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CASE STUDY

Competition Nutrition Practices of Elite Ultramarathon Runners

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Anecdotal claims have suggested that an increasing number of ultramarathoners purposely undertake chronic low-carbohydrate (CHO) ketogenic diets while training, and race with very low CHO intakes, as a way to maximize fat oxidation and improve performance. However, very little empirical evidence exists on specific fueling strategies that elite ultramarathoners undertake to maximize race performance. The study's purpose was to characterize race nutrition habits of elite ultramarathon runners. Three veteran male ultrarunners (*M* ± *SD*; age 35 ± 2 years; mass 59.5 ± 1.7 kg; 16.7 ± 2.5 hr 100-mi. best times) agreed to complete a competition-specific nutrition intake questionnaire for 100-mi. races. Verbal and visual instructions were used to instruct the athletes on portion sizes and confirm dietary intake. Throughout 2014, the athletes competed in 16 ultramarathons with a total of 8 wins, including the prestigious Western States Endurance Run 100-miler (14.9 hr). The average prerace breakfast contained 70 ± 16 g CHO, 29 ± 20 g protein, and 21 ± 8 g fat. Athletes consumed an average of 1,162 ± 250 g of CHO (71 ± 20g/hr), with minor fat and protein intakes, resulting in caloric intakes totaling 5,530 ± 1,673 kcals (333 ± 105 kcals/hr) with 93% of calories coming from commercial products. Athletes also reported consuming 912 ± 322 mg of caffeine and 6.9 ± 2.4 g of sodium. Despite having limited professional nutritional input into their fueling approaches, all athletes practiced fueling strategies that maximize CHO intake and are congruent with contemporary evidence-based recommendations.

Keywords: ultramarathon, nutrition, carbohydrate, calories, fueling

In 1924–1925, the first series of prolonged exercise performance studies (Boston Marathon) concluded that "exhaustion, weakness, shock and other symptoms of hypoglycemia following prolonged effort may be prevented by the adequate and timely ingestion of carbohydrate" (p. 509, Gordon et al., 1925). Since then, numerous studies have confirmed these findings, including a recent systematic review that found 82% of investigations (n = 50 studies) demonstrated statistically greater endurance performance or capacity with carbohydrate (CHO) intake when compared with water alone (Stellingwerff & Cox, 2014). In support, and contrary to what some believe, the few studies that have directly measured substrate oxidation over prolonged intense endurance exercise (~2.5–5 hr) in well-trained nonfat adapted subjects have shown these exercise durations to be very CHO dominant (>70% of total energy expenditure [EE] when consuming CHO (Bosch et al., 1990; Jeukendrup et al., 2006; O'Brien et al., 1993; Stellingwerff et al., 2007).

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Nevertheless, recent reviews have hypothesized that increasing numbers of ultramarathoners purposely undertake chronic low-CHO ketogenic diets to maximize fat oxidation, allowing them to race with very low CHO intakes and with the hope of improving ultraendurance performance by preventing glycogen depletion (Noakes et al., 2014; Volek et al., 2015). Although this ketogenic ultraendurance performance hypothesis is intriguing, these reviews have not cited empirical evidence that supports the performance-enhancing claims of ketogenic diets or low-CHO fueling strategies in ultraendurance athletes.

Published data on fueling intake strategies of elite ultramarathoners (*elite* meaning athletes with performances that would allow for wins) are limited. Of the published studies on ultramarathoner (>50 km) nutritional intake, the subjects of only six can be considered elite (Fallon et al., 1998; Rontoyannis et al., 1989; Sengoku et al., 2015). Therefore, the primary purpose of the case studies in this article was to characterize the nutrition habits of three very elite ultramarathoners (162 km or 100 mi.) in competition. A secondary purpose was to use heart rate and GPS data of one ultramarathoner to estimate his caloric and substrate utilization over a 100-km race.

Background and Athletes

Ultramarathoner Characteristics

Each elite veteran ultramarathoner (n = 3 men, 35.3 ± 1.5 years old with 22.3 ± 4.2 years of running experience; all data reported as M ± SD) competed in five or six ultramarathons in 2014 (>50 km), winning nearly half of those entered (Table 1). These ultramarathoners are truly world class as proven by their personal bests and recent accolades, including 2014 Western States Endurance Run and Leadville 100-mi. winners, