable collective training time that could be used to develop technical and tactical aspects of play, as a major disadvantage of ET is the large time commitment involved (23).

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FIGURE LEGENDS

Figure 1. Schematic of the SIT running protocol. Each interval run was 110 m in total distance, and involved forward and backward sprints over distances ranging from 5 to 20 m. A set consisted of 3 x 110 runs with a 20 s recovery period between each run. Each training session consisted of three sets of high intensity running interspersed with a 5 min recovery period between sets.

Figure 2. Changes in maximal oxygen uptake (VO_{2max}) in response to two weeks of endurance training (ET) or sprint interval training (SIT). Data are mean±SD. Filled boxes (■) represent pre-training values, and open boxes (□) represent post-training values. *Main effect for time ($p<0.008$) vs. pre-exercise.

Figure 3. Changes in high intensity endurance capacity assessed by time-to-exhaustion at 110% vVO_{2max} in response two weeks of endurance training (ET) or sprint interval training (SIT). Data are mean±SD. Filled circles (●) represent pre-training values, and open circles (○) represent post-training values. *Main effect for time ($p<0.05$) vs. pre-exercise.

Figure 4. Changes in maximal enzymatic activity of (A) 3-β-hydroxylacyl coenzyme A dehydrogenase (HAD), and (B) citrate synthase (CS) in response to two weeks of endurance training (ET) or sprint interval training (SIT). Data are mean±SD. Filled boxes (■) represent pre-training values, and open boxes (□) represent post-training values. *Main effect for time ($p<0.05$) vs. pre-exercise

Table 1. Blood lactate concentration before, during, and after each SIT and ET training session.

	SIT				ET	
	Pre-exercise	**Set 1**	**Set 2**	**Post-exercise**	**Pre-exercise**	**Post-exercise**
Session 1	1.20 ± 0.36	9.30 ± 2.43*	10.70 ± 2.50*	11.41 ± 0.50*[a]	1.03 ± 0.26	5.64 ± 3.36*
Session 2	1.03 ± 0.21	8.83 ± 3.13*	11.64 ± 1.04*	12.19 ± 1.32*[a]	1.09 ± 0.20	4.54 ± 3.30*
Session 3	1.23 ± 0.41	7.58 ± 3.32*	12.06 ± 1.23*	12.45 ± 1.59*[a]	0.97 ± 0.15	4.66 ± 3.51*
Session 4	1.29 ± 0.36[a]	7.63 ± 3.71*	10.94 ± 2.96*	11.88 ± 1.69*[a]	0.90 ± 0.17	2.97 ± 2.27*
Session 5	1.29 ± 0.39	6.84 ± 3.42*	13.19 ± 2.08*	13.26 ± 1.72*[a]	1.01 ± 0.38	3.64 ± 2.39*
Session 6	1.05 ± 0.31	7.46 ± 3.93*	10.90 ± 3.30*	12.90 ± 2.16*[a]	0.93 ± 0.34	3.94 ± 2.14*

Values are mean ± SD, mmol·L^{-1}; *Main effect for time ($p<0.05$) vs. pre-exercise; [a] main effect for time x group interaction ($p<0.05$) vs. post-ET

Table 2. Physiological parameters pre-training and in response to two weeks of training

	SIT		ET	
	Pre-training	**Post-training**	**Pre-training**	**Post-training**
VE_{max} ($L \cdot min^{-1}$)	101.18 ± 17.42	113.52 ± 14.92	99.57 ± 17.38	105.50 ± 20.64
RER_{max}	1.08 ± 0.64	1.11 ± 0.07	1.10 ± 0.06	1.04 ± 0.08
HR_{max} (bpm)[a]	185 ± 12	189 ± 9	200 ± 13	189 ± 11
$v\dot{V}O_2max$ ($km \cdot h^{-1}$)	14.68 ± 1.68	16.31 ± 2.82	14.66 ± 1.73	15.00 ± 1.62
Vel. @ LT ($km \cdot h^{-1}$)	11.3 ± 0.3	11.8 ± 1.7	10.6 ± 1.1	10.7 ± 1.2
Vel. @ 2 mM ($km \cdot h^{-1}$)	10.0 ± 1.9	9.9 ± 1.2	8.5 ± 0.6	10.4 ± 1.9
Vel. @ 4 mM ($km \cdot h^{-1}$)	12.8 ± 1.2	12.9 ± 1.4	11.6 ± 0.6	12.7 ± 1.3
$\%\dot{V}O_2$ at LT	80.3 ± 7.6	75.1 ± 9.8	78.1 ± 13.2	78.4 ± 15.4
$\%\dot{V}O_2$ at 2.0 $mmol \cdot L^{-1}$	75.8 ± 10.5	67.0 ± 12.6	69.4 ± 13.4	75.8 ± 19.3
$\%\dot{V}O_2$ at 4.0 $mmol \cdot L^{-1}$	87.8 ± 7.8	80.5 ± 10.9	82.3 ± 11.6	88.6 ± 10.8
%HR at LT	89.6 ± 4.4	89.9 ± 4.3	89.1 ± 9.2	83.7 ± 7.3
%HR at 2.0 $mmol \cdot L^{-1}$	84.9 ± 8.5	83.0 ± 7.7	82.2 ± 11.3	81.7 ± 8.2
%HR at 4.0 $mmol \cdot L^{-1}$	94.0 ± 2.9	93.9 ± 2.2	90.3 ± 8.6	91.4 ± 4.1

Values are mean ± SD; [a]main effect for group ($p<0.05$). VE_{max}, ventilation at maximal effort; HR_{max}, heart rate at maximal effort; RER_{max}, respiratory exchange ratio at maximal effort; bpm, beats per min; LT, lactate threshold; 2 and 4 $mmol \cdot L^{-1}$ refers to blood lactate concentration