Nutrition counselling improves time trial endurance performance – a randomized cross-over controlled study

Nutrition counselling in endurance performance

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Abstract

Ingestion of food and fluids before endurance performance influences the human performance capability. Any athlete with sufficient knowledge in sports nutrition should be able to develop his own strategy. We investigated whether an athlete"s self-chosen nutrition strategy (A), compared to a scientifically determined one (S), led to an improved endurance performance in a laboratory time trial. Eighteen endurance-trained cyclists (16 male and 2 female) were tested in a randomised crossover-design at intervals of two weeks, following either A or S. After a warm-up, a VO2max-test was performed on a cycling ergometer. Following a 30 minute break, an endurance test on a bicycle ergometer using the athletes" own road bikes was carried out at 70%VO2max for 2 h 30 min. After 5 minutes rest, a time trial of ~40 miles was completed. The nutrition strategies were recorded each 15 minutes. The total intake of fluid and nutrition was significantly higher in S compared to A ($p<0.01$). In S, the athletes completed the time trial faster (127 min versus 135 min; $p<0.001$) and with 15% more power ($p<0.01$). We concluded that a time trial performance in a laboratory setting was significantly improved after a scientific controlled nutritional counselling.

Keywords: endurance performance, cycling, competition diet, fluid intake, carbohydrates

Introduction

Nutrition during endurance performance is of major importance for a successful completion in an endurance race. During intensive physical long-term endurance performance, a sufficient carbohydrate intake is the essential basis for a high performance. Carbohydrate feeding leads to an improved performance (Curell & Jeukendrup, 2008; Cogan & Swanson, 1992; Jeukendrup & Jentjens, 2000; McConell, et al., 1999). The consumption of carbohydrates, both before and during performance, spares the muscle glycogen storage during exercise and thus increases the exercise capacity (Kerksick, et al., 2008; El-Sayed, et al., 1997). The carbohydrate intake prior to endurance performance is considered to be especially important if the muscle glycogen storage is minimised (Widrick, et al., 1993).

Considering the different kinds of ingested carbohydrates, glucose is preferably oxidized in the skeletal muscle (El-Sayed, et al., 1997). During loads lasting longer than one hour, carbohydrate feeding of 30 to 60 g per hour leads to a delay in physical fatigue (Convertino, et al., 1996; Coyle & Montain, 1992). The maximum glucose intake averages 1 g per minute or 60 g per hour (Kerksick, et al., 2008). New findings concerning mixed intakes of glucose and fructose, namely that ingesting glucose and fructose in a 2:1 ratio leads to an increase in the oxidation rate and thus to a rise in performance compared to a solitary intake of glucose (Currell & Jeukendrup, 2008; Kerksick, et al., 2008; Jentjens, et al., 2004b; Jentjens & Jeukendrup, 2005). Hence, a combination of glucose and fructose can raise the carbohydrate resorption from 60 g to 90 g per hour. A carbohydrate feeding in small quantities every 15-30 minutes is said to be beneficial during a continuous endurance performance (Tarnopolsky, et al., 2005).

Apart from energy, electrolytes are also important for endurance performances. A high ambient temperature may lead to a sweat loss of one litre per hour or even more (Rehrer, 2001). Initiated by intensive loads, or exercise in heat, the increased sweat production causes an increased sodium loss in the form of sodium chloride (Anastasiou, et al., 2009). Therefore, the sodium loss should be compensated for by an additional ingestion of this electrolyte during an endurance activity. The decrease in sodium concentration correlated with a reduction in the activity time during an endurance exercise (Vrijens & Rehrer, 1999). To prevent a decline in blood sodium concentration, an adequate amount of ~19.9 mmol/L should be regularly ingested in combination with a carbohydrate solution (Anastasiou, et al., 2009). An intake of 1-2 g sodium chloride per hour can prevent hyponatremia (Sharp, 2006). Another study of marathon runners revealed the importance of a 450 mg sodium intake per hour in order to preserve plasma volume (Murray, 2007).

During intense physical activity, optimised nourishment can be the determining factor for an athlete‟s success. Numerous food supplement products persuade athletes they would be performance-enhancing, but the effect cannot be proven scientifically for most of these products. However, in regards to the supplementation of carbohydrates while performing for hours, there is evidence of a performance-stabilising or performance-enhancing effect. Assuming that seriously-trained endurance athletes are well informed about the energy-, fluid- and mineral ingestion during intensive endurance loads, through publications and advertisements within professional journals, they should be in a position to tailor an optimised nutrition diet relating to their performance requirements and to use this in an appropriate way in a competition.

Considering the recommendations on fluid, energy and electrolyte intake, a scientific nutrition strategy for an intensive endurance exercise should consist of 400-1.200 ml/hr fluid, in portions of 100-300 ml per 15 minutes duration, about 60 g/hr glucose and 30g/hr fructose (Reference)

The purpose of this study was to observe whether an athlete‟s self-chosen nutrition strategy (A) differs basically from a scientifically-given one (S), and whether these different nutrition strategies have an impact on the performance capability of competition-specific long-term endurance loads. We hypothesised that athletes using the S would show a higher time-trial performance compared to those using A. Due to the improved performance higher lactate concentration and an increased mean heart rate are expected.

Materials and Methods

Subjects and Experimental Design

Following approval from the ethical committee of the Martin-Luther-University Halle-Wittenberg, a group of eighteen (16 male; 2 female)well-trained cyclists and triathletes participated in the study. Their age, anthropometric and physiological characteristics are presented in Table 1. The subjects signed an informed consent form to participate in the study. The study was performed in a randomizedcross-over design. Using the principle of contingency, all of the 18 athletes were divided into two groups. While the first group started the study using the scientifically-given diet strategy (S) during the first measuring time, the second group carried out their self-chosen nutrition strategy (A). After two weeks both groups repeated the tests, while changing to the other nutrition strategy. Both investigations took place under the same conditions at the same time of day.

Measurements

The exercise protocol, as described in Figure 1, started with a warm-up programme of 20 minutes at 100 W on a computerised electronic bicycle ergometer (RacerMate, model Compu Trainer, UK). In this setting the athletes could use their own road bikes. This was followed by an incremental cycling ergometer test (FES, model E 2000s, Germany) using spirometry (Cortex, model Metamax 3b, Germany) in order to determine maximal oxygen intake(VO2max). The exercise started at 150 W and the workload was increased every 30 s by 25 W until the exhaustion of the subject. After a 30 minute break the protocol continued with an endurance exercise of about 2 h 30 min on the cycling ergometer at 70% VO2max. On the preinstalled computer-program, a virtual route of 16.09 km (10 miles) defined the altitude profile. The athletes followed the virtual route corresponding to the animation on the screen placed in front of them. To guarantee constant conditions for the time trial each athlete had to ride approximately on a level with his own virtual cyclist, recorded during the first measuring session, when completing the second measuring session of the study design. After a five minute break the athletes had to ride the same route four times, resulting in a total length of 64.36 km (40 miles) as a time trial on the cycling ergometer. The altitude profile did not change compared to the one used for the endurance load. The athletes were instructed to complete the course in the shortest time possible.

Provided Nutrition and Nutrition Counselling

Considering the scientific nutrition strategy (S) the athletes were provided with two different mixed energy drinks in the form of two carbohydrate powders (see Table 2), first the “High5 Energy Source” and secondly the „High5 Extreme Energy Source" (High5 Ltd., UK). Figure 1 shows the release of nutrition during performance. 50 g of the „High5" powder were dissolved in 500 ml of water and distributed in two bottles of 250 ml each. Both at the warm-up/ VO2max test (30 minutes), as well as during the break (30 minutes), the athletes were given 500 ml of „High5 Energy Source" (50 g of each powder). During the first 30 minutes of the endurance exercise a weight-related amount of „High5 Extreme Energy Source" of between 375 ml and 750 ml was served. For the following 15 min time intervals of the endurance load, as well as the time trial afterwards, the athletes were given 250 ml of water mixed with 25 g „High5 Energy Source". The athletes in S were supposed to supply themselves with an individually preferred nutrition strategy. Analogous to the A-strategy, the supply and return of the consumed drinks, gels, bars etc. was listed in corresponding time intervals (warm-up/VO2max test and break of 30 minutes each; endurance exercise and time trial 15 minutes each). The weight of the single products and drinks was measured before and after consumption and listed in the protocols. In order to determine the amount, or rather the weight, of the consumed products, the supply and return of the drinks and other products were measured using a kitchen scale (TCM, model 253363, Tchibo GmbH, Germany) with an accuracy of ± 1 g. Thereafter, the difference was calculated. During the course of this, the following parameters were determined: fluid consumption [ml], energy consumption [kcal], carbohydrate [g], mono- and disaccharides [g], sodium [mg], potassium [mg], magnesium [mg], caffeine [mg]. An additional recording was conducted taking into consideration the athletes using their own nutrition strategy (A), including the type and quantity of the consumed foods and drinks as well as of the energy powders and sport nourishments.

Body mass was measured using a commercial balance to the nearest 0.1 kg. Ten µl of capillary ear blood was taken at rest, two and five minutes after exhaustion in the VO2max test, after completing the single route sections of the endurance load, as well as after the time trial, in order to determine the concentration of plasma glucose and lactate concentration by using the enzymatic-amperometric measuring method (Dr. Müller, model Super GL ambulance, Germany). Urinary specific gravtiy was determined at rest, as well as after the endurance exercise and the time trial using a test strip, (Roche, Model Combur 10, Switzerland). The visual evaluation of the test strips was performed by the same person. Heart rate was measured using a portable heart rate monitor with a chest strap (Polar Electro, model S810i/WearLink, Finland) and recorded every 15 s during the entire test. Afterwards the heart rate data was computerized and if they revealed an artifact ratio less than 5%, they were valid and thus used for the evaluation of the data (Software Polar Pro Trainer 5; filtering power “very low”).

Statistical Analysis

The statistical analysis was performed using a Student t-Test for paired samples (SPSS Statistics 17.0). The Kolmogorov-Smirnov-Test was used to check whether the data was normally distributed. In case of normal distribution, the t-test was used for an inter-group-comparison. For the non-normally distributed data, the Wilcoxon test was used. Intra-group comparisons were performed using ANOVA and Bonferroni Post Hoc test. The following variables were selected for comparison between scientific and athlete protocol (S or A): body weight, mean heart rate, lactate concentration, glucose concentration, maximal power, lap time and urinary pH-value as well as fluid quantity [ml], energy [kcal], carbohydrates [g], mono- and disaccharides [g], sodium [mg], potassium [mg], magnesium [mg] and caffeine [mg]. The significance levels were defined as follows: significant refers to the value $p \leq 0.05$ (*: inter-group comparisons or ◆: intra-group comparisons), instead high-significance reveals $p \leq 0.01$ (**/◆◆) and highest significance belongs to $p \leq 0.001$ (***/◆◆◆).

Results

Performance

Comparing the two athlete groups in respect of their performance, it was noticed that the S group cycled at an average of 212 Watt, and the A group at 184 Watt during the time trial. This difference of 15.1% was highly significant ($p < 0.001$). The higher performance resulted in a significantly lower cycling time of 8 minutes. By relying on the A strategy the athletes needed 02:16:20 [hh:mm:ss] for the time trial, whereas the S strategists finished the same distance in 02:08:25 [hh:mm:ss] (**see Figure 2**).

