



## Physiological and Psychological Adaptations of Trained Cyclists to Spring Cycling Camps

by

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*The purpose of our study was to assess physiological adaptations and measure mood outcomes following a cycling training camp in competitive athletes. Fourteen competitive athletes (8 males, 6 females) performed 2 incremental tests to exhaustion before and after a training camp. Volume and intensity (load) of the training regimen were recorded. Submaximal and maximal metabolic data were analysed, as well as economy variables (gross mechanical efficiency and cycling economy). Skeletal muscle adaptations were assessed using near infrared spectroscopy (NIRS). For both genders ( $n = 14$ ), peak power output, peak power output-W/kg ratio and peak power output-B[La] were significantly increased ( $p < 0.05$ ) after the cycling training camp ( $p < 0.05$ ). Significant increases occurred for gross mechanical efficiency measured at the lactate threshold (+4.9%) and at the same precamp lactate threshold power output (+2.9%). At the lactate threshold and Post Camp Lactate Threshold Power, cycling economy increased by 5.2 and 2.9%, respectively ( $p < 0.05$ ). These power measurements were significantly correlated with individual fluctuations in deoxyhaemoglobin in the vastus lateralis for male cyclists only. Profile of Mood State questionnaire results showed that subcategories "Tension-Anxiety", "Confusion", "Fatigue" and "Total Global Score" significantly decreased after the training camp. Cycling training camps were associated with positive adaptations (increased cycling economy, gross mechanical efficiency and power output) as well as some mental benefits. This indicates that despite some significant physiological adaptations participants probably did not overreach during their CTC.*

**Key words:** winter camp, cycling, profile of mood states, gross efficiency.

### Introduction

To accumulate higher amounts of specific training hours during winter, cyclists from areas with snow are frequently involved in preseason cycling training camps (CTCs), a popular procedure in several endurance sports (Hawley and Stepto, 2001). CTCs seem to be an excellent way for them to initiate outdoor training and quickly increase their training volume. In Canada, cyclists racing at the regional, provincial and national levels spend much of the winter season indoors on a cycling home-trainer, cycle outside with the now popular fat bikes or train different endurance sports (e.g. cross-country skiing). Still, it is known that differences exist between indoor

cycling and field conditions because of multiple biomechanical, psychological and natural factors (Bertucci et al., 2007; Grappe, 2009; Janikowska et al., 2014). CTCs can be defined as more or less prolonged periods when cyclists from cold winter areas go to warmer regions to train on the road (e.g. real conditions instead of indoor training on a trainer) in the season's specific preparation phase. The main goal of CTCs is to increase cycling volume in the period of the year preceding (late February and early March) the first races of the season in late April and early May (Bompa and Haff, 2009; Meeusen et al., 2013).

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CTCs can be compared to short-term endurance training (4-12 days), where subjects train at submaximal intensities for several hours per day. This type of training can significantly enhance submaximal and maximal physiological variables over a short period of time in amateur athletes (Green et al., 1987, 2008; McKay et al., 2009) and well trained athletes (Neary et al., 2002).

Thus, the principal aim of this study was to describe physiological adaptations after short-term cycling training camps by measuring submaximal and maximal capacities before (pre-camp) and after (post-camp) a CTC in a group of competitive athletes. In order to investigate whether a short term overreaching period such as a CTC represents a source of psychobiological stress in addition to the physiological stress (Morgan et al., 1987) for athletes, we also included in our analyses a psychometric test (Profile of Mood State, POMS). Thus, our first hypothesis was that a CTC would significantly improve submaximal and maximal physiological variables due to a short training period in the field, leading to enhanced physiological capacities. Our second hypothesis was that a CTC may represent a significant source of psychobiological stress as measured by mood disturbance that could impair physiological performance. Mood states measured during a short-term overtraining period were shown to be more affected in the second week of a three week program (Berger et al., 1999). Mood disturbances were also found after nine days of intensified cycling training (Killer et al., 2017).

## Methods

### *Participants*

Fourteen trained athletes (8 males, 6 females) gave their written informed consent to participate in this investigation. Females were competitors in cycling (provincial = 2; national = 1), triathlon/duathlon (provincial = 1; national = 2), mountain biking (world cup = 1) and males in cycling (senior 1 provincial = 2; professional division 3; senior 1 national = 2; triathlon international = 1; senior 3 provincial = 1). All of them were already familiar with laboratory procedures and had been practicing indoor cycling as part of their training regimen since the arrival of snow. Our study was approved by the Université du Québec à Trois-Rivières Ethics Committee.

### *Experimental design*

Cyclists organized the camp on their own, following their coach's program and traveled either to Virginia, North Carolina, Cuba, Florida or Arizona for stays of an average of 11 days for male and 7 days for female cyclists (Table 1). Two to five days before (pre-camp) and after (post-camp) the CTC, they came to the Université du Québec à Trois-Rivières Exercise Physiology Laboratory to perform an incremental peak power output (PPO) test with their own bicycles for testing. Anthropometric (body height and mass) and psychometric data were recorded before the PPO test. Prior to testing, the participants were asked to avoid eating solid foods within 3 h, drinking coffee within 6 h, drinking alcohol within 24 h and refrain from strenuous exercise within 48 h prior to the testing procedures.

### *Peak Power Output tests*

After calibration of the equipment, each participant was installed on his/her own bicycle and began pedalling for about 5 min for a low-intensity warm-up and calibration of the Computrainer at the same time (Racermate, Computrainer Lab, Seattle, WA, USA). The test for men began at 130 watts (W) resistance and the resistance was increased by 30 W every 5 minutes, while for women, it started at 120 W and increased by 20 W. Five minute stages, separated by 3-minute bouts of active recovery at resistance of 1 W per kilogram of body mass (W/kg) helped to optimize data collection for gas exchange (Hopker et al., 2009) and blood lactate concentration (B[La]). The last minute of each test stage served to analyse submaximal and maximal variables. Participants were asked to maintain a self-selected pedaling rate at or above 80 revolutions per minute (RPM), stay seated on the bicycle and keep the same RPM and gears for all test duration. They had to pedal until volitional exhaustion. In all tests, humidity was kept stable (25-30%), and laboratory temperature was set at 20-22°C. A cooling fan (Honeywell, Marlborough, MA) was installed to ventilate at the trunk level of participants during the test. The setting was the same for all participants during all tests.

### *Metabolic and mechanical data collection*

Ventilation ( $\dot{V}_E$ ) and pulmonary gas exchange ( $\dot{V}O_2$  and  $\dot{V}CO_2$ ) were measured by a gas analyser (Moxus, AEI Technologies, Pittsburgh, PA, USA). Prior to the test, the device was

calibrated according to the manufacturer's instructions. The HR (beats per minute or BPM) was recorded during all laboratory testing procedures with a heart rate transmitter (Polar Electro Oy, Kempele, Finland). Gross efficiency was measured by the following formula (Jeukendrup et al., 2000):

$$[60 \times W] \div [20934 \times \dot{V}O_2]$$

Cycling economy was determined by dividing power output (W) by moment  $\dot{V}O_2$  (W/L/min) (Jeukendrup et al., 2000; Hawley, 2000). Mechanical power (W) and all derived data were recorded by the Computrainer, which had been validated (Westgarth-Taylor et al., 1997). Blood lactate (B[La]) was measured from a sample of fingertip capillary whole blood at the end of each bout of work and recovery (Pro-Lactate, Arkray Inc., Kyoto, Japan). The lactate threshold (LT) or onset of blood lactate accumulation was defined as the power corresponding to a blood lactate concentration of 4 mmol/L as in Heck et al. (1985). Oxygen pulse ( $O_{2-PULSE}$ ) was obtained by dividing the cardiac heart rate by  $\dot{V}O_2$  (Higgenbotham and Cobb, 1996).

#### **Near infrared spectroscopy (NIRS)**

During the tests, participants wore a portable near infrared spectrophotometer (NIRS) (Portamon, Artinis Medical Systems BV, Utrecht, the Netherlands) to monitor local muscle oxy/deoxygenation. Deoxyhemoglobin-myoglobin ( $\Delta[HHb]$ ) was measured in the *vastus lateralis* muscle. This signal was "zeroed" during resting baseline and reported as relative differences in concentration during exercise. The  $\Delta[HHb]$  signal from NIRS is less sensitive than  $\Delta[HbO_2]$  to changes in blood volume under the probe and has been considered an estimate of fractional oxygen extraction in the microcirculation (Ferreira et al., 2005; Grassi et al., 2003). Therefore, the HHb data were used to investigate the dynamic increase in microvascular fractional oxygen extraction during the maximal aerobic power test. To record the NIRS signal, the probe was placed over the right *vastus lateralis* muscle (Belardinelli et al., 1995). NIRS measures of every exercise bout during the test were defined as the last 30-s interval averaged. The Computrainer system, metabolic analyser, lactate analyser and NIRS apparatus were calibrated at every single test to ensure data accuracy.

#### **Determination of intensities for data collection**

We calculated all physiological data at 3 different intensities: 1) the same submaximal mechanical intensity; 2) power at LT in W; and 3) PPO. Since many variables are frequently calculated at the same submaximal working rate, such as gross efficiency and cycling economy (Hopker et al., 2009; Jeukendrup et al., 2000), along with other physiological data, we made comparisons between pre-camp mechanical power at the LT (PreCP@LT in Watts) and at the same absolute mechanical power during the follow-up. Then, during the camp follow-up, we calculated gross efficiency, cycling economy,  $\dot{V}O_2$ , B[La],  $\dot{V}_E$ , RER and NIRS variables at the same pre-camp mechanical power measured at the LT (PreCP@LT). Gross efficiency and cycling economy were calculated at PreCP@LT and at the new LT, since a new LT was found after the camp. For example, gross efficiency at PreCP@LT refers to pre-camp gross economy at lactate threshold power (W) calculated at the same mechanical power at post-camp.

#### **Time spent in training zones**

We provided a training diary to participants that included training zones based on the maximal HR at pre-camp to quantify training loads (Grappe, 2009). Seven training zones were calculated and divided into two major zones: 1) below the LT (zones 1, 2 and 3), and 2) at and above the LT (zones 4, 5, 6 and 7). Participants needed to wear their personal HR monitor at every training session during the CTC and they were instructed on how to enter their training data in their logbook during the CTC. Using their training zones we calculated their total load (for the camp), which is the time spent in each heart rate zone multiplied by the value (1-7) of each zone. The load density per day is the total load divided by the number of days.

#### **Psychometric data collection**

Participants were asked to complete the French version of the POMS questionnaire (Cayrou et al., 2003) to assess motivation and mood fluctuations (McNair et al., 1992). Scores on the 7 subcategories (Tension-Anxiety, Anger, Depression, Vigour, Fatigue, Confusion and Relationship) as well as the Total Global Score were calculated at pre-camp and post-camp.

#### **Statistical analyses**

All values were expressed as means and

standard deviation (means  $\pm$  SD). Student's unpaired *t*-tests compared the men's and women's CTC data, e.g. total time (hours), time spent in particular intensity zones (minutes), distance (km) and number of days of the CTC. Student's paired *t*-tests compared the means of pre-camp and post-camp physiological variables and analysed the POMS questionnaire data ( $n = 14$ ). Pearson correlations ascertained the relationship between gain in gross efficiency and cycling economy with gain in other physiological variables. Statistical significance was set at  $p = 0.05$  (unless otherwise specified). The data were analysed by SPSS software, version 20.0 for Microsoft Windows.

## Results

### *Time spent in intensity zones during the CTC*

Table 1 shows significant differences between men and women for total time, total distance and total number of days spent in the CTC ( $p < 0.05$ ), while the total number of daily hours of training was the same. Cyclists of both genders spent more time ( $p < 0.01$ ) at intensities below the LT compared to intensities at or above the LT (Table 1). The total estimated load and the estimated daily load were significantly higher in men (Table 1).

