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ORIGINAL ARTICLE

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Nutrient intake and performance during a mountain marathon: an observational study

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Abstract In order to study nutrient intake of amateur runners during a mountain marathon, compliance with recommendations, and association with performance, an intake of 42 participants in a Swiss mountain marathon was assessed by direct observation. Data on demographics, dietary preparation and race experience were obtained by questionnaires. Anthropometrical measures were performed before and after the race. Mean hourly intakes (SD) of fluid, carbohydrate, energy and sodium were 545 (158) ml, 31 (14) g, 141 (63) kcal [or 590 (264) kJ], and 150 (203) mg respectively. A third of the runners drank 600 ml h^{-1} or more, 52% consumed less than 30 g h^{-1} carbohydrates, 95% consumed less than 500 mg h^{-1} sodium. Mean weight loss was 4 (1.5) kg; 30 runners (71%) lost over 3% body mass. Mean running time was 7 h 3 min (1 h 17 min). Most participants failed to meet nutritional recommendations. None were at risk of overhydration. Body composition and race experience were correlated with performance, but not nutrient intake. Because experienced runners are well trained, fitter, and know better their personal needs during such a race, it is difficult to disentangle these associations. As causal relationship cannot be proven with this cross-sectional design, non-compliance with intake recommendations requires additional experimental research on the impact of nutrient intake on field performance.

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Introduction

During ultra-endurance running, the challenge is not only the physical performance, but also the maintenance of fluid balance. Some authors have stressed the danger of failing to adequately replace fluids during a race, which could lead to dehydration, increased fatigue, cognitive dysfunction and poor performance (Barr et al. 1991; Cian et al. 2001). For many years, athletes have been told to "stay ahead of their thirst" and replace fluid loss during exercise to prevent dehydration. This recommendation has been questioned following several reports of fatal cases of hyponatremia from overhydration. Infrequent, though potentially life threatening, this disorder is associated with overconsumption of fluids during long duration sport events (Hew et al. 2003; Noakes 2003). The current trend is to encourage the long-distance runner to drink according to personal thirst sensation (Casa 2004; Noakes 2002). In most forms of recreational and competitive events, recommended fluid intake ranges between 400 and 800 ml h^{-1}; less for slower, smaller athletes exercising in mild environmental conditions, more for elite athletes competing at higher intensities in warmer environments (Noakes 2003).

Apart from fluid intake, another important issue is fuel availability during exercise, especially when hot weather increases carbohydrate oxidation (Burke 2001). Carbohydrates are a primary fuel during a marathon (O'Brien et al. 1993) and should be consumed before and during prolonged exercise, to delay fatigue and increase performance (Burke 2001). During endurance exercise, intake of 30–60 g h^{-1} carbohydrate is recommended (American College of Sports Medicine 2000), and 1 g kg^{-1} h^{-1} has been suggested to meet maximum carbohydrate oxidation rate (Hawley et al. 1992).

Even though it is still debated (Noakes 2003), sodium replacement is generally recommended for ultra-distance athletes to stimulate thirst, increase voluntary fluid intake, enhance glucose absorption and decrease the risk of developing hyponatremia (Applegate 1991; Kimber et al. 2002; Speedy et al. 1999; Vrijens and Rehrer 1999). Modest amounts of sodium (0.5–0.7 g l^{-1}) can be of benefit to the long-distance runners, and cause no harm. Beverages should contain 1.7–2.9 g l^{-1} NaCl (680–1,160 mg sodium) during ultra-endurance exercise (Maughan 1991; Rehrer 2001). Sodium requirements can also be met by consumption of solid food (Rehrer 2001).

Many of these recommendations are derived from observations conducted in controlled settings, generally among highly trained athletes. However, data on nutrient intake during real endurance races are scant (Fallon et al. 1998; Kimber et al. 2002; Rehrer et al. 1992; Speedy et al. 2001). Although these studies provide some insight into what athletes consume when racing, they concern only a small number of participants, most of them highly trained. There is a lack of data on actual intake in larger samples, including recreational amateur runners. The principal objective of our study was to describe dietary practices and nutrient intake in a group of amateur runners during a mountain marathon, and their compliance with nutritional intake recommendations. As a secondary objective, we also studied the association between nutrient intake and performance.

