1 **Effect of a training camp in the heat on nutritional intake of well-trained endurance athletes**

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Abstract

We investigated the effect of a training camp in the heat on energy and macronutrient intake and hunger. Twenty-two athletes completed two training periods (8 days each) of similar load. One group (HEAT, n=14) trained successively in a temperate environment (10±3 °C, RH 58±11%) then in a hot environment (30 ± 5°C, RH: 74 ± 15%), while the other group (CON, n=8) trained in the same temperate environment. Daily energy intake (EI), carbohydrate (CHO) and protein (PRO) intake were higher ($p<0.001$) in HEAT (+23.9±20.3%, +36.1±24.3 %, +27.5±21.2%, respectively) during the heat camp compared to the temperate condition. More specifically, EI, CHO and PRO intake were greater at breakfast in HEAT (+90.1±65.5%, +107.2±74.3%, +69.8±54.1, respectively). PRO intake also increased at dinner ($p<0.001$) in HEAT. Mean EI and macronutrients intake during the training sessions were significantly increased ($p<0.01$) in HEAT. Hunger was greater before breakfast in HEAT ($p<0.01$) during the heat camp. In CON, none of the measures differed between the two training periods. The present results suggest that athletes spontaneously adapt their energy intake to the greater physiological demand when exercise is conducted in the heat. Breakfast would represent the most appropriate time to adjust energy intake when training in the heat.

Key words: tropical climate, appetite, dietary intake, energy, carbohydrate

INTRODUCTION

Nowadays, major sporting competitions may take place in hot environmental conditions. As a consequence, elite athletes who compete in major international events are frequently exposed to heat stress. Moreover, organising training camps in hot environments (≥30°C) has become a popular strategy to enhance performance in subsequent competitions (Buchheit et al., 2013). Indeed, training in the heat has been shown to provide a greater training stimulus and increased physiological adaptation, leading to performance enhancement, regardless of the thermal conditions (Lorenzo et al., 2010).

The literature has constantly demonstrated physiological changes associated with heat exposure during exercise (Bennett et al., 2024; Febbraio, 2001; Burke, 2001). Indeed, exercising in the heat has been shown to elicit a greater metabolic demand (Consolazio et al., 1963) and is associated with a substrate shift towards a greater carbohydrates (CHO) metabolism (Febbraio, 2001; Burke, 2001) and alterations in the circulating amino acid availability (Bennett et al., 2023). As evidenced by Impey et al. (2016), feeding for the work required, i.e. adapting energy and CHO intake to the changing demand of the training load is a key factor for performance in endurance-based athletes. However, very little information is available on the way athletes change their diet when they are exposed to heat.

To date, the few studies having investigated the effect of the environment on dietary patterns have focused on acute expositions to heat (i.e. one training session) and their effects within the next hours. Shorten et al. (2009) reported no increase in energy intake in the next meal ingested 30min after a running exercise (40min at 70% VO_{2max} on a treadmill) performed in the heat (36°C) compared to a control situation (25°C). In this study, energy intake was increased only in the control situation, suggesting an appetite-suppressive effect of heat exposure. More recently, Kojima et al. (2015) reported a decrease in hunger sensation immediately after the completion of 30min of cycling at 65% VO_{2max} performed either in neutral (24°C), hot (36°C) or cold (12°C) condition. Interestingly, the reduction in hunger persisted only in the hot condition. The authors did not record the post-exercise energy intake therefore it is not known whether this difference in hunger resulted in different energy intakes. Wasse et al. (2013) examined the effect of a longer exposure to different environmental conditions. Participants were exposed to different temperatures (10°C, 20°C and 30°C) for 7 h. After completing 1 h of treadmill running at 65% of VO_{2max}, participants rested for 6 h during which they were proposed two *ad libidum* buffet-type meals, 1 h and 4.5 h after exercise. Total energy intake at both meals tended to decrease in 30°C and increase in 10°C compared with the 20°C neutral condition. The magnitude of decrease in energy intake in the heat was similar (12%) after each meal compared with the meals eaten in neutral situation suggesting a persistent appetite-suppressive effect of heat.

Taken together, the results from the literature suggest that performing a bout of exercise in hot environmental condition reduces appetite (Wasse et al. 2013; Kojima et al., 2015) and decreases energy intake at the subsequent meals (Shorten et al., 2009; Wasse et al., 2013). We may wonder now whether the decrease in energy intake reported after an acute bout of exercise in the heat would result in an overall decrease in daily energy intake when athletes are exposed to a constant hot environment such as in a training camp taking place in a hot location. This question is of particular interest since maintaining appropriate energy balance during training and competition is crucial to prevent excess fatigue and performance decrement (Achten et al., 2004).