Intake of energy, fluids and electrolytes

During the S protocol, athlete consumed more fluid compared to the A strategy ($p \leq 0.001$) during the endurance exercise (see Figure 3). Moreover, the energy-, carbohydrate-, mono- and disaccharide-, sodium-, magnesium- and caffeine intake of the scientific nutrition strategy was significantly higher compared to the A strategy during the endurance load (**see Table 3**). Furthermore, during the time-trial the sodium intake was higher regarding the S ($p \leq 0.001$) group compared to those on the self-chosen strategy (**see Figure 4**). Equal results were also revealed when looking at the caffeine ingestion, as well as at the entire intake of essential nutrients during the TT (**see Table 3**). The energy intake between the two groups only differed slightly during the time trial (S: 75.22 ± 21.92 kcal; A: 73.79 ± 21.34 kcal).

Heart rate

The mean heart rate of S and A strategies was comparable during the endurance exercise (S: 141,8 bpm vs. A: 142,43 bpm; $p=0,72$). During the first three laps of the time trial, and then at 16 km ($p = 0.012$), 32 km ($p = 0.049$) and 48 km ($p = 0.046$) the mean heart rate with S was significantly higher compared with the other group. This tendency continued during the last lap, but without revealing any significant difference. Regarding the duration of the time trial, the mean heart rate of both strategies was almost stabilized.

Change in body mass and urinary specific gravity

Body mass was lower during the A protocol, especially during the time trial. Comparing the body weight between the S and A, there were significant differences after the endurance exercise ($p = 0.027$) and after the time trial ($p = 0.05$) (see Figure 5). The urinary specific gravity of the group relying on their own nutrition strategy showed significant differences. The athletes had a urinary specific gravity at rest of 1.010 g/mL which was significantly lower ($p \leq 0.01$) than the one after the endurance exercise (1.017 g/mL). Likewise, the urinary specific gravity significantly increased ($p \leq 0.001$) between the endurance exercise and the break following the time trial (1.019 g/mL) (**see Figure 3**).

Lactate and Glucose

The mean plasma lactate concentration was constant during the endurance exercise (**see Figure 6**). There were no differences between the S and A strategy, and the lactate concentration did not change despite the increased performance during the course of the exercise. Hence the physical strain intensity was comparable for both strategies, and thus the aim of the endurance exercise before the time trial was fulfilled. During the first 90 min of the endurance exercise, the average plasma glucose concentration was not different between the two nutrition strategies. Plasma glucose concentration, however, differed significantly during the endurance exercise after 120 min ($p = 0.026$).

After the time-trial mean plasma lactate concentration tended to be higher in S compared to A strategy but without statistical significance (S: 2.92 mmol/l vs. A: 2.30 mmol/l). Mean plasma glucose didn‟t show a significant difference between both strategies.

Discussion

The aim of this study was to investigate whether an athlete"s self-chosen nutrition strategy (A) differs basically from a scientifically-given one (S), and whether these different nutrition strategies have an impact on the performance capability of competition-specific long-term endurance loads. We hypothesised that athletes using S would show a higher time-trial performance compared to those using A. Due to the improved performance higher lactate concentration and an increased mean heart rate were expected.

Performance

Within both of the athlete groups there was an increase in the lap times during the time trial caused by physical fatigue, but it has to be mentioned that the S strategists had significantly faster laptimes throughout all four laps. This was the result of a significantly higher mean power accompanied by significantly higher mean heart rate values. Presumably the improved performance can be explained by the combined effects of timing, amount and composition of nutrition used in the S strategy.

Intake of energy, fluids and electrolytes

The nutrition strategies showed significant differences between S and A, as athletes ingested more energy, fluids and electrolytes in S than in A.

A sufficient carbohydrate intake during long-term endurance loads, containing a combination of glucose and fructose (2:1), positively influences the endurance performance (Jentjens, et al., 2004b). Thus, the results of other authors are confirmed (Jeukendrup, et al., 2006; Kerksick, et al., 2008). Regarding the electrolytes, sodium seems to support this effect. Within the S group the energy ingestion was mostly realised by carbohydrates. The athletes ingested 26 g carbohydrates every 15 minutes during the endurance exercise, consisting of 9.8 g mono- or disaccharides. This constant intake of carbohydrates during the load obviously achieved a more efficient energy supply to the muscles compared to the sporadic ingestion guided by a feeling of hunger. In contrast, the athletes in the A group simply ingested 12 g of carbohydrates (thereof 6.6 g mono- and disaccharides) during the endurance exercise. During the warm up and the VO2max determination the supply of the A strategists was only realised by water, whereas the carbohydrates were evenly ingested during the time trial (S 18.6 g carbohydrates; A 15.6 g carbohydrates).

The A strategists consumed energy bars as well as complex carbohydrates (bread rolls and bread with cold cuts) more often. The intake of complex carbohydrates in combination with fats, proteins and fibre, obviously cause a delay in the glucose resorption (Jeukendrup & Gleeson, 2004). The predominantly consumed products were gels, bars, carbohydrate powder and bananas, the latter do not only contain potassium but also complex carbohydrates. These belonged to the nutrition strategy of 7 athletes, when using strategy A. A high potassium intake may cause a displacement of sodium out of the interstitial tissue and can dehydrate the subcutaneous tissue.

The idea of strategy S was to minimise the fluid deficit during the endurance performance. The guideline of a 250 ml fluid intake every 15 minutes could only be realised by the S group regarding the endurance load. During the intensive time trial athletes were only able to ingest 192 ml/15 minutes. This fluid amount corresponds to the standards given by Convertino et al. (1996). In order to minimise the load on the digestive system a distributed fluid intake at short intervals of 15 minutes is said to be advantageous/beneficial (Latzka & Montain, 1999). It has to be mentioned, that only two athletes, weighing 55 kilos, reneged on the fluid standards of the S strategy and drank less. Thus, when speaking of the fluid supply during loads, one always has to consider the body mass.

The fluid supply within the A group was significantly lower, especially before and during the endurance exercise, compared to the other group (144 ml versus 241 ml). As a result the fluid deficit led to a higher urine concentration concerning the A strategy, since the insufficient fluid intake increased the urine concentration. It is important to pay attention to a sufficient fluid supply before the competition (Convertino, et al., 1996). That the fluid supply between the two groups was almost identical during the time trial may be the result of an earlier dehydration in the A strategists during the endurance exercise, but the body weight loss during the endurance exercise with A strategy, which was caused by an insufficient fluid intake, was not compensable during the time trial (Figure 5, Panel A).

In order to avoid hyponatremia a sufficient sodium intake is necessary (Convertino, et al., 1996). By the addition of 0.8–1.2 g/l of common salt (circa 0.4 g sodium) hyponatremia can be prevented (Sharp, 2006). Athletes relying on the S strategy averagely ingested 0.65 g of sodium per hour compared to the A group with 0.2 g/h, which probably was not sufficient. Hence, it is likely that the sodium amount, and nutrition strategy, within the A group caused a sodium undersupply accompanied by a carbohydrate deficit during endurance loads.

Caffeine consumption can improve glucose uptake in the small bowel (Nieuwenhoven, et al., 2000), as well as the endurance performance (Wiles, et al., 1992; Kovacs, et al., 1998; Cox, et al., 2002), which is a result of a higher exogenous carbohydrate oxidation when glucose is coingested with caffeine during exercise (Yeo, et al., 2005). The mechanisms that influence the carbohydrate oxidation by the intake of caffeine have not been revealed yet. Caffeine ingestion was significantly higher in the S group, which could be one of the main contributing factors that lead to their improved performance capability.

Change in body mass and urinary specific gravity

Considering the S strategy, the body weight increased slightly during the endurance load, which indicates a balanced water supply as well as an optimised fluid intake.

Compared to the S athletes, the A athletes ingested less water and nutrition. After the time trial both of the strategies showed a weight loss that should be the result of a slight hypohydration. This emphasises the fact that none of the nutrition, or rather fluid ingestion, strategies could compensate for either the energy use or the mass loss over the given distance. Compared to the initial mass the weight loss was lower within the S group than within the A one. Even 30 minutes after the time-trial there still existed a non-significant difference between the S and the A strategies. The body weight of the A group remained almost at the same level during the rest after the time trial, whereas athletes in the S group showed a slight loss in body weight.

Plasma metabolites

Lactate

The intensity during the endurance load of about 2:30 h was comparable between the two nutrition strategies as revealed by the measurement of the mean plasma lactate concentration. It has to be mentioned, that there is evidence for higher lactate concentrations during exercise, when fructose is fed before (Koivisto, et al., 1981) or co-ingested with glucose during exercise (Jentjens, et al., 2004a, Jeukendrup, et al., 2006). However, the constant measuring of the heart rate confirmes our assumption by revealing no significant difference between the mean heart rate of the A or S strategies during the endurance exercise. Thus an equal metabolic condition was guaranteed for the time trial.

Glucose

At the beginning of the endurance load the blood glucose concentration between the A and S group did not reveal any significant differences, whereas after 120 min the blood glucose was significantly higher and at the end of the endurance exercise tended to be higher in the S group compared to the A group (Figure 6, Panel A). The S group‟s rising glucose concentration seems to be an effect of the increased carbohydrate consumption (Coyle, et al., 1986). Regarding the A strategists, they were not mindful of supplementing carbohydrates continuously compared to the other group, which is proven by the previous discussion of the nutrition strategies.

Conclusions

Obviously the S strategy showed an improved performance. This was presumably due to an accurately timed, regular and optimal supply of energy, fluid and electrolytes during a long-term endurance activity. The higher step power in S was associated with significant higher heart rates and increased lactate accumulation. Concerning long-term endurance performances, a nutrition strategy following scientific findings leads to an improved performance.

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	males	females	all
n	14	2	14
Age [y]	33.3 ± 10,1	40.5 ± 7.8	34.4 ± 9.8
Body weight [kg]	78.0 ± 8.7	62.0 ± 7.4	76.0 ± 9.9
Body height [m]	1.80 ± 0.05	1.72 ± 0.05	1.79 ± 0.06
BMI [kg/m²]	24.1 ± 1,9	21.0 ± 1.3	23.7 ± 2.1
VO2max [ml·min−1·kg−1]	56.2 ± 7,6	45.4 ± 1.7	54.9 ± 8.0

Table 1: Age, anthropometric and physiological characteristics of the subjects.

	EnergySource [100 g]	EnergySource Xtreme [100 g]
Energy [KJ/kcal]	1649/388	1571/376
Proteins [g]	0	0
Carbohydrates [g]	97	94
thereof Sugar [g]	33	46
thereof Maltodextrin [g]	79,1	48
Fat [g]	0	0
thereof saturated Fat [g]	0	0
Dietary fibre [g]	0	0
Sodium [mg]	690	690
Potassium [mg]	180	180
Magnesium [mg]	25	120
Caffeine [mg]	60	300

Table 2: Nutrition facts of the High5 carbohydrate powder

Parameters		Endurance exercise [every 15 min]	Time trial [every 15 min]	Overall intake	mean intake per kg body mass
Fluid [ml]	**S**	**274.5 ± 29.2**	**195.1± 57.4**	**5,036.7 ± 687.8**	**66.6 ± 7.3**
	A	**178.4 ± 75.0*** **	**184.9 ± 56.0**	**4,006.3 ± 1,173.1***	**54.4 ± 17.3***
Energy [kcal]	**S**	105.1 ± 11.0	75.2 ± 21.9	1,932.05 ± 261.2	25.5 ± 2.7
	A	56.1 ± 22.9***	73.8 ± 21.3	1,382.5 ± 426.0**	18.8 ± 5.6**
Carbo-hydrates [g]	**S**	26.0 ± 2.7	18.6 ± 5.4	478.6 ± 64.7	6.3 ± 0.7
	A	12.0 ± 4.7***	15.6 ± 5.5	289.8 ± 97.1***	3.9 ± 1.2***
Mono-. Disaccharide [g]	**S**	9.8 ± 1.0	6.6 ± 1.9	176.6 ± 23.9	2.3 ± 0.2
	A	6.7 ± 3.7**	8.2 ± 3.0	162.3 ± 67.0	2.2 ± 0.9
Sodium [mg]	**S**	187.9 ± 19.7	133.8 ± 39.0	3,447.9 ± 466.3	45.6 ± 4.8
	A	54.6 ± 50.1***	65.1 ± 40.8***	1,324.3 ± 801.5***	17.8 ± 10.8***
Potassium [mg]	**S**	49.0 ± 5.1	34.9 ± 10.2	899.5 ± 121.6	11.9 ± 1.3
	A	36.6 ± 40.7	55.6 ± 38.5	999.9 ± 728.2	13.7 ± 9.7
Magnesium [mg]	**S**	11.3 ± 1.4	4.9 ± 1.4	178.5 ± 25.9	2.4 ± 0.2
	A	6.4 ± 6.7*	11.5 ± 10.7	196.3 ± 147.0	2.7 ± 1.9
Caffeine [mg]	**S**	27.7 ± 3.4	11.6 ± 3.4	435.7 ± 63.8	5.7 ± 0.5
	A	3.8 ± 9.9***	2.3 ± 4.3***	35.5 ± 55.7***	0.5 ± 0.7***

Table 3: Nutritional value intake during the endurance exercise, the time trial (every 15 minutes) and the entire load time, and body mass, between A und S. * = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$.

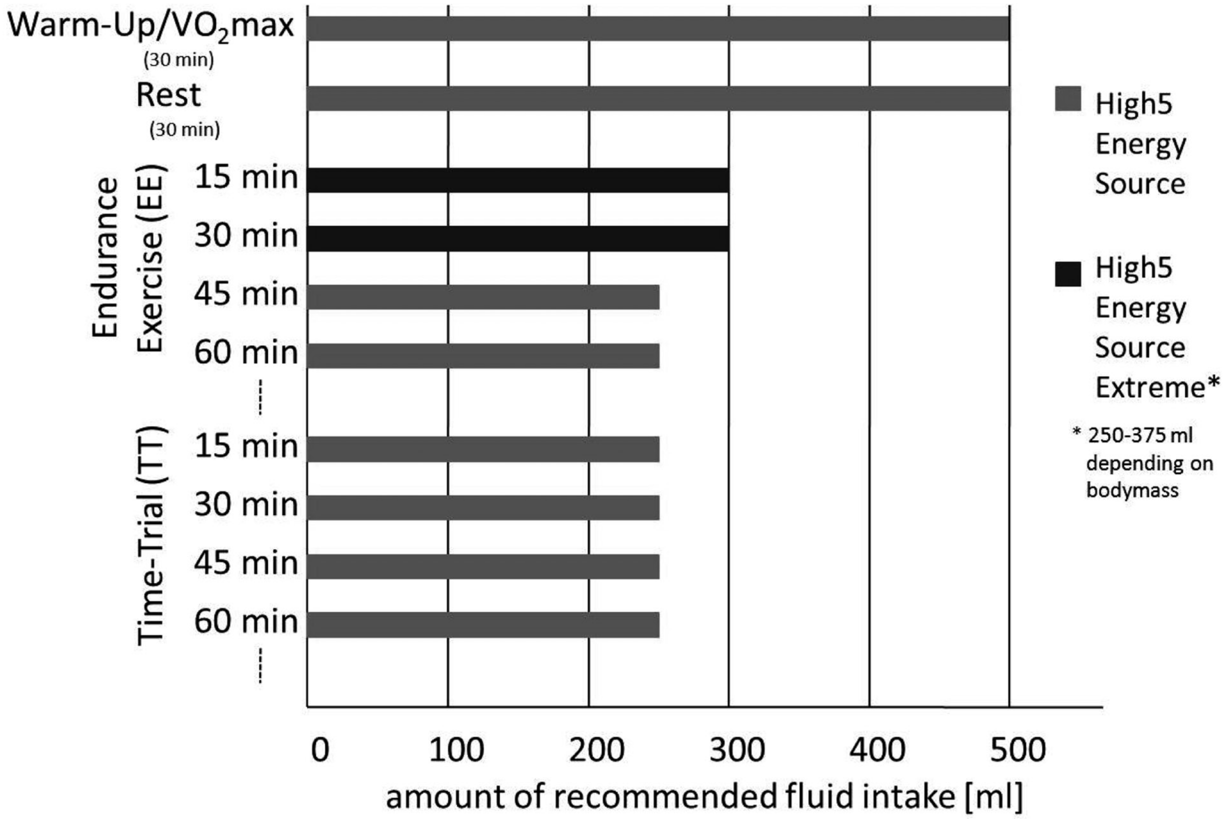

Figure 1: Exercise protocol and provided nutrition.

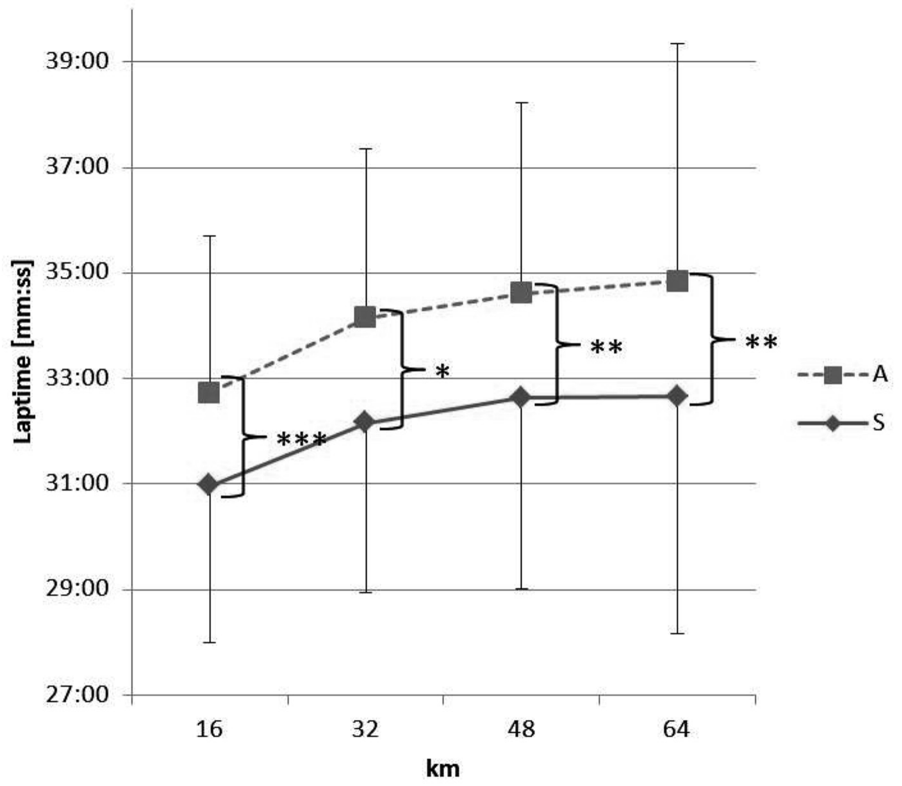

Figure 2: Mean cycling time and standard deviation every 16 km, and the entire cycling time, regarding the 64 km time trial for scientific nutrition strategy (S) or the athlete’s nutrition strategy (A).

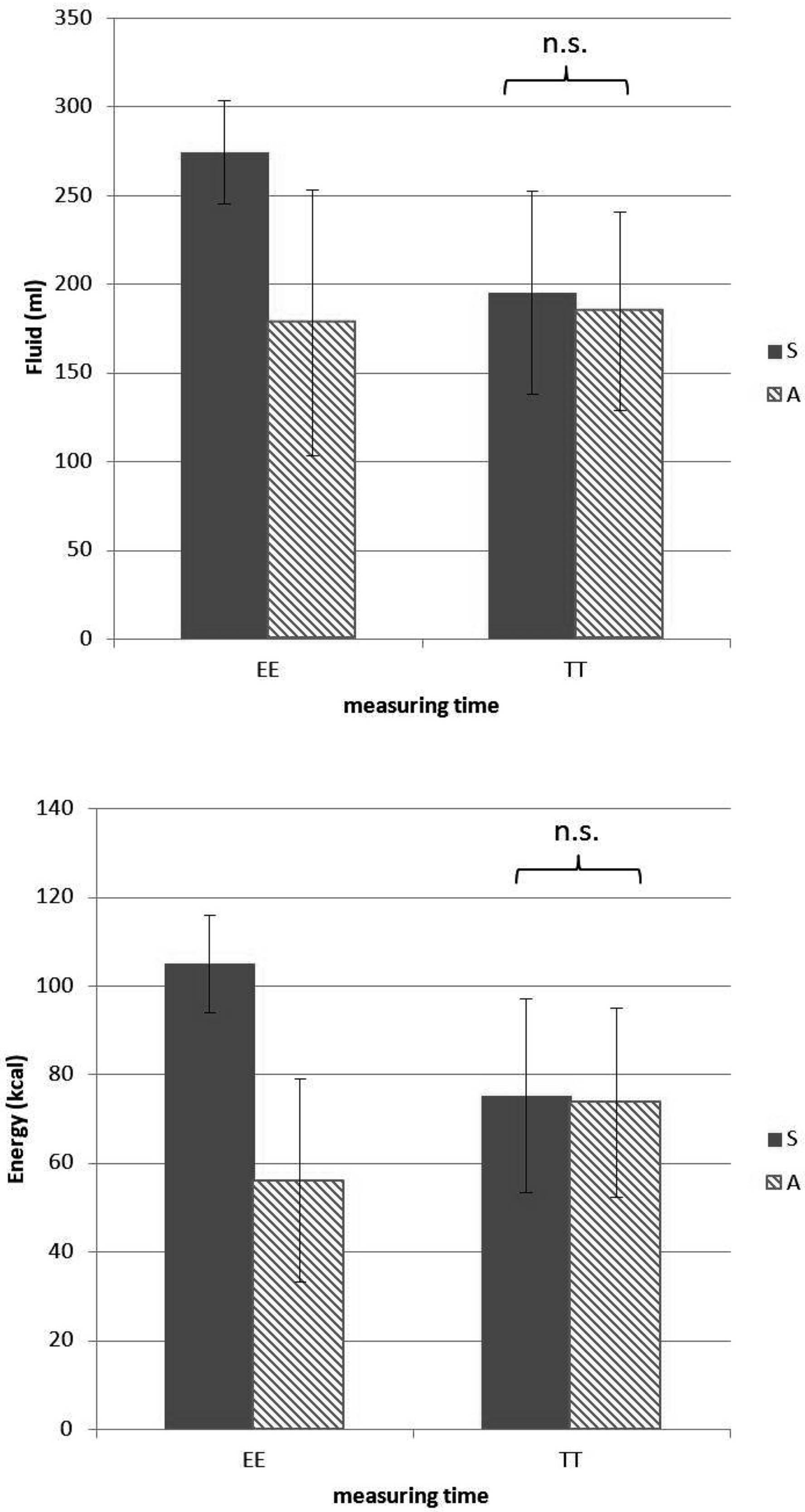

Figure 3: Fluid (Panel A) and energy intake (Panel B) between trials.

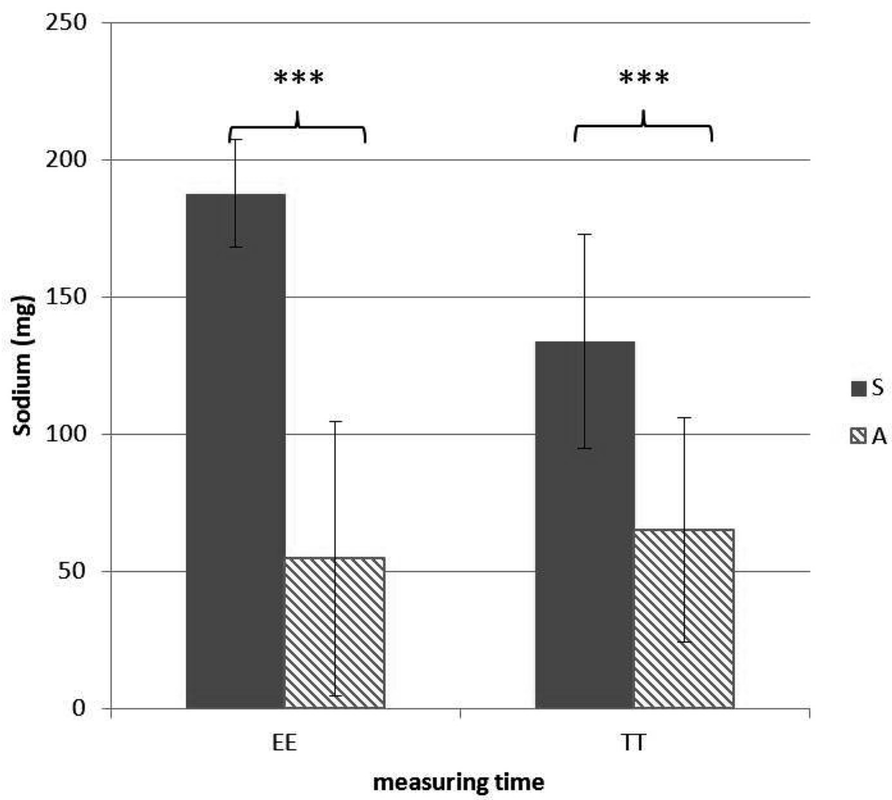

Figure 4: Sodium intake between trials.