Methods

Setting

The study was conducted during the 38th "Tour des Dents du Midi" race, Switzerland's oldest mountain marathon, held during the last weekend of August 2001. Race distance was 44 km, with a total of 2,890 m ascent and descent over small and steep trails, between 860 m and 2,494 m. Air temperature was 18°C at 6:00 a.m., 24°C at 9:00 a.m., 27°C at 1:30 p.m. and 30°C at 3:00 p.m. Humidity levels at 6:00 a.m. and 4:00 p.m. were, respectively, 61% and 34% at the lowest altitude, and 92% and 57% at the highest altitude. Wind speeds ranged between 1 and 21 km h^{-1} between 6:00 a.m. and 4:00 p.m. (lowest altitude), and between 2 and 12 km h^{-1} (highest altitude).

Study design and participants

The study design was an observational cohort, with data collection based on self-administered questionnaires, interviews and direct observations of food and fluid intake by dieticians and specifically trained research assistants (two per support station). Among the total of 102 registered participants in the race (all amateurs), 52 randomly selected runners were asked to participate in the study (34 who sent their participation bulletin early, and 18 who signed in on-site the day before the race). Two participants could not be contacted and four did not participate because of injury or professional commitments. The remaining 46 eligible runners (88%), including three women, were given detailed written and oral information about the study and gave their oral informed consent to participate to the study. They could withdraw from the study at any time. The study protocol complied with the ethical standards of the Helsinki Declaration and was in accordance with the local legislation.

Data collection

Information on prior race experience, dietary preparation and expected finishing time was obtained with a self-administered questionnaire before the race. The questionnaire was mailed to the 28 first registered participants who faxed, mailed or handed it in on the day of the race. The 18 runners who were recruited on-site either filled the questionnaire in on the spot, or brought it back the next day, before the race.

All participants were weighed 30–60 min prior to the start of the race on a scale (Soehnle, precision to 100 g) placed on a hard, level surface. Upon their arrival at the end of the race, before eating or drinking, all subjects were weighed again on the same scale. On both occasions, participants were weighed with their running clothes and shoes on, but without accessories (caps, bottles, bags, etc.). Total body mass change was used to estimate fluid loss. Body mass index (BMI) was calculated using self-reported height.

Skinfold thickness was measured after the race at four sites (triceps, biceps, sub-scapula and supra-iliac) by an experimented investigator with a calibrated caliper (Holtain, Crymych, UK). Body fat mass was calculated according to the formula of Durnin and Womersley (1974).

Food and fluid intake during the race was evaluated by direct observation by 30 trained research assistants, all trained during a specific session. They were instructed to observe carefully the number of cups actually consumed (and not to count the water thrown over in order to refresh head and body) by the participants of the study who where displaying a colored tag on their number. Runners were aware of the observation and informed the observers of the actual number of cups ingested. The assistants were present throughout the race at each of the 15 support stations, where food and drinks were available. A separate table for the runners participating in the study was used at most stations. Food and fluids were pre-portioned and displayed identically at the various stations. Fluids (water, sweet tea with 50 g l^{-1} sugar, soup or Rivella Marathon[1])

[1] a Swiss refreshment beverage, based on the constituents of milk serum; 100 ml contains 84 kJ, <0.1 g protein, 5 g carbohydrate, <0.1 g fat, 9 mg vitamin C and 0.21 mg vitamin B1

were available in plastic cups containing 1-dl portions. Bananas and oranges were available in 2-cm and 4-cm slices, respectively, dried fruit mix was portioned in plastic cups, cereal bars were sliced into four and grape sugar was available in 3 g cubes. All intakes by the participants were carefully entered onto a standardized form by the assistants.

Information about any personal supply (food and fluids the runners carried with them and consumed during the race) was collected by two trained dieticians at the end of the race, who also enquired about gastro-intestinal symptoms, cramps and thirst.