### *Psychometric data*

In the men's POMS results, the "Relationship" subcategory increased significantly ( $p < 0.05$ ). With both genders combined, "Tension-Anxiety", "Confusion", "Fatigue" and "Total Global Score" were significantly different at pre-camp compared to post-camp ( $p < 0.05$ ). When considering individual variations a consistent trend towards decreased scores was found: Relationship (8 increased 1 to 6; 4 same; 2 decreased -1 and -2), Tension-Anxiety (3 increased 1 to 3; 1 same; decreased -2 to -13), Confusion (0 increased; 7 same; 7 decreased -1 to -5), Fatigue (3 increased 1 to 2; 4 same; 7 decreased -2 to -5), and Total Global Score (4 increased 1 to 7; 2 same; 8 decreased -4 to -16). We measured Pearson's correlation coefficients between total load and fatigue variation from the POMS ( $r = -0.054$ ) and the total POMS score ( $r = 0.24$ ). Both coefficients were not significant.

### *Changes in submaximal and maximal physiological variables*

For both genders ( $n = 14$ ), PPO, PPO-

W/kg ratio and PPO-B[La] were significantly increased ( $p < 0.05$ ) after the CTC ( $p < 0.05$ ). PPO, LT power, PPO-W/kg,  $\dot{V}O_2$  at PreCP@LT, LT-W/kg, B[La] at PreCP@LT, PPO-B[La] and  $\dot{V}_E$  at PreCP@LT were all increased after the CTC (Table 3).

### *NIRS parameters*

Training induced no modulation of  $\Delta HHb$  in men, women and both genders at LT, PPO and PreCP@LT (Table 3). However, when we calculated men's differences between post-camp and pre-camp for  $\Delta HHb$  ( $[\Delta HHb \text{ at post-camp}] - [\Delta HHb \text{ at pre-camp}]$ ), we found strong correlations between improvements of this variable and gains in gross efficiency and cycling economy at PreCP@LT intensity. The decrease in  $\Delta HHb$  at PreCP@LT in males was strongly associated with the decrease in  $\dot{V}O_2$  at PreCP@LT ( $r = 0.88$ ,  $p < 0.004$ ), and increases in gross efficiency at PreCP@LT ( $r = -0.87$ ,  $p < 0.005$ ) and cycling economy at PreCP@LT ( $r = -0.87$ ,  $p < 0.005$ ).

### *Changes in efficiency variables*

Gross efficiency at LT, at PreCP@LT, cycling economy at LT and at PreCP@LT were increased ( $p < 0.05$ ) for both males and females after the CTC (Table 4). For men only, LT-CE was increased after the CTC ( $p < 0.05$ ). At PreCP@LT, gross efficiency and cycling economy were calculated at an intensity averaging  $79.4 \pm 6.5\%$  of PPO at pre-camp and  $74.6 \pm 7.7\%$  at post-camp, values similar to those reported by Sassi et al. (2008).

## Discussion

Participants spent most of their total CTC training time below the LT (an average of 91.2% for both genders). We found two major outcomes in this study. First, efficiency variables (gross efficiency and cycling economy) were improved, probably due to submaximal alterations (Table 4). Secondly, no indication of psychobiological fatigue was found among cyclists after the CTC. On the contrary, subcategories "Tension-Anxiety", "Confusion", "Fatigue" and "Total Global Score" significantly decreased after their training camp. Also vigour did not decrease as shown in other studies.

**Table 1***Physiological, anthropometric characteristics and training camp physical activity of participants*

	Men (n = 8)	Women (n = 6)
Age (years)	25.1 ± 5.9	26.7 ± 5.5
Body height (cm)	176 ± 5*	166 ± 5
Body mass (kg)	70.6 ± 6.7*	59.7 ± 9.4
BMI (kg/m <sup>2</sup> )	22.9 ± 1.9	21.7 ± 2.2
Total distance (km)	933 ± 271*	557 ± 240
Number of days in CTC	11 ± 3*	7 ± 3
Total time (h)	33.5 ± 7.9*	24.0 ± 8.7
Training hours per day (h)	3.2 ± 0.5	3.4 ± 0.6
Distance per day (km)	88 ± 13	77 ± 13
Time below LT (min / mean [range of %])	1826 ± 411* / 90.8 [74-98]	1317 ± 561* / 91.5 [71-97]
Time at or above LT (min / mean [range of %])	184 ± 219 / 9.2 [2-26]	123 ± 98 / 8.5 [3-29]
Total camp load	3559 ± 1229*	1729.6 ± 588.9
Load density per day	356 ± 74*	250.6 ± 65.1

Values are means ± SE. cm: centimeters; kg: kilograms; BMI: body mass index; kg/m<sup>2</sup>; W: watts; PPO: peak power output; HR: heart rate; BPM: beats per minute; \* different from women ( $p < 0.05$ ).

\*Total time spent at intensities below the LT is significantly greater than total time spent at or above the LT for both genders ( $p < 0.01$ ). LT: Lactate threshold.

**Table 2***Differences in average scores obtained in different categories of the POMS questionnaire between pre-camp and post-camp*

POMS subcategories	Men (n = 8)		Women (n = 6)		Both genders (n = 14)	
	PRECAMP	POSTCAMP	PRECAMP	POSTCAMP	PRECAMP	POSTCAMP
Tension-anxiety	8.4 ± 3.3	7.5 ± 2.9	9.8 ± 1.7	7.0 ± 4.0	9.0 ± 2.7	7.3 ± 3.3**
Anger	5.3 ± 3.2	5.0 ± 3.2	4.3 ± 4.5	2.8 ± 2.2	4.9 ± 3.7	4.1 ± 2.9
Confusion	6.0 ± 3.4	5.0 ± 2.6	5.7 ± 4.2	4.5 ± 2.8	5.9 ± 3.6	4.8 ± 2.6*
Depression	2.1 ± 3.1	2.4 ± 3.3	1.2 ± 2.4	0.5 ± 1.2	1.7 ± 2.8	1.6 ± 2.7
Fatigue	4.0 ± 2.5	2.9 ± 2.2	4.3 ± 3.1	2.7 ± 1.6	4.1 ± 2.6	2.8 ± 1.9*
Vigour	19.9 ± 3.8	19.0 ± 5.0	20.0 ± 4.1	22.3 ± 4.2	19.9 ± 3.8	20.4 ± 2.3
Relationship	18.1 ± 3.0	19.8 ± 2.9*	20.0 ± 2.1	20.8 ± 4.1	18.9 ± 2.7	20.2 ± 3.4
Total global score	63.6 ± 18.7	61.5 ± 18.2	65.7 ± 10.8	60.7 ± 9.6	64.5 ± 15.3	61.1 ± 13.9*

Values are means ± SD. \*Significantly different from pre-camp ( $p < 0.05$ ). \*

\*Significantly different from pre-camp ( $p < 0.01$ ).

**Table 3**

Evolution of physiological variables before and after the CTC for men, women and both genders combined.

Variables	Men (n = 8)		Women (n = 6)		Both genders (n = 14)	
	PRECAMP	POSTCAMP	PRECAMP	POSTCAMP	PRECAMP	POSTCAMP
Body mass (kg)	70.6 ± 6.7	70.7 ± 6.6	59.7 ± 9.4	60.0 ± 9.4	66.2 ± 9.7	66.1 ± 9.4
PPO (W)	321 ± 22	340 ± 28*	220 ± 28	237 ± 23*	278 ± 57	296 ± 59**
LT (W)	252 ± 28	269 ± 23	179 ± 34	188 ± 29	221 ± 48	234 ± 48*
maxHR (BPM)	191 ± 13	195 ± 9	190 ± 12	190 ± 12	191 ± 12	193 ± 10
$\dot{V}O_{2max}$ (L/min)	4.60 ± 0.22	4.71 ± 0.29	3.15 ± 0.43	3.27 ± 0.46	3.98 ± 0.81	4.10 ± 0.82
$\dot{V}O_{2max}$ (mlO <sub>2</sub> /min/kg)	65.5 ± 6.7	66.8 ± 5.1	53.2 ± 4.5	55.0 ± 4.7	60.2 ± 8.5	61.8 ± 7.7
LT-W/kg	3.57 ± 0.46	3.80 ± 0.31	3.00 ± 0.41	3.16 ± 0.43	3.33 ± 0.52	3.53 ± 0.48*
PPO-W/kg	4.55 ± 0.42	4.81 ± 0.31*	3.72 ± 0.49	4.00 ± 0.51*	4.20 ± 0.61	4.46 ± 0.58**
PPO-B[La] (mmol/L)	11.0 ± 2.0	13.0 ± 1.9*	9.4 ± 2.3	11.2 ± 2.4*	10.3 ± 2.2	12.2 ± 2.3**
B[La] at PreCP@LT-	4.00 ± 0.00	3.34 ± 0.92	4.00 ± 0.00	3.27 ± 1.26	4.00 ± 0.00	3.31 ± 1.03*
O <sub>2</sub> PULSE at LT- (mlO <sub>2</sub> /beat)	22.12 ± 2.86	22.50 ± 2.05	16.71 ± 2.74	17.26 ± 2.79	19.37 ± 4.28	19.71 ± 4.11
O <sub>2</sub> PULSE at PPO- (mlO <sub>2</sub> /beat)	24.13 ± 2.02	24.24 ± 1.75	15.69 ± 2.78	15.99 ± 3.01	20.95 ± 4.43	21.25 ± 4.18
$\dot{V}O_2$ (L/min) at LT	3.79 ± 0.43	3.90 ± 0.28	2.75 ± 0.45	2.74 ± 0.47	3.35 ± 0.68	3.40 ± 0.70
$\dot{V}O_2$ at PreCP@LT (L/min)	3.79 ± 0.43	3.73 ± 0.49	2.75 ± 0.45	2.66 ± 0.50	3.35 ± 0.68	3.23 ± 0.71*
$\dot{V}E$ (L/min) at LT	100.8 ± 14.5	101.8 ± 12.2	80.2 ± 14.6	79.3 ± 17.0	92.0 ± 17.5	92.2 ± 18.0
$\dot{V}E$ at PreCP@LT (L/min)	100.8 ± 14.5	94.4 ± 14.8	80.2 ± 14.6	75.5 ± 18.5	92.0 ± 17.5	86.3 ± 18.5*
RER at PreCP@LT ( $\dot{V}CO_2/\dot{V}O_2$ )	0.92 ± 0.05	0.90 ± 0.04	0.94 ± 0.06	0.94 ± 0.07	0.93 ± 0.06	0.92 ± 0.06

Values are means ± SD. \*Significant at  $p < 0.05$ ; \*\*Significant at  $p < 0.01$ . PPO: peak power output; PreCP@LT: at power of the precamp lactate threshold; LT: lactate threshold; RER: Respiratory Exchange Ratio; W: watts;  $\dot{V}E$ : ventilation; HR: heart rate; BPM: beats per minute; B[La]: blood lactate;  $\dot{V}O_{2max}$ : maximal oxygen uptake; kg: kilograms.

**Table 4**

Evolution of efficiency variables between pre-camp and post-camp at the lactate threshold (LT) and at pre-camp lactate threshold power (PreCP@LT)

	Men (n = 8)		Women (n = 6)		Both genders (n = 14)	
	PRECAMP	POSTCAMP	PRECAMP	POSTCAMP	PRECAMP	POSTCAMP
LT-GE (%)	19.07 ± 1.18	19.78 ± 1.28	18.58 ± 1.15	19.78 ± 1.40	18.86 ± 1.15	19.78 ± 1.28*
GE at PreCP@LT (%)	19.07 ± 1.18	19.41 ± 0.75	18.58 ± 1.15	19.35 ± 1.32	18.86 ± 1.15	19.39 ± 0.99*
LT-CE (W/L/min)	66.6 ± 4.1	69.4 ± 4.7*	64.8 ± 4.0	69.0 ± 4.8	65.8 ± 4.0	69.2 ± 4.6**
CE at PreCP@LT (W/L/min)	66.6 ± 4.1	67.8 ± 2.6	64.8 ± 4.0	67.5 ± 4.6	65.8 ± 4.0	67.7 ± 3.4*

