Energy Intakes of Ultraendurance Cyclists During Competition, an Observational Study

Katherine E. Black, Paula M.L. Skidmore, and Rachel C. Brown

Endurance events >10 hr are becoming increasingly popular but provide numerous physiological challenges, several of which can be attenuated with optimal nutritional intakes. Previous studies in ultraendurance races have reported large energy deficits during events. The authors therefore aimed to assess nutritional intakes in relation to performance among ultraendurance cyclists. This observational study included 18 cyclists in a 384-km cycle race. At race registration each cyclist’s support crew was provided with a food diary for their cyclist. On completion of the race, cyclists were asked to recall their race food and drink intakes. All food and fluids were analyzed using a computer software package. Mean (SD) time to complete the race was 16 hr 21 min (2 hr 2 min). Mean (SD) energy intake was 18.7 (8.6) MJ, compared with an estimated energy requirement for the race of 25.5 (7.4) MJ. There was a significant negative relationship between energy intake and time taken to complete the race \( (p = .023, r^2 = -.283) \). Mean (SD) carbohydrate, fat, and protein intakes were 52 (27), 15.84 (56.43), and 2.94 (7.25) g/hr, respectively. Only carbohydrate \( (p = .015, r^2 = -.563) \) and fat \( (p = .037, r^2 = -.494) \) intake were associated with time taken to complete the race. This study demonstrates the difficulties in meeting the high energy demands of ultraendurance cycling. The relationship between energy intake and performance suggests that reducing the energy deficit may be advantageous. Given the high carbohydrate intakes of these athletes, increasing energy intake from fat should be investigated as a means of decreasing energy deficits.

Keywords: energy balance, fat, cycling

Extreme endurance events provide numerous physiological challenges, several of which can be attenuated with optimal nutritional intakes. Much of the previous research has been based on running events (Fallon, Broad, Thompson, & Reull, 1998; Glace, Murphy, & McHugh, 2002) or multistage races (Gabel, Aldous, & Edgington, 1995), during which the provision of carbohydrate and fluid has been seen as the major nutritional indicator of performance. Continuous, longer distance events of more than 10 hr duration are becoming increasingly popular, both in the number of events and the popularity of competing in them. One of the likely challenges is an athlete’s ability to consume sufficient energy to cover the large energy requirements to ensure that performance is not compromised. Energy for such races will be derived from a combination of carbohydrate, protein, and fat. Traditionally, because carbohydrate stores in the body are limited, dietary recommendations have primarily focused on obtaining sufficient amounts of carbohydrate. Inadequate ingestion of carbohydrate could have a negative impact on blood glucose concentrations, placing an athlete’s health at risk. Hypoglycemia has been one of the medical complications among athletes competing in grueling endurance events (Peters, 2003). Blood glucose is maintained during ultraendurance events from hepatic glucose output via glycogenolysis and gluconeogenesis, as well as the ingestion of exogenous glucose. During endurance exercise it has been shown that ingesting 40 g of carbohydrate every hour delays fatigue (American Dietetic Association et al., 2009), and this is supported by the observation that a female athlete completing an ultraendurance run consumed around 44 g of carbohydrate per hour (Moran, Dziedzic, & Cox, 2011). Current recommendations for carbohydrate intake suggest that athletes should ingest 40–75 g/hr during endurance events (Jeukendrup, Jentjens, & Moseley, 2005). This would equal around 640–1,200 kJ/hr and therefore 7,680–14,000 kJ over a 12-hr period. Reported energy expenditure from the limited literature on prolonged continuous endurance exercise has been estimated at 2,780 kJ/hr (Colombani, Mannhart, Wenk, & Frey, 2002). Therefore, based on current guidelines for endurance exercise, energy from exogenous carbohydrate sources would cover only 23–43% of predicted energy requirements. Given that the energy demands of extreme endurance events are so high, obtaining adequate energy per se may limit performance. Therefore, reliance on endogenous fuel stores and other exogenous sources such as fat and protein will be important to prevent large energy deficits that could negatively affect performance.
Previous studies in ultraendurance runners and swimmers have reported large energy deficits during events. These sports differ from cycling, in which access to food and fluid is easier. Therefore, whether the same problems affect cyclists is currently unknown. To date the energy and nutrient intakes of nonelite cyclists taking part in continuous ultraendurance races have not been well documented. It would therefore be of interest to examine these intakes to ascertain which may be limiting endurance performance. Further challenges during these types of events include prolonged exposure to variable or extreme weather conditions, exercising during the nighttime, sleep deprivation, and the need to stop for food or carry all nutritional items during the race. These issues will influence food choice. In addition, compared with elite stage racing described in previous cycling studies, many competitors in these types of sports are amateurs (termed “weekend warriors”) who have limited or no professional nutritional support.

We therefore aimed to assess nutritional intakes in relation to performance among competitors taking part in the K4 cycle race, a 400-km 1-day race that has been described as the toughest 1-day race in the Southern Hemisphere.

Methods

Recruitment of Participants

All 36 competitors in the K4 cycle race received an e-mail from race organizers about the study. Interested individuals contacted the investigators and were provided with more information on the study.

Ethical approval was obtained from the University of Otago ethics committee, and written, informed consent was provided by the 18 study participants (16 men and 2 women). Of the 36 competitors in the K4 cycle race, only 28 finished the race. All 18 participants in the current study successfully completed the race. Because of the large distances covered by the K4 cyclists and the fact that those abandoning the race did not report back to the start/finish line, officially determining the reasons for abandonment by some cyclists was difficult.

The K4 Race

The course for the K4 cycle race follows a 186-km route around the Coromandel Peninsula, New Zealand, for a total distance of 384 km. There are 14 classified climbs covering a vertical ascent of 4,600 m, and the average gradient of the race is 7.5%. The race began at 10 p.m. Riders were permitted to have a support crew for the first lap of the race. For the remaining lap there were six aid stations that provided water, jelly beans, and bananas, and at four of these aid stations an electrolyte sports drink was provided (Balance Nutrition Vitaco, Auckland, New Zealand).

Temperature and relative humidity during the race ranged from 10.6 to 20.4 °C and 65% to 87%, respectively.

Protocol

At race registration all support crews in K4 were provided with a food diary to complete for their cyclists. In addition, on completion of the race cyclists were asked by a trained nutritionist to recall their food and drink intakes during the race. When available, food packaging was obtained from the cyclist. All food and fluids were analyzed using Diet Cruncher (Waydownsouth Software, New Zealand), which references the New Zealand Food Composition database (Marshall, 2003). Additional nutritional information was obtained from the respective manufacturers’ Web sites for specialist food and drink items.

Blood samples were collected and analyzed pre- and postrace using a handheld portable i-STAT analyzer (Abbott Point of Care, Princeton, NJ) for blood glucose concentration. Whole-blood samples were collected from a finger into a plain capillary tube and transferred into a single-use disposable cartridge sample well (CG8+, Abbott Point of Care). The i-STAT analyzer has previously been used with success in sports settings (Erickson & Wilding, 1993; Hsieh, Roth, Davis, Larrabee, & Callaway, 2002); the coefficient of variation was .59%.

Body mass was measured before the start of the race and at the completion of the event on Tanita Innerscan BC-568 scales (Tanita, Kowloon, Hong Kong).

Estimation of Substrate Utilization

To determine an approximation of the energy used during the cycle race the calculations of McCole, Claney, Conte, Anderson, and Hagberg (1990) were used to determine individual energy expenditure based on average race speed and prerace body mass.

Statistical Analysis

All data were tested for normality of distribution using the Kolmogorov–Smirnov test and found to be normally distributed. All data are presented as M (SD). Correlations between performance and substrate ingestion were determined using Pearson’s correlation coefficient, and differences pre- to postrace were determined by paired t tests. Data were analyzed using SPSS for Windows version 16.0 (Chicago, IL). A .95 level of confidence was predetermined to denote statistical significance (p < .05).

Results

The mean time to complete the race was 16 hr 21 min, with a standard deviation of 2 hr 2 min (range 12 hr 49 min to 21 hr 34 min).
From pre- to postrace there was a mean (SD) percentage change in body mass of –0.72% (0.70%), which corresponds to an absolute change of –0.56 (0.57) kg (see Table 1).

The mean (SD) total energy intake of the cyclists was 18.7 (8.6) MJ, with the distribution from carbohydrate, protein, and fat 75.6% (12.0%), 14.5% (9.2%), and 6.1% (6.3%), respectively. The mean energy requirement for the race was estimated at 25.5 (7.4) MJ.

Mean (SD) blood glucose concentration at the start of the race was 6.28 (0.86) mmol/L, and at the end of the race it was 6.28 (1.48) mmol/L (p = 1.000). No cyclists recorded a blood glucose concentration below 4.00 mmol/L at the end of the race, and the largest drop in blood glucose during the race was 3.40 mmol/L. There was no relationship between blood glucose concentration and the time taken to complete the race (p = .830, $r^2 = .003$).

There was a significant negative relationship between energy intake per hour and time taken to complete the race (p = .023, $r^2 = -.283$).

The mean (SD) carbohydrate intake was 823 (348) g. Relative to time, mean (SD) carbohydrate intake was 52 (27) g/hr. There was an inverse relationship between carbohydrate intake per hour and time taken to complete the race (p = .015, $r^2 = -.563$). This was also seen when body mass was taken into account (p = .034, $r^2 = -.253$).

Mean (SD) fat intake during the race was 72.12 (79.80) g, or 15.84 (56.43) g/hr. The amount of fat consumed per hour was inversely related to the time taken to complete the race (p = .037, $r^2 = -.494$). The major sources of fat ingested during the race were fruitcakes, cookies, and cereal bars (see Table 2).

Mean (SD) protein intake was 2.94 (7.25) g/hr. Unlike the other macronutrients the amount of protein ingested per hour was not related to the time taken to complete the race (p = .181, $r^2 = -.330$). Protein intake during the race mainly came from sports supplements such as meal replacements and sports bars.

Of the 18 cyclists, 14 consumed commercially available sports drinks. The other 4 consumed cola, other soda, water, and coffee. Only 1 cyclist reported consuming additional caffeine in the form of pills (No-Doz), with 3 participants recording that they ingested electrolyte tablets (Endurolytes, Hammer Nutrition). All participants reported consuming some type of supplement during the race. Two of the 18 cyclists followed a gluten-free diet. Table 2 provides a list of the most commonly consumed food and drinks.

At the end of the race 2 participants reported having swollen hands or feet, 2 reported having a headache, and 1 reported feeling nauseous and light-headed.

### Table 1: Body Mass Pre- and Postrace, Height, and Age of the 18 Participants Who Completed the Race

<table>
<thead>
<tr>
<th>Category</th>
<th>M (SD)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass pre-race (kg)</td>
<td>79.08 (11.86)</td>
<td>63–100</td>
</tr>
<tr>
<td>Body mass postrace (kg)</td>
<td>77.47 (11.31)</td>
<td>62.6–98.80</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>176 (6)</td>
<td>166–185</td>
</tr>
<tr>
<td>Age (years)</td>
<td>45 (14)</td>
<td>30–74</td>
</tr>
</tbody>
</table>

### Table 2: Number of Participants Consuming Common Food and Drink Items

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sports drinks</td>
<td>Balance, Powerade, homemade, Hammer Perpetuem, Leppin Enduro Booster</td>
<td>13</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Lollies/jelly sweets</td>
<td>Aeroplanes, jelly beans, snakes</td>
<td>9</td>
</tr>
<tr>
<td>Carbohydrate gel</td>
<td>Leppin Squeezy, Hammer Gels, Peak Fuel</td>
<td>8</td>
</tr>
<tr>
<td>Cereal bars</td>
<td>Homemade, supermarket brand</td>
<td>8</td>
</tr>
<tr>
<td>Sandwiches</td>
<td>Cheese, jam, peanut butter</td>
<td>8</td>
</tr>
<tr>
<td>Banana</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Caffeine drinks</td>
<td>Coffee, cola (flat)</td>
<td>6</td>
</tr>
<tr>
<td>Cake</td>
<td>Fruit, banana</td>
<td>3</td>
</tr>
</tbody>
</table>

### Discussion

This study demonstrates the difficulties in meeting the high energy demands of continuous ultraendurance cycling. The large energy deficit faced by athletes in this study highlights the need for specific nutritional recommendations for these types of events to optimize energy intake. The mean estimated energy requirement for this event was 25.5 MJ, and mean intake was 18.7 MJ, indicating an average deficit of around 7 MJ. It is not uncommon to see energy intakes that are less than half the energy demands of ultraendurance races (Colombani et al., 2002; Kimber, Ross, Mason, & Speedy, 2002). Because energy deficit was positively correlated with time taken to complete the race, dietary strategies to increase energy intakes are important.

The mean energy intake among the cyclists competing in the K4 race was lower (3.9 MJ) than that recently reported during a 244-km multisport race during which participants were exercising for a similar period of time (Colombani et al., 2002). It should be noted that some of this energy deficit may be a result of cyclists or their support crew failing to report their entire intake during the race. However, researchers who were trained in dietary assessment were responsible for checking the completed food records and conducting the diet recalls, so errors were minimized. The negative correlation between time taken to complete the race and energy intake probably
reflects the delay in the onset of fatigue in those consuming the largest amount of energy per hour. The onset of fatigue would also be affected by prerace nutrition, in particular muscle and liver glycogen levels. However, because of the distances participants traveled to the race and the recruitment of some athletes at the race briefing, we were unable to obtain dietary information for before the race. During the race, most of the ingested energy was derived from carbohydrates (75%). The carbohydrate intake of 52 g/hr is slightly below the optimal amount to sustain a high carbohydrate-oxidation rate (1.0–1.5 g/min; Jeukendrup &entjens, 2000). The intake of 52 g/hr corresponds to an intake of 10.65 g/kg relative to body mass, which is within the recommended range for extremely prolonged and intense exercise (Hawley, 1998).

The importance of carbohydrate intake for performance is shown by a significant negative correlation between carbohydrate intake and the time taken to complete the race. A relationship between carbohydrate intake and race performance was also seen by Havemann and Goedecke (2008) and Kimber et al. (2002). This suggests that those consuming the most carbohydrate relative to body mass, per hour of exercise, were best able to conserve their muscle and liver glycogen stores for the latter stages of the race, with exogenous carbohydrate sources being used for a greater proportion of the race. However, even with this relatively large intake of carbohydrate, the energy deficit was large and correlated with performance. Therefore, the intake of other macronutrients such as fat and protein could be increased to help cover the large energy demands of this type of sporting event. Greater reliance on these substrates may spare the limited carbohydrate stores in the body, thus delaying the onset of fatigue. Some previous research has shown that increasing the fat content of the diet of endurance athletes does not adversely affect performance. Such a regimen has been successfully adopted by ultraendurance rowers (Brown, 2002). In the current study fat contributed only 14% of energy intake, with fat ingestion negatively correlated with time to complete the race. Given the relatively large intakes of carbohydrate and yet the persisting energy deficit, one option could include the manipulation of the diet whereby energy derived from fat is increased without compromising carbohydrate intake.

Protein intakes during the race averaged 67 g, which corresponds to a mean intake of 2.94 g/hr. This is higher than the reported intakes among Ironman triathletes (Kimber et al., 2002) and probably reflects the longer duration of the K4. During a multisport race of a similar duration, protein intakes relative to body mass were similar to those seen during the K4. The major protein sources were meal-replacement formulas (Ensure nutrition shake, Abbott Nutrition, Columbus, OH, and Hammer Perpetuem, Hammer Nutrition, Napier, New Zealand) and sports bars (PowerBar performance, PowerBar, Victoria, Australia), with 1 participant consuming tuna pasta bake. Although protein ingestion during shorter exercise periods has not been conclusively shown to improve performance, in ultraendurance racing the effects of ingesting protein during the race are yet to be determined. In the current study, of all the macronutrients, protein was the only one to show no relationship with performance.

Most of the ingested carbohydrate was derived from sports foods. Seventy-seven percent of the cyclists reported using a sports drink during the race, with the remainder preferring to drink cola, juice, or water. Other sources of carbohydrate included lollies, fruitcake, and sandwiches. All the participants reported ingesting some form of sports or caffeine supplement such as carbohydrate gels, No-Doz, electrolyte tablets, and sports bars. This is similar to findings of Havemann and Goedecke (2008), who found that 98% of participants used sports supplements during an ultraendurance cycle race. A wide variety of foods and supplements were consumed during the race with no gastrointestinal distress reported. This is probably because of the prolonged nature of the race, whereby periods of low-intensity exercise enabled greater food choice. Providing a variety of foods for ultraendurance athletes may enhance energy intake, because sensory-specific satiety is less likely to occur. The sustained exposure to sweet carbohydrate-containing food and beverages can decrease the desire to eat and drink these types of products and potentially exacerbate energy deficit (Moran et al., 2011).

The prevalence of individuals with celiac disease and thus following a gluten-free diet is thought to be 1 in 200 for the general population, and there are others who make a lifestyle decision to follow a gluten-free diet despite not being diagnosed with an allergy to gluten (Kumar, 2003). It is therefore not surprising that 2 of the 18 cyclists in the K4 race followed a gluten-free diet. Consuming only gluten-free foods during such events adds a further complication to nutritional demands, because many food items designed for endurance athletes contain gluten. The prevalence of athletes currently following a gluten-free diet is not known, but this study suggests that there is probably a group of athletes for whom this would affect nutritional intakes during training and racing. This is a group of athletes with specific nutritional needs that are not currently being met by the sports-food industry.

In conclusion, this study demonstrates the large energy deficits experienced by ultraendurance cyclists during a continuous event. The relationship between energy intake and performance suggests that reducing the energy deficit may be an advantage. In addition, carbohydrate and fat intakes were also positively associated with performance, highlighting their importance to exercise performance. Given the already high carbohydrate intakes of this group of athletes, energy from other sources may need to be investigated. This group of cyclists did not intuitively choose food sources rich in fat and protein to help cover their large energy needs. This may be because they are more familiar with the recommendation to consume high-carbohydrate foods for endurance sports. However, during prolonged continuous endurance exercise that lasts longer than 10 hr, different
dietary regimens with an emphasis on carbohydrate but including all macronutrients may need to be designed. An increase in the intake of fat and protein may supplement carbohydrate intake and thus reduce the energy deficit.

References


International Journal of Sport Nutrition and Exercise Metabolism, 18(6), 551–566.