Total nutrient intake calculations were performed with Prodi 4.2 Plus (Nutri-Science, Karlsruhe, Germany). All data were entered by two dieticians and calculations were made following the same procedure.

Energy expenditure to complete the race was estimated using the energy cost of running and walking on extreme slopes according to Minetti's model (Minetti et al. 2002). The race profile was separated in 23 sections according to the gross altitude profile of the race (Fig. 1) with a 1:25,000 scale map. Straight horizontal, vertical and hypotenuse distances, as well as mean gradients, were calculated for each section. Using Minetti's polynomial equations, energy cost for running or walking each part of the race was calculated. Three different estimates of total energy cost for completing the race were then determined: (1) running all the time, (2) running downhill and uphill except when slopes were steeper than +20% and (3) running downhill and walking uphill. Best theoretical race performance was calculated using the highest speed versus gradient relationship from the Minetti model (Minetti et al. 2002), based on best performance of world-class mountain runners.

Final race time served as a measure of overall performance.

Statistical analysis

Statistical analyses were performed with SPSS 11.0 (statistical package for social sciences, Chicago, Ill.).

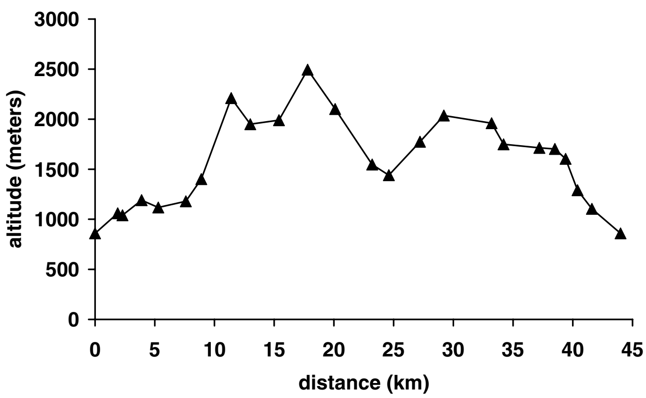

Fig. 1 Race profile, Tour des Dents du Midi, Switzerland, 2001

Descriptive statistics (mean, standard deviation, minimum, maximum, tertiles) were calculated for final race time, physical characteristics of the runners (age, BMI, body fat mass), total and hourly nutrient intake (fluid, carbohydrates, lipids, proteins, sodium) and energy intake. Pearson coefficients were used to study correlations between hourly nutrient intakes. To examine the relationship between running time, physical characteristics and nutrient intake, runners were split into three groups (tertiles) according to their performance. Analysis of variance and test for linear trend were used to test for difference in mean values across the three levels of performance. Cross-tabulations and χ^2 tests were used to compare discrete characteristics of the runners and examine their relationship with performance (sex, dietary preparation, prior participation in mountain marathons). We also calculated the proportion of runners in conformity with international guidelines for fluid, carbohydrate, and sodium intake, for each tertile of performance, and for total body mass loss as a marker of dehydration. Finally, factors statistically associated in univariate analyses with performance were entered in a linear regression model, and a backward stepwise procedure, guided by the analyst, was used to identify the variables in the final model. All tests were two-tailed, with a significance level of 0.05.

Results

Four runners did not finish the race and were lost to follow-up. The data of the 42 remaining participants were analyzed, including the data for the winner of the race. Participants ran in three age categories: 20–39 years (40%), 40–49 years (38%), >50 years (22%). Three participants (7%) were women, one in each age group. Mean age was 42 years (SD 9.7, range 23–62, quartiles 37–42–49). Mean body mass was 71 kg (SD 7.8, range 52–87, quartiles 67–71–77). Mean BMI was 23.0 kg m^{-2} (SD 1.9, minimum 19.2, maximum 28.4, quartiles 21.9–22.7–23.9). Thirty-four (81%) participants had a BMI between 20 and 25, two had a BMI <20 and six had a BMI >25. Mean body fat mass was 19.0 kg (SD 4.8, minimum 9.6, maximum 29.1, quartiles 15.4–20.0–22.1). Most runners were experienced, and 64% ($n=27$) had participated in more than ten mountain races.