Values are means ± SD. \*Significant at  $p < 0.05$ ; \*\*Significant at  $p < 0.01$ . GE: gross efficiency; PPO: peak power output; LT: lactate threshold; W: watts; CE: cycling economy; PreCP@LT: at power of the precamp lactate threshold;

### *Effects of the CTC on submaximal and maximal variables*

Interestingly, we found that PPO, W/kg ratio and PPO-B[La] were all significantly increased after the CTC in accordance with other investigations into short-term endurance training (Faude et al., 2008; McKay et al., 2009; Neary et al., 2002). Individual scores showed that 9 athletes increased their PPO and in 5 athletes it remained the same. Coyle et al. (1991) showed that higher PPO was strongly correlated ( $r = -0.88$ ,  $p < 0.01$ ) with better 40-km time-trial performance. It is possible that increased submaximal capacities may improve time to exhaustion owing to lesser metabolic disturbances for a given submaximal work rate (Holloszy and Coyle, 1984), leading to higher maximal capacities. Even if the training regimen of athletes in our study was short ( $9 \pm 3$  days), it is likely that muscle lactate concentration for the same workload occurred to a lower extent, as shown by reduced lactate levels at PreCP@LT. Additionally, power (W) at the LT was significantly increased following the CTC in both genders with individual scores showing 9 athletes increasing their PPO and 6 athletes with their PPO remaining at the same level. This is suggestive of greater pyruvate and lactate oxidation by the mitochondria or a greater clearance rate of blood and muscle lactate after only a few days of training (Green et al., 2008).

B[La] at PreCP@LT was decreased after the CTC ( $p < 0.05$ ) which is consistent with the findings of McKay et al. (2009). B[La] concentration has been well-documented to decline at submaximal intensities after a period of endurance training (Donovan and Brooks, 1983; McKay et al., 2009; Putman et al., 1998) because of increased lactate conversion to glucose as well as greater use of fatty acids for energy production. However, the lack of change in RER at PreCP@LT (Table 3), likely demonstrates no greater use of fatty acids for energy production.

### *Changes in efficiency variables*

Gross efficiency at the new LT improved significantly by an absolute 0.92% (4.9% relative) after the CTC, as did gross efficiency at PreCP@LT (+0.53% or 2.8% relative) for all athletes ( $n = 14$ ). To our knowledge, this is the first time that gross efficiency has been shown to be improved over a time period as short as the one of the present study ( $9 \pm 3$  days). Individual values of gross

efficiency increased for 11 athletes (from 0.07 to 4.23%), remained the same for 1 and decreased for 3 cyclists (from -0.11 to -0.45%). This is a significant competitive advantage since Jeukendrup et al. (2000) reported that a 1% increase in absolute gross efficiency resulted in a 63-s improvement in a 40-km time-trial. Recently, Hopker et al. (2010) found that gross efficiency was changed in a group of professional cyclists (+1.6% absolute) after high-intensity training, but this occurred over a period of 6 weeks in a well-controlled training regimen. Since trained cyclists living in countries like Canada cannot perform outdoor road cycling during the winter, it is likely that gross efficiency decreases during the off-season, but may be recovered quickly at the onset of a CTC. To improve gross efficiency, the athletes have to produce more power at a given metabolic cost or, reversely, consume less oxygen for a given power output (Hopker et al., 2009; Jeukendrup et al., 2000). In our study, cycling economy at the LT and at PreCP@LT was significantly improved after the CTC (+5.2 and 2.9%, respectively). Individual values of cycling economy at the LT were distributed in 11 increases (from 0.2 to 15.6%), 1 remained the same and 3 decreased (from 0.4 to 1.6%). What is interesting is that after the CTC, cyclists did not consume significantly more O<sub>2</sub> at the LT (Table 3), but produced more power (+4.9%, Table 3).