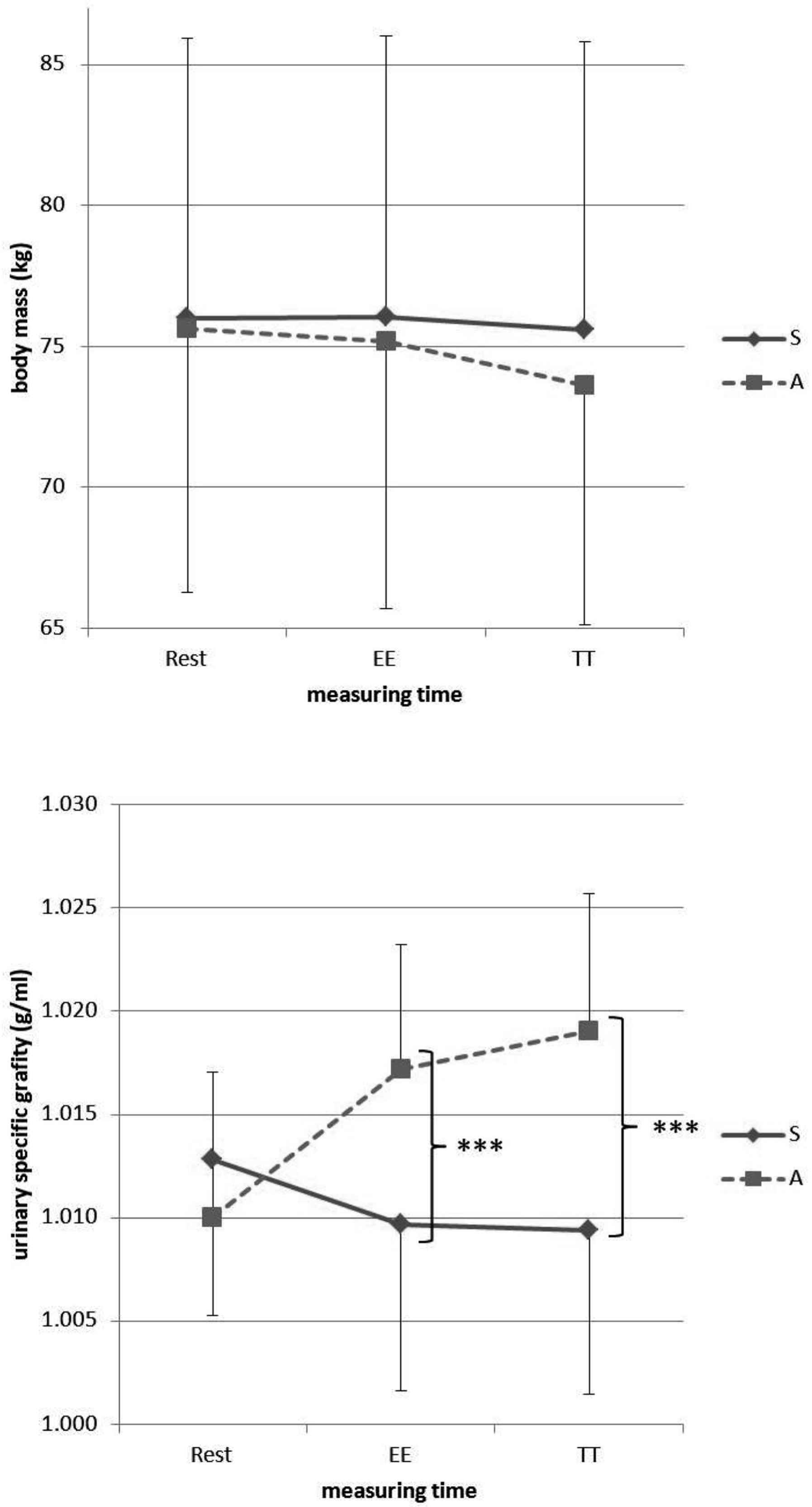

Figure 5: Change of body mass (Panel A) and urinary specific gravity (Panel B) across time.

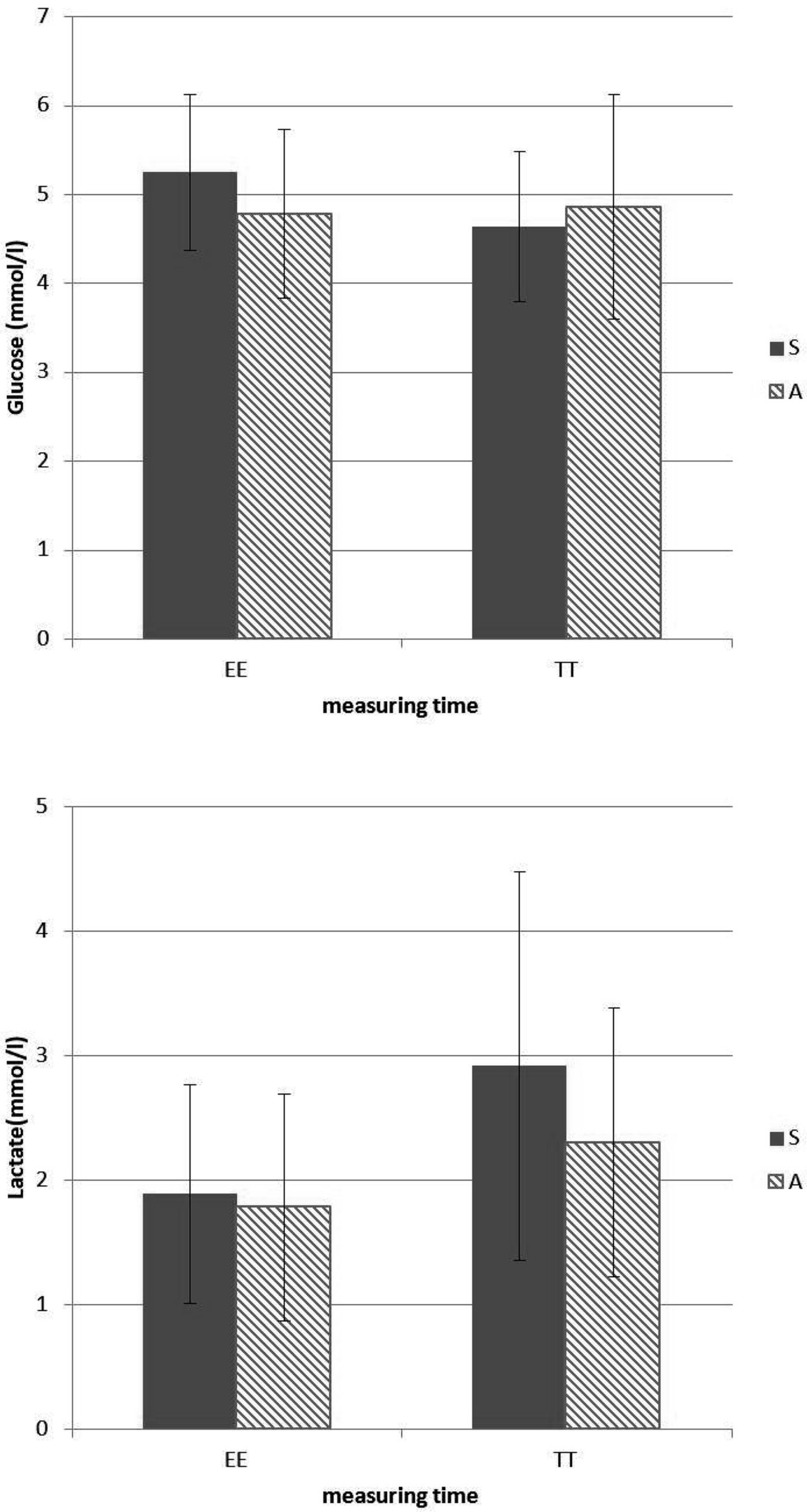

Figure 6: Change in plasma glucose (Panel A) and plasma lactate (Panel B) between trials.