Within this context, the aim of the present study was to investigate the effect of a training camp in the heat (performed in ecological conditions) on energy intake, macronutrients intake and hunger in unacclimatized well-trained endurance athletes. Based on the literature, we hypothesized a decrease in energy intake and hunger for the athletes training in the heat.

MATERIALS AND METHODS

Participants

A sample size estimation was performed using G*Power 3.1.9.7 software for a within-participant repeated- measures analysis of variance (ANOVA). The analysis assumed a medium effect size (f = 0.7), an alpha level of 0.05, and a desired statistical power of 0.80, yielding a minimum required sample size of 20 participants. Twenty-four well-trained male triathletes volunteered to participate in this study (participants' characteristics are presented in table 1). They had been competing for more than 3 years and were training a minimum of 7 sessions per week. All participants were given medical clearance for participation in the study by a Cardiologist and were not taking any medication or dietary supplement during the study. The study protocol was approved by the Ethics Committee of *Hotel Dieu*, Paris (acceptance no 2013-A00824-41) and the protocol was carried out in accordance with the Declaration of Helsinki. After comprehensive verbal and written explanations of the study, all participants gave their written informed consent for participation.

Study design

The study was conducted according to a parallel group design, with the cohort of participants being divided into two groups who undertook two consecutive training periods (7-8 days each) of similar training load, but in different environmental conditions (Figure 1). The first period of training (P-BASE)

was completed in the same location (Paris, France, 10±3 °C, RH: 58±11%) for both groups. The second period of training (P-EXP) was completed under different environmental conditions according to the experimental groups. The HEAT group (n=16) completed the second period of training in Point-à-Pitre (Guadeloupe, Caribbean Island, 30±5°C, RH: 74 ± 15%) whereas the CON group (n=8) stayed in Paris (12±1°C, RH: 58±11%). All participants completed two 7-day weighted food diaries during the training periods. Participants were instructed to follow their habitual diet and did not receive any nutritional guidance during the entire study, allowing them to eat what they wanted. During the P-EXP, body mass of each participant was measured every morning in a fasted state. Fat mass was also measured by using dual-energy X-ray absorptiometry (Lunar iDXA, General Electrics, Boston, USA) before and immediately after the P-EXP only for 10 participants of the HEAT group due to logistical constraints.

Heat exposure

During the heat training camp, from breakfast to dinner, participants were instructed to remain outdoors and asked to return to their accommodation only to shower after training sessions. Meals, recovery periods and resting occupations were all outdoor-based activities, occurring with no air-conditioned. Running, cycling and swimming sessions were all performed outdoors (30±5°C, 74±15% RH) while strength and conditioning was performed in a gymnasium (26±3°C, 43±16% RH).

Training monitoring

The participants maintained their habitual weekly training program so that training distribution, activities and content were kept constant between Paris and the heat training camp (Table 2). All participants recorded their usual training program using a Global Positioning System (GPS) monitor (Garmin Forerunner 305 GPS®, Garmin International, Inc., Kansas, MO, USA) to measure training distance and speed and were instructed to report a session-RPE (Borg, 1998) and training duration immediately after each session to quantify individual training loads (Foster et al., 2001). Throughout the entire study, the same sport scientist was responsible for oversight of training loads for all subjects.

Dietary records

Participants completed two 7-day weighted food diaries during the training periods. They were instructed to fill in as many details as possible. To enhance reliability of data, food records were

reviewed by an experienced sports nutritionist in an interview process with each participant at the end of each training period. Participants were prompted for more information such as food preparation, brands, type of oil/dressing, condiments, type of dairy (skimmed, semi skimmed or full fat) in order to get precise values. If needed, portion sizes were specified, with the assistance of the nutritionist, using a validated colour photo representation of commonly consumed foods and their portion sizes (Le Moulec et al., 1996). Energy and macronutrients intake were assessed based on the French Food Composition Database CIQUAL 2013. When packaged foods were consumed, participants were asked to provide the researcher with the packaging. Nutrition facts were then added to the initial database. Food diaries were analysed for daily energy and macronutrients intake (expressed in $kcal \cdot d^{-1}$, $kcal \cdot kg^{-1} \cdot d^{-1}$) and for breakfast, lunch, dinner, snacks and exercise sessions during the P-BASE and P-EXP. In addition, in order to identify what kind of foods were preferred or rejected by the participants, foods were categorized into 13 food categories, including beverages (Table 3).