Almost 90% of the participants believed that nutrition had some influence on performance. Whereas 79% ($n=33$) reported an increased consumption of starchy foods, only 60% ($n=25$) said they had practised dietary changes as part of their preparation prior to the race. Main dietary changes before the race were increased consumption of pasta, rice or bread (33, 79%) and non-sweet drinks (20, 48%), and a decreased consumption of cake, biscuits or chocolate (13, 31%) and sweet drinks (12, 29%). Seven (17%) participants followed a specific glycogen loading diet (Bergstrom et al. 1967).

Intake and body mass loss

Average fluid intake throughout the race was 3,777 ml, with a mean hourly fluid intake of 545 ml h^{-1} (Table 1). On average, participants consumed 213 g of carbohydrate, 11 g of fat, 6 g of protein and 1,099 mg sodium. Mean energy intake was 971 kcal (4,065 kJ), mostly provided through carbohydrates (88%). Higher intakes of carbohydrates, energy, sodium and protein were associated with higher fluid consumption (Table 2). Sodium was mostly provided through solid food, and associated with protein intake.

Some participants carried personal food items during the race. Overall, approximately one-third of the carbohydrates and <15% of the fluid were brought as personal supplies. The fastest runners used more personal supplies than the slowest.

When considering all liquid items, sweet drinks were consumed most often (53% of all occasions), followed by water (39%). Soup was rarely chosen (8%). Water, sweet drinks and glucose were consumed as often by the fastest as by the slowest runners. Soup, fruits and cereal bars were chosen more often by the slowest runners. Gels were used only among the fastest runners. One participant, in the slowest group, consumed dried meat, bread, cheese and biscuits during the race.

Mean body mass loss during the race was 2.9 (1.1) kg. All participants lost at least 1% of their body weight: 12 (29%) 1–3%, 22 (52%) 3–5%, and 8 (19%) over 5%. Loss of body mass was associated with lower total fluid intake (Spearman $r=-0.37$, $P=0.02$). Twenty-one participants (50%) suffered from cramps, 15 (36%) from gastrointestinal symptoms (diarrhea, nausea, stomach pain) and 12 (29%) reported suffering from thirst at least once during the race. No significant association was found between these symptoms and body mass loss (data not shown).

Energy expenditure and energy deficit

Average estimated energy expenditure ranged between 3,441 (375) kcal [14,406 (1,570) kJ] when running, 3,329 (364) kcal [13,937 (1,524) kJ] when walking on slopes >20%, and 2,860 (312) kcal [11,974 (1,306) kJ] when running downhill and walking uphill. Based on energy intake, the energy deficit accumulated during the race thus amounted to an average of 2,470 (513) kcal [10,341 (2,147) kJ] when running, 2,358 (507) kcal [9,872 (2,122) kJ] when walking on slopes >20%, and 1,889 (479) kcal [7,908 (2,005) kJ] when running downhill and walking uphill.

Performance

Mean running time was 7 h 3 min (SD 1 h 17 min, minimum 4 h 37 min, maximum 9 h 20 min). The best theoretical performance according to the model of Minetti et al. (2002) was 4 h 35 min, very close to the performance of the winner.

Predictors of performance and conformity with recommendations

Younger age, lower BMI, lower body fat mass, higher hourly intake of fluid, carbohydrates and energy were associated with better performance (Table 3). Previous experience, defined as having run more than ten mountain races in the past, was also associated with better performance (mean time 6 h 39 min versus 7 h 47 min, $P=0.004$).

All runners consumed at least 200 ml h^{-1} fluid, 35 (83%) at least 400 ml h^{-1}, 13 (31%) at least 600 ml h^{-1}, and 2 (5%) 800 ml h^{-1} or more. Less than half of the runners, ($n=18$, 43%), consumed over 30 g h^{-1} carbo-

Table 1 Total and hourly intake of 42 runners during a mountain marathon, Switzerland, 2001. *Min–max* Minimum value to maximum value

	Mean	SD	Min–max	25th Percentile	50th Percentile	75th Percentile
Total intake						
Fluid (ml)	3,777	1,146	1,950–8,150	2,950	3,750	4,020
Carbohydrates (g)	213	86	52–517	150	197	252
Lipids (g)	11	19	0–89	1	3	12
Protein (g)	6	6	0–30	2	4	7
Sodium (mg)	1,099	1,729	108–9,734	382	531	1,074
Energy (kcal)	971	422	219–2,405	711	880	1,171
Energy (kJ)	4,065	1,766	917–10,069	2,976	3,684	4,902
Hourly intake						
Fluid (ml h^{-1})	545	158	227–1,094	458	537	607
Carbohydrates (g h^{-1})	31	14	7–69	22	28	37
Lipids (g h^{-1})	2	3	0–12	0	0.5	2
Protein (g h^{-1})	0.8	0.8	0.0–4.0	0	0.5	1
Sodium (mg h^{-1})	150	203	12–1,123	53	80	165
Energy (kcal h^{-1})	141	63	30–323	93	131	188
Energy (kJ h)	590	264	126–1,352	389	549	787

Table 2 Correlation (Pearson coefficients) between hourly nutrient intakes of 42 runners of a mountain marathon, Switzerland, 2001

	Fluid intake (h^{-1})	Carbohydrate intake (h^{-1})	Fat intake (h^{-1})	Protein intake (h^{-1})	Sodium intake (h^{-1})
Carbohydrate intake (h^{-1})	0.48 **	–	–	–	–
Fat intake (h^{-1})	−0.04	0.08	–	–	–
Protein intake (h^{-1})	0.42**	0.27	0.36*	–	–
Sodium intake (h^{-1})	0.43**	0.19	0.20	0.59***	–
Energy intake (h^{-1})	0.43**	0.92***	0.47**	0.42**	0.27

*$P < 0.05$
**$P < 0.01$
***$P < 0.001$

Table 3 Performance, physical characteristics and nutrient intake of 42 participants of a mountain marathon, Switzerland, 2001. Values are means (SD)

	Running time			
	Slowest tertile[a]	Intermediate tertile[b]	Fastest tertile[c]	P value[d]
Physical characteristics				
Age	47.7 (6.5)	41.9 (9.2)	36.9 (10.3)	0.002
Body mass index	23.7 (1.9)	23.4 (2.2)	22.1 (1.3)	0.03
Body fat mass (kg)	22.1 (3.5)	19.5 (4.0)	15.5 (4.3)	< 0.001
Fluid and food intake				
Fluid (ml h^{-1})	463 (137)	578 (178)	595 (131)	0.03
Carbohydrates (g h^{-1})	26.0 (7.1)	29.6 (18.0)	37.6 (11.3)	0.02
Protein (g h^{-1})	1.0 (0.7)	0.9 (1.0)	0.4 (0.4)	0.08
Lipids (g h^{-1})	1.2 (1.3)	2.2 (4.0)	1.4 (2.4)	0.81
Sodium (mg h^{-1})	187 (325)	150 (130)	111 (66)	0.34
Energy (kcal h^{-1})	117 (35)	141 (90)	165 (44)	0.05
Energy (kJ h^{-1})	490 (147)	590 (377)	691 (184)	0.05

[a]Slowest tertile: 8 h 1 min–9 h 20 min
[b]Intermediate tertile: 6 h 18 min–7 hr 57 min
[c]Fastest tertile: 4 h 37 min–6 h 14 min
[d]Linear trend test

Table 4 Number of runners in conformity with various nutritional recommendations during a mountain marathon, Switzerland, 2001. Values are *n* (%)

	Running time		
	Slowest tertile	Intermediate tertile	Fastest tertile
Fluid[a]			
≥200 ml h^{-1}	14 (100)	14 (100)	14 (100)
≥400 ml h^{-1}	9 (64)	13 (93)	13 (93)
≥600 ml h^{-1}	2 (14)	5 (36)	6 (43)
≥ 800 ml h^{-1}	0	1 (7)	1 (7)
Carbohydrates[b]			
≥30 g h^{-1}	4 (29)	5 (36)	9 (64)
60 g h^{-1}	0	2 (14)	1 (7)
1 g (kg body mass)$^{-1}$ h^{-1}	0	0	0
Sodium[c]			
≥500 mg h^{-1}	2 (14)	0	0

[a]Based on The International Marathon Medical Directors Association guidelines for fluid replacement (Noakes 2002)
[b]Based on American College of Sports Medicine 2000and Hawley et al. 1992
[c]Based on the USA Track and Field Advisory (Casa 2004)

hydrate, and only three (7%) consumed 60 g h^{-1} or more. None of the runners consumed 1 g (kg body mass)$^{-1}$ h^{-1}. Two (5%) consumed sodium at a rate of 500 mg h^{-1} or more. Higher hourly intakes of fluid and carbohydrate were more frequent among faster runners, and higher sodium intake was more frequent among slowest runners, but these differences were not statistically significant (Table 4).

When adjusted in a linear model, previous experience, BMI below 23.3 kg m^{-2}, and body fat mass below 17.8 kg were significantly associated with better performance (Table 5).

Discussion

Intake and recommendations

Most participants failed to meet nutritional recommendations, whereas 83% drank 400 ml h^{-1}, which is the minimum recommended in mild environmental conditions, 31% drank at least 600 ml h^{-1}, and only two runners drank 800 ml h^{-1} or more. One-third of the runners experienced sensations of thirst. More than half did not meet the minimal carbohydrate intake recommendation (30 g h^{-1}), only three runners reached 60 g h^{-1}, and none ingested 1 g kg^{-1} h^{-1}. The average sodium intake matched the American College of Sports Medicine recommendations (American College of Sports Medicine 2000), but it was below specific ultra-endurance recommendations (Maughan 1991); only two runners had an intake of more than 500 mg h^{-1}. In an event as physiologically demanding as a mountain marathon, it is illusory to expect a balance between energy intake and expenditure. Other studies have shown that during long endurance events, endogenous fuel stores contributed to half or more of the total energy requirements (Kimber et al. 2002). The runners in our study were indeed not able to refuel effectively during the race, as they ingested only 141 kcal (590 kJ) h^{-1}, which resulted in an estimated energy deficit accumulated during the race of between 2,470 kcal (10,341 kJ) and 1,889 kcal (7,908 kJ).

Table 5 Characteristics and performance of 42 participants in a mountain marathon, Switzerland, 2001

		Δ Time compared with fastest tertile (min)	95% Confidence intervals (min)
Over ten prior participations in a mountain marathon		−66	−100 to −31
Body mass index (kg m^{-2})	(minimum—maximum)		
Lowest tertile	(19.2–22.2)	−48	−88 to −8
Intermediate tertile	(22.3–23.3)	−44	−84 to −3
Highest tertile	(23.4–28.4)	–	–
Body fat mass (kg)			
Lowest tertile	(9.6–16.2)	−99	−139 to −59
Intermediate tertile	(17.8–21.1)	−35	−75 to 6
Highest tertile	(21.7–29.1)	–	–

Previous studies on ultra-marathons showed comparable intakes. During a similar mountain marathon (Rehrer et al. 1992), mean estimated fluid intake was 350 ml h^{-1}. Fallon et al. (1998) studied seven participants in an Australian ultra-marathon and found an intake rate of 540 (210) ml h^{-1} fluid, 43 (15.6) g h^{-1} carbohydrate and <100 kcal h^{-1} (419 kJ); the contribution of carbohydrates to total energy intake (88%) was identical that found in our study.

Although those studies were different in terms of measurement methods, ambient temperatures and participants' training level, the body mass losses were similar to those in our study, around 4%. It should be noted that only 15 support stations were available in this race, in contrast with the 26 aid stations in many 42 km marathon races in the USA. This limited access to fluid and the risk of overhydration.

During an ironman triathlon, Speedy et al. (2001) and Kimber et al. (2002) showed higher fluid and carbohydrate intakes among 18 subjects (716 ml h^{-1} and approximately 69 g h^{-1} respectively), and lower body mass loss (3.5%) than in our study. The authors noted that most of the intake took place during cycling, when food and fluids are easier to ingest, rather than during running or swimming (Kimber et al. 2002).