Our first hypothesis to explain changes in efficiency variables concerns peripheral adaptations in skeletal muscle oxygen extraction. The CTC failed to demonstrate alterations in  $\Delta\text{HHb}$  for a given intensity when all subjects were compared, which is consistent with the findings of McKay et al. (2009) and Neary et al. (2002). However, we found that the alteration in  $\Delta\text{HHb}$  at PreCP@LT was positively correlated with alteration in O<sub>2</sub> at PreCP@LT and was negatively correlated with alterations in gross efficiency and cycling economy at PreCP@LT. As  $\Delta\text{HHb}$  can be viewed as the capacity of working muscles to extract and use O<sub>2</sub> (McKay et al., 2009), it is likely that after the CTC, working muscles extracted less O<sub>2</sub> from haemoglobin-myoglobin with lesser O<sub>2</sub> consumption at the pulmonary level, as seen in our study at PreCP@LT. This reinforces the idea that cycling economy and gross efficiency are improved because of better muscular efficiency (Holloszy and Coyle 1984; Putman et al., 1998;

Spina et al., 1996) at the muscular level after a short period of training (for the same power output). Spina et al. (1996) reported that only 7-10 days of submaximal cycle training in healthy but untrained subjects resulted in a significant increase in mitochondrial enzyme activity. The most plausible hypothesis for the increased efficiency is that learning and neuromuscular adaptations may have occurred during the training camp owing to, in particular, better agonist-antagonist coordination or decreased recruitment of type II fibers for the same effort (Bonacci et al., 2009).

#### ***Effect of the CTC on the POMS***

The second aim of the present work was to determine if a CTC might be a source of psychological fatigue, since CTCs are thought to be an exhausting exercise for athletes because of the higher cycling load and the presence of other potential psychological stressors. Recent studies in groups of trained cyclists showed a decreased score in "Vigour" (Faude et al., 2009; Slivka et al., 2010) and an increased score in "Fatigue" after either 13 days-1 (9) or 3 weeks-1 (10) of intensified training on the field. However, our results demonstrate that scores obtained within subcategories "Tension-Anxiety", "Confusion", "Fatigue" and "Total Global Score" were all significantly reduced after training for both genders (Table 2), even if there was a cycling overload sufficient to increase PPO/kg, LT-W/kg, cycling economy and gross efficiency. This may suggest that amateur cyclists not supervised by a team may still have a margin to increase their training load to obtain optimal adaptations to normal training in a camp shorter than 13 days. Also, the return to their favorite activity away from the winter and from cycling indoor may have a mood enhancing effect and help counterbalance the increased workload during the camp. We compared the variation of the POMS's dimensions between triathletes/duathletes vs. cyclists; professional/international vs. provincial athletes and males vs. females. The only trends we observed were between the latter, a higher decrease of the anxiety dimension in female athletes ( $p < 0.06$ ), and a trend for a higher increase of vigour in males ( $p < 0.06$ ). This result warrants further investigation.

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#### ***Study limitations***

Sample size represents a limitation of the present study. When we could not match men and women for data analysis, we only had a sample of 8 men and 6 women. Although our sample size was 14, it was not the case for all data in this work (e.g. NIRS correlation with efficiency variables) mainly because the test duration was not the same for men and women. The fact that baseline training volume prior to training camps was not documented may also constitute a limitation. The lack of standardization of the camp training load may also be considered by some as a weakness. It would have been interesting to measure the percentage of the work load increase during the camp compared to the pre-camp period. However, we consider it was interesting to have a realistic sample of athletes to see what were the effects of their camp on physiological and psychological outcomes.

#### **Conclusion**

In summary, efficiency variables (gross efficiency and cycling economy) were the variables that increased the most after the CTC. This might be, in part, due to rapid increases in cyclists' mechanical power for a given submaximal metabolic intensity, caused by significant peripheral adaptations (O<sub>2</sub> distribution and utilization in working muscles). Men's improvements in efficiency variables are related to better efficiency in oxygen extraction in the vastus lateralis muscle. Moreover, these rapid submaximal alterations could be responsible for increases in maximal capacities, e.g. higher PPO. Also, our results suggest that this type of a self-planned CTC is not a source of fatigue for cyclists toward the end of the general preparation as it has been proposed. Therefore, although further research is needed because of a dearth of data on short-term endurance training on the field by trained athletes, it appears that between 7 and 11 days of an early-season CTC may be beneficial for trained athletes to increase maximal aerobic power, cycling efficiency variables without a decrease in mood states as it was indicated in other over-reaching studies.



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