Hunger assessment

Ratings of subjective feelings of hunger were evaluated using a 100-mm Visual Analog Scale (VAS) according to the method described by Flint et al. (2000). Hunger was evaluated on the 1st, 4th and last day of each training period. VAS were completed immediately before and after breakfast, lunch and dinner. A score for the entire day was calculated by summing the score recorded for each meal.

Plasma volume

Plasma volume (PV) was measured before the departure to Guadeloupe and after 7 days of training in the heat (HEAT group only). PV was derived from measurement of total haemoglobin mass, identified with the carbon monoxide (CO) rebreathing technique, as previously described (Robach et al., 2014). During the training camp, haematocrit percentage (micromethod, 4 min at 13 500 rpm) and haemoglobin concentration (Dill and Costill, 1974) were analysed in quadruplicate and used to estimate alterations in PV. All tests were performed by the same experienced operator.

Statistical analyses

Statistical analyses were conducted with Jamovi software (version 2.3.28). Data are expressed as mean ± SD. Data distribution was checked using the Shapiro-Wilk normality test. Data which were not

normally distributed were analysed with non-parametric Wilcoxon tests. A 2 ways repeated-measures analysis of variance was used to assess the effect of heat exposure (HEAT vs CON) and time (P-BASE vs P-EXP) on energy and macronutrients intake and hunger. When a significant effect was found, post hoc tests were performed using Tuckey HSD procedures. Regarding training load, in order to account for one missing value, a linear mixed-effects model was used. The model included Time (P-BASE, P-EXP), Group (CON, HEAT), and their interaction as fixed effects, with Subject included as a random intercept. Statistical significance was set at $\alpha = .05$.

RESULTS

Two subjects did not follow the prescribed training due to injury or personal obligations and were excluded from subsequent analyses. The final samples were n = 8 and n = 14 for CON and HEAT groups, respectively. Their characteristics are presented in Table 1 and there were no baseline differences between groups for all parameters.

Training characteristics

Table 2 displays the breakdown of training performed by CON and HEAT groups during the 2 training periods (P-BASE and P-EXP). No significant difference between groups nor between periods was reported. The duration of training, the number of training sessions as well as the distance covered in swimming, cycling and running was similar between groups and training periods. Linear mixed-effects model including Time (P_BASE, P_EXP), Group (CON, HEAT), and their interaction as fixed effects, with Subject as a random effect, revealed no significant interaction between Time and Group ($p > 0.05$). In addition, neither the main effect of Time nor the main effect of Group reached statistical significance (all $p > 0.05$).

Energy intake

There was a significant interaction effect between group (HEAT vs CON) and time (P-BASE vs P-EXP) for absolute ($kcal \cdot day^{-1}$; $p<0.05$) and relative ($kcal \cdot kg^{-1} \cdot day^{-1}$; $p<0.01$) values of daily energy intake (Table 4). Mean absolute and relative daily energy intake increased significantly (absolute: + 23.9 ± 20.3 %, $p<0.001$; relative: + 25.8 ± 20.6 %, $p<0.001$) in HEAT during P-EXP compared with P-BASE with no difference for CON. Mean energy intake at breakfast increased significantly (+90.1 ± 65.5%; $p<0.001$) in HEAT during P-EXP compared with P-BASE with no alteration in CON (Figure 2). Wilcoxon test

revealed a significant increase in energy intake during the training sessions performed in P-EXP only for the HEAT group (Figure 2). There was no significant group x time interaction effect for energy intake at lunch (p=0.23), dinner (p=0.14) and snacks (p=0.65) (Figure 2).

Macronutrient intake

There was a significant interaction effect between group and time for absolute (in $g \cdot day^{-1}$; p<0.001) and relative (in $g \cdot kg^{-1} \cdot day^{-1}$; p<0.001) CHO intake (Table 4). Mean absolute and relative CHO intake increased significantly (absolute: + 36.1 ± 24.3 %, p<0.001; relative: +38.1 ± 24.1 %, p<0.001) in HEAT during P-EXP compared with P-BASE with no difference in CON (Table 4). A significant group x time interaction effect in CHO intake was observed at breakfast (p<0.001). Mean CHO intake at breakfast increased significantly (+ 107.2 ± 74.3 %; p<0,001) in HEAT during P-EXP compared with P-BASE with no difference for CON (Figure 2). Wilcoxon test also revealed a significant (P<0.05) increase in CHO intake during training sessions performed in P-EXP (25.1 ± 16.2 $g \cdot d^{-1}$) compared to P-BASE (8.5 ± 9.3 $g \cdot d^{-1}$) in HEAT only (Figure 2). There was no significant group x time interaction effect in CHO intake at lunch (p=0.21), dinner (p=0.13), and snacks (p=0.64).

There was a significant group x time interaction effect for absolute (in $g \cdot day^{-1}$; p<0.01) and relative (in $g \cdot kg^{-1} \cdot day^{-1}$; p<0.05) protein intake (Table 4). Mean absolute and relative daily protein intake increased significantly (absolute: + 27.5 ± 21.2 %, p<0.001; relative: + 29.6 ± 22.8 %, p<0.001) in P-EXP compared with P-BASE in HEAT only. Mean protein intake increased significantly at breakfast (+ 69.8 ± 54.1; p<0,001) and dinner (+ 45.1 ± 41.3 %; p<0,001) during P-EXP compared with P-BASE in HEAT only (Figure 2). Wilcoxon test also revealed a significant (P<0.01) increase in protein intake during the training sessions performed in P-EXP (1.3 ± 1.7 $g \cdot d^{-1}$) compared to P-BASE (0.2 ± 0.6 $g \cdot d^{-1}$) in HEAT with no difference in CON (Figure 2). There was no significant group x time interaction effect in protein intake at lunch (p=0.51), dinner and snacks (p=0.94).

There was no significant group x time interaction effect in absolute and relative values of fat intake. Neither was any interaction effect for fat intake at breakfast, lunch, dinner and snacks (Table 4). Wilcoxon test revealed a significant (P<0.01) increase in fat intake during the training sessions performed in P-EXP (1.6 ± 1.2 $g \cdot d^{-1}$) compared to P-BASE (0.2 ± 0.7 $g \cdot d^{-1}$) in HEAT, with no difference in CON (Figure 2).

Hunger

The only significant group x time interaction effect for VAS scores of hunger was recorded before breakfast (p<0.05; Table 5). Hunger before breakfast was higher in P-EXP compared with P-BASE (p<0.01) in HEAT with no difference in CON (Table 5).

Body composition

HEAT mean body weight increased gradually from day 1 to day 5 during the training camp in P-EXP (from 70.1 ± 5.2 to 71.0 ± 5.7kg; $p<0.01$) and then plateaued for the rest of the training camp (days 5 to 8) (Table S3). CON mean body weight did not change over P-EXP (from 71.0 ± 8.3 kg to 70.8 ± 8.0 kg, NS)(Table S3). Fat mass tended to decrease (-0.46 ± 0.64 kg, $p=0.052$) for 10 participants of the HEAT group between P-BASE and P-EXP.

Plasma Volume

Plasma volume increased significantly during the heat training camp by 16.6 ± 8.5% ($P<0.05$), from 3603 ± 508 mL before the departure to Guadeloupe to 4190 ± 602 mL recorded within 24h after the return to Paris.

DISCUSSION

The aim of this study was to investigate the effect of a training camp taking place in hot environmental condition on voluntary energy intake, macronutrients selection and hunger in endurance athletes. To the best of our knowledge, the present study is the first to provide an insight into the adaption of dietary intake during a training camp in the heat in unacclimatized endurance athletes. The main outcome was an increase in daily energy intake while training in the heat compared to similar training in temperate condition, which contrasts with previous acute interventions in the heat. The increase in energy intake was mainly explained by a higher CHO intake and to a lower extent a higher protein intake whereas fat intake was not altered. Increased energy intake, as well as other nutritional adjustments, occurred mainly during breakfast in accordance with hunger scores which increased only before breakfast.

Energy intake and internal training load in the heat

The main result was an increase in mean daily energy intake during the training camp in the heat whereas energy intake didn't change in temperate condition between the two training periods. Based upon previous data from Wasse et al. (2013), showing a trend towards a lower energy intake during a 7-hour exposure to hot temperature (30°C) starting with a 1 h exercise, we hypothesized that this regimen applied over several days would result in a decrease in daily energy intake. Our results do not support the initial hypothesis. The increase in energy intake during the heat training camp should be interpreted in light of body composition data showing a rise in body mass associated with a minor decrease in fat mass (-0.46 ± 0.64 kg for 10 participants of the HEAT group). Body weight increased

241 regularly during the first 4 days in the heat (from 70.1 ± 5.2 to 71.0 ± 5.7kg; $p<0.01$) and then stabilised
242 until the end of the training camp. This time course of changes in body composition probably mirrors
243 the increase in total body water associated with acclimatization. Indeed, heat acclimatization is well
244 known to trigger numerous physiological adaptions amongst which an increased total body water and
245 plasma volume expansion (Periard et al., 2015). These adaptations are known to occur after a
246 minimum of 3-4 days of repeated exposure to heat (Sawka et al., 1999). Consistent with those data,
247 we recorded a 16.6 ± 8.5% increase in plasma volume at the end of the heat training camp. Although
248 not measured, it can be suggested that water retention occurred in others compartments of the body,
249 accounting for the increase in body mass. The fact that the increase in energy intake was not associated
250 with an increased body fat also suggests a greater energy expenditure during the heat training camp
251 compared with the baseline training despite similar external training loads. This result is in accordance
252 with pioneers data from Consolazio et al. (1963) indicating a greater metabolic rate of a fixed physical
253 activity when this latter was performed in the heat compared with temperate condition. The primary
254 explanation for a higher energy expenditure in hot compared to cooler environments is the energy
255 expended in the production and secretion of sweat. The other explanatory factors include a
256 combination of increased blood flow, increased ventilation and heart rate, and a rise in body
257 temperature (Consolazio and Schnakenberg, 1977). However, it should be noted that some authors
258 failed to confirm such an increase in metabolic rate associated with exercising in the heat (Shorten et
259 al., 2009). This discrepancy could be explained by several factors such as differences in training level
260 of participants, level of heat acclimatization, duration and intensity of exercise, intensity of the
261 environmental stress and the hydration status (Committee on Military Nutrition Research, 1993).

262 ***Macronutrients selection in the heat***

263 The Increase in energy intake reported in our study was mainly due to an increased CHO intake (+36%)
264 and increased protein intake (27.5%) whereas fat intake did not change. The observed increase in CHO
265 intake is in accordance with the alteration in substrate metabolism previously recorded under heat
266 stress. Indeed, several studies have reported a shift towards a greater reliance on whole body sources
267 of CHO when exercising in the heat (Febbraio, 2001). The CHO cost of a training session would be
268 increased in hot condition leading to a greater CHO requirement (Burke 2001). This shift towards an
269 increased CHO oxidation in the heat has been suggested to be mediated by an augmented sympatho-
270 adrenergic response and an increase in intramuscular temperature (Febbraio, 2001, Fernandez-Elias
271 et al., 2015); this phenomenon being attenuated by heat acclimation (Periard et al., 2015). In our study,
272 an increase in the consumption of starchy foods, fruits and sweets accounted for the increase in CHO
273 intake during the heat training (Table S1). Protein intake was also increased during the heat training
274 camp compared with baseline training whereas it was unchanged in CON. The protein content of the

diet during the baseline training was 1.9 ± 0.3 g·kg^{-1}·day^{-1} which was slightly above the recommended intake for elite endurance athletes (1.7 g·kg^{-1}·day^{-1}) (American Dietetic Association et al., 2009). Protein intake increased to 2.4 ± 0.3 g·kg^{-1}·day^{-1} during the heat training camp. This increase was mainly due to a greater intake of foods from the Meat/Egg/Fish group and, to a lesser extent, to starchy foods (Table S2). Previous work from Febbraio et al. (1994) has reported an increased accumulation of intramuscular ammonia (NH3) in endurance athletes exercising in the heat, suggesting an increased protein degradation. More recently Bennett et al. (2023) highlighted distinct alterations in the circulating amino acid availability, including increased alanine, glutamine, leucine and isoleucine when training under heat-stress. This finding suggests that exercising in the heat might involve specific requirements in protein intake, though this remains to be determined. Ingesting more protein would provide some benefits during intense endurance training (Witard et al., 2013; Hansen et al., 2015). These benefits include less muscle damage (Hansen et al., 2015), improved recovery leading to enhanced performance after a strenuous 1-week training camp (Hansen et al., 2015) and prevention of training-induced impairments of immune system (Witard et al., 2013).

Timing of nutritional adaptations to heat

Alterations in energy and macronutrient intake in HEAT between P-BASE and P-EXP occurred mainly at breakfast. This is in accordance with appetite data showing an increase in hunger only prior to breakfast during the heat training camp. On contrary, in an acute protocol (only one training session in the heat) Wasse et al. (2013) reported a decline in energy intake lasting several hours after exercise, likely explained by a heat suppressive effect on appetite and food intake. Taken together, data from the literature and our study suggest that the effect of heat on the regulation of dietary intake and appetite might be different according to the duration of the heat exposure. Indeed, energy intake would be decreased in the immediate post-exercise meal (Shorten et al., 2009) and during several hours after exercise (Wasse et al., 2013) in an acute exposition to heat. However, when exercise is performed regularly in the heat associated with a passive chronic exposition to heat (like in our study), energy intake and appetite would be increased mainly at breakfast. In our study, the participants had their breakfast directly after waking-up and early in the morning (before 8am), suggesting that breakfast was the meal the least impacted by heat and exercise and probably the best opportunity to compensate for the increase in internal training load throughout the day. Male junior elite triathletes were shown to ingest more energy during a week of intensive training compared with a week of moderate training (Carlsohn et al., 2012). Like in our study, changes in food intake occurred mainly at breakfast which reinforces the importance of this meal, especially when training load increases. Conversely, this compensatory behaviour is not systematic, and the literature reports inadvertent failure to increase energy intake in compensation for increased energy expenditure (Stubbs et al.,

2004; Schaal et al., 2015). Therefore, coaches and athletes should be aware of the effects of heat training on metabolism and appetite and that athletes may not adapt spontaneously their energy intake. In consequence, a prolonged imbalance between energy expenditure and energy intake may lead to excessive fatigue and increase the risk of overreaching (Achten et al., 2004).

Conclusion

Contrary to our initial hypothesis, training chronically under heat stress elicited an increase in energy intake compared to training in temperate condition. An increase in CHO intake at breakfast, and to a lower extent an increase in protein intake at breakfast and dinner, accounted for the increase in daily energy intake recorded during the heat training camp compared to baseline training. This is in accordance with appetite data showing an increase in hunger only before breakfast during the heat training camp. In light of the present results, coaches and athletes should adapt food supply and energy intake when training in the heat in order to optimise the adaptation to training and avoid excessive fatigue. Breakfast would represent the most appropriate time to adjust energy intake when training in the heat. These results remain to be confirmed with further studies conducting direct measurements of energy expenditure and substrate utilization.

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DECLARATION OF INTEREST STATEMENT

The authors have no relevant financial or non-financial interests to disclose.

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406 **Table 1.** Baseline subject characteristics of the two experimental groups (CON and HEAT). Data are
407 expressed as mean ± SD. PPO, Peak Power Output.
408

Subject characteristics	CON (n = 8)	HEAT (n = 14)
Age (years)	30 ± 8	32 ± 5
Height (cm)	180 ± 7	180 ± 4
Body mass (kg)	69.8 ± 8.9	70.9 ± 5.8
$\dot{V}O_{2max}$ ($L.min^{-1}$)	4.32 ± 0.42	4.66 ± 0.50
$\dot{V}O_{2max}$ ($ml.min^{-1}.kg^{-1}$)	62.4 ± 6.1	65.7 ± 3.7
PPO (W)	381 ± 38	406 ± 35
PPO ($W.kg^{-1}$)	5.5 ± 0.7	5.7 ± 0.3

409

410 **Table 2.** Training characteristics of both control (CON) and experimental (HEAT) groups during the first
411 (P-BASE) and the second (P-EXP) periods of training. Data are expressed as mean ± SD. AU, arbitrary
412 units. S, Swimming. C, Cycling. R, Running

		P-BASE	P-EXP
CON	Weekly volume (min)	792 ± 157	774 ± 129
	Weekly volume in S / C / R (km)	6 / 242 / 39	6 / 238 / 38
	Weekly number of S / C / R sessions	2/4/3	2/4/3
	Training load (AU)	11192 ± 2488	10804 ± 2404
HEAT	Weekly volume (min)	841 ± 212	853 ± 209
	Weekly volume in S / C / R (km)	8 / 248 / 34	8 / 237 / 38
	Weekly number of S / C / R sessions	2/5/3	2/5/3
	Training load (AU)	10895 ± 1974	12094 ± 2463

413

414 **Table 3.** Description of the different food categories taken into account for dietary analysis

Categories	Items
Starches and grain	Pasta, rice, potatoes, bread, vegetables, unsweetened cereals
Vegetables	Fresh/canned vegetables, green salad, soups
Meat/Eggs/Fish	Meat, poultry, eggs, fish, seafood, ham
Fresh dairy	Yoghurt and cottage cheese, plain or sweetened
Fruits	Fresh fruits, mashed fruits
Cakes	Cakes, pastries, biscuits, pies, muffins, cookies, all flour-based deserts
Sandwiches	Sandwiches, burger, pizza, quiche, salted pies, Croque-Monsieur
Sweets	Chocolate, chocolate bars, candies, honey, jam, all desserts that are not flour-based, sweetened cereals, canned fruits in syrup, custard
Energy food	Energy bars, protein bars, recovery bars
Cheese	All cheese
Deli meat	Pâté, sausages …
Mixed dishes	Dishes containing several food categories (Meat/Fish/Egg, vegetables, starches) For example: couscous, lasagna, paella, mixed salad …
Caloric drinks	Soda, flavoured and unflavoured milk, soya drink, fruit juices, vegetable juices, water with syrup
Sport Drinks	Commercial sport drinks

415

Table 4.

Mean daily absolute (kcal·d^{-1}; g·d^{-1}) and relative (kcal·kg^{-1}·d^{-1}; g·kg^{-1}·d^{-1}) energy and macronutrient intake of control (CON) and experimental (HEAT) groups during the first (P-BASE) and the second (P-EXP) periods of training. Data are expressed as mean ± SD. P-values correspond to Tuckey HSD post hoc test which was applied for any significant group x time effect.

Dietary intake		CON			HEAT		
		P-BASE	P-EXP	p	P-BASE	P-EXP	p
Energy	kcal·d^{-1}	3018 ± 578	3109 ± 760	.964	3525 ± 499	4295 ± 479	<0.001
	kcal·kg^{-1}·d^{-1}	42.9 ± 9.3	42.7 ± 13.3	.998	49.6 ± 8.2	61.4 ± 8.4	<0.001
CHO	g·d^{-1}	411 ± 94	400 ± 104	.970	438 ± 85	584 ± 91	<0.001
	g·kg^{-1}·d^{-1}	5.8 ± 1.3	5.8 ± 1.8	.999	6.2 ± 1.4	8.4 ± 1.5	<0.001
Protein	g·d^{-1}	120 ± 22	121 ± 38	.999	136 ± 20	171 ± 24	<0.001
	g·kg^{-1}·d^{-1}	1.7 ± 0.4	1.8 ± 0.7	.968	1.9 ± 0.3	2.4 ± 0.3	<0.001
Fat	g·d^{-1}	86 ± 14	100 ± 30	-	124 ± 26	131 ± 17	-
	g·kg^{-1}·d^{-1}	1.2 ± 0.3	1.5 ± 0.6	-	1.7 ± 0.3	1.8 ± 0.3	-

Table 5

Mean subjective feeling of hunger before and after breakfast, lunch and dinner and the entire day (sum of these 3 meals) in the control (CON) and the experimental (HEAT) groups during the first (P-BASE) and the second (P-EXP) periods of training. Data are expressed as mean ± SD. * P<0.05 significantly different from P-BASE HEAT

		CON		HEAT	
		P-BASE	P-EXP	P-BASE	P-EXP
Day	Before	22.6 ± 2.4	22.2 ± 2.4	19.4 ± 4.1	20.2 ± 4.2
	After	8.2 ± 3.4	6.6 ± 2.9	6.9 ± 3.8	4.8 ± 2.9
Breakfast	Before	6.8 ± 2.0	6.6 ± 1.4	5.8 ± 1.6	6.9 ± 1.4 *
	After	2.5 ± 1.7	2.5 ± 1.2	2.0 ± 1.2	1.7 ± 1.0
Lunch	Before	7.0 ± 0.4	7.9 ± 1.2	6.6 ± 1.5	6.7 ± 1.4
	After	1.0 ± 1.1	1.6 ± 0.9	2.5 ± 1.5	1.9 ± 1.5
Dinner	Before	8.1 ± 0.7	8.0 ± 0.6	6.8 ± 1.6	6.7 ± 1.8
	After	2.8 ± 1.8	2.5 ± 1.5	2.1 ± 1.3	1.8 ± 1.3

Figure captions

Figure 1. Schematic representation of the study design.

Figure 2. Mean energy (A), carbohydrates (CHO) (B), protein (C) and fat (D) intake at breakfast, lunch, dinner, snacks and during exercise sessions of the control group (CON) and the experimental group (HEAT) during the first (P-BASE) and the second (P-EXP) periods of training. Data are presented as mean ± SD. # significant difference from CON P-BASE (# p< 0.05, ### p<0.001); § significant difference from CON P-EXP (§ p<0.01, §§§ p<0.001) *** significant difference from HEAT P-EXP (p<0.001), $$ significant difference from HEAT P-BASE (Wilcoxon test, p<0.01

Figure 3. Mean daily consumption ($g \cdot d^{-1}$) of the different food categories intakes in the control group (CON) and the experimental group (HEAT) during the first (P-BASE) and the second (P-EXP) periods of training. Data are presented as mean ± SD. # significant difference from CON P-BASE (# p< 0.05, ### p<0.001); § significant difference from CON P-EXP (§ p<0.01) * significant difference from HEAT P-EXP (**p<0.01, ***p<0.001), $$ significant difference from HEAT P-BASE (Wilcoxon test, p<0.01)

443 **Supplementary material**

444 **Table S1.** Dietary sources of CHO. Data represent the contribution of food categories to CHO intake
445 (g of CHO·d^{-1} for each food category) in the control group (CON) and the experimental group (HEAT)
446 during the first (P-BASE) and the second (P-EXP) periods of training. Data are presented as mean ±
447 SD. * P<0.05, **p<0.01, ***p<0.001 significantly different from HEAT P-BASE; # P<0.05, ## p<0.01
448 significantly different from CON P-BASE; §§ p<0.01 significantly different from CON P-EXP; $ p<0.05
449 (Wilcoxon test) significantly different from HEAT P-BASE

	CON		HEAT		
	P-BASE	P-EXP	P-BASE	P-EXP	
Starches	178 ± 50	164 ± 69	172 ± 53	244 ± 72	***
Cakes	55 ± 26	76 ± 39	82 ± 34	74 ± 29	
Sweets	34 ± 20	40 ± 15	42 ± 15	62 ± 13	*** ##
Fruits	39 ± 27	32 ± 18	37 ± 20	56 ± 33	*
Beverages	38 ± 21	34 ± 17	35 ± 17	45 ± 29	
Sandwiches	10 ± 17	16 ± 15	15 ± 14	9 ± 6	
Sports Food	8 ± 12	2 ± 3	15 ± 14	17 ± 10	
Fresh dairy	17 ± 14	11 ± 14	12 ± 11	26 ± 18	**
Vegetables	9 ± 5	5 ± 3	10 ± 6	17 ± 7	** # §§
Mixed dishes	4 ± 5	5 ± 8	10 ± 15	1 ± 1	$
Meat/Eggs/Fish	1 ± 1	2 ± 2	1 ± 1	3 ± 1	
Deli meat	<1	<1	<1	<1	
Cheese	<1	<1	<1	<1	

450

Table S2. Dietary sources of protein (mean ± SD). Data represent the contribution of food categories to protein intake (g of protein·d^{-1} for each food category) in the control group (CON) and the experimental group (HEAT) during the first (P-BASE) and the second (P-EXP) periods of training.

* P<0.05, **p<0.01 significantly different from HEAT P-BASE; ## p<0.01 significantly different from CON P-BASE; § p<0.05 significantly different from CON P-EXP; $ p<0.05 (Wilcoxon test) significantly different from HEAT P-BASE

	CON		HEAT	
	P-BASE	P-EXP	P-BASE	P-EXP
Meat/Eggs/Fish	38 ± 13	40 ± 20	42 ± 16	66 ± 19 ## § **
Starches	29 ± 7	26 ± 10	29 ± 9	37 ± 11 *
Cheese	8 ± 7	7 ± 6	13 ± 7	14 ± 7
Cakes	6 ± 3	9 ± 4	10 ± 4	10 ± 3
Beverages	9 ± 6	7 ± 5	8 ± 6	5 ± 3 $
Fresh dairy	8 ± 3	6 ± 3	7 ± 5	10 ± 7 *
Sandwiches	3 ± 4	5 ± 5	6 ± 6	4 ± 3
Mixed dishes	2 ± 2	3 ± 5	5 ± 5	2 ± 2
Deli meat	6 ± 6	8 ± 6	4 ± 6	3 ± 3
Sweets	2 ± 2	3 ± 1	4 ± 2	6 ± 3
Vegetables	3 ± 1	2 ± 1	3 ± 2	5 ± 2
Fruits	2 ± 2	2 ± 1	2 ± 1	3 ± 2
Sports Food	1 ± 1	<1	2 ± 1	2 ± 3

458 **Table S3:** Mean body weight during the second period of training spent in temperate condition for the
459 control group (CON) and in hot condition for the experimental group (HEAT). Data are presented as
460 mean ± SD. * significant difference from HEAT Day 1 ($p<0.001$)

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
CON	71,2 ± 8,8	70,9 ± 8,4	70,8 ± 8,2	70,9 ± 8,2	71,0 ± 8,3	71,0 ± 8,2	70,8 ± 8,0	70,8 ± 7,9
HEAT	69,8 ± 5,7	69,9 ± 5,7	70,2 ± 5,6	70,5 ± 5,5	71,1 ±5,7*	70,9 ±5,7*	71,0 ±5,7*	71,1 ±5,6*

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