It follows that published recommendations are not met in such field conditions. The present study was not designed to investigate the reasons for non-compliance with published recommendations. Therefore, explanations such as insufficient availability or palatability of fluid and food during the race, effect of intense exercise on thirst, hunger and satiety, food aversion or control of food intake, as well as the practical difficulty of drinking or eating while running/walking remain possible. Guidelines should perhaps provide more practical advice and a range of acceptable nutrient intake. It would also be interesting to study the impact of nutrient intake on performance during an intervention study. In this study, the fastest runners consumed gels, which may have contributed to their higher energy intake. It is conceivable that a more adequate carbohydrate and fluid consumption during the race would have increased comfort and performance for many participants. No one was at risk of overhydration. By contrast, over 3% body mass loss was observed in more than two-thirds of runners.

Intake and performance

A secondary goal of this study was to assess the relationship between nutrient intake and performance. As observed by Fallon on seven participants (Fallon et al. 1998), after adjustment for runners' characteristics, nutrient intake was not anymore associated with better performance in our study, and the strongest predictors of good performance were lower fat mass and higher level of experience in mountain marathons. Body mass was not associated with performance (Spearman $r=0.25$, $P=0.11$). Because experienced runners are well trained, fitter, and know their personal needs better during such a race, it is impossible to precisely separate the associations we found, especially in a cross-sectional design. In addition, training increases the benefits of adequate nutrition, and favors the accumulation of muscle glycogen after exercise (Hickner et al. 1997).

Limits and strengths of the study

There are several limitations to our study. Being a cross-sectional, observational study, no causal relationship can be drawn between intake and performance. Secondly, we did not record information on fluid intake before the body mass measurement prior to the race, which could have biased our body mass loss estimates. Thirdly, we only measured skin folds after the race. It is possible that these measurements, in conditions of underhydration, yielded less reliable data for the calculation of body composition as compared to control conditions. Fourthly, it would have been interesting to record the training level of the participants and study the potential confounding effect of training level on nutritional intake during a race. However, race experience seems an adequate indirect marker of training, as is body fat mass. Indeed, the association between fluid and nutrient intake and performance was not longer significant when adjusted for these factors. Also, it would have been interesting to know previous individual performance for the same event. This was not possible for two reasons. First, the route of the race was not identical between years, for security reasons and changes in the natural environment. Second, because participants were amateurs, some participated for the first time in this event. However, the best performance was similar to the one predicted by the Minetti model (Minetti et al. 2002), and the general results were very close to those of previous years. Finally, we did not formally validate the method we used for food and fluid intake assessment. However, we believe that the precise portioning of fluid and food, the specific training of the research assistants who observed the athletes' intake, and the use of standardized forms for data entry probably limited the lack of accuracy. This study, however, is one of the few detailed reports of direct observation of liquid and food intake in a large group of amateur runners during an ultra-endurance event. Although these results of our study cannot be directly extrapolated to other ultra-endurance events, they show the need for better instruction of ultra-endurance athletes.

Conclusions

The main finding of our study is that the majority of our amateur ultra-endurance runners did not meet current fluid and energy intake requirements for such events. Those athletes who performed better had intakes closer to the recommendations than did the slowest ones.

We reported actual nutrient intake during a mountain marathon in amateur runners. Most participants failed to meet current nutritional recommendations. None were at risk of overhydration, but important body mass loss was observed. Adequate fluid and carbohydrate intake were associated with better running times, but body composition and race experience were the only significant factors correlated with performance. However, our cross-sectional design, as well as the lack of validation of the direct observation method we used, does not allow us to conclude any definitive causal relationships, and the correlations reported are potentially spurious. Nevertheless, as methodology usually limits nutritional intake measurements during endurance exercise (Edwards et al. 1993; Rehrer 2001; Titchenal 1988), our direct observations could be valuable to guide further research to better understand sports physiology and nutrition in mountain marathons or other long-distance races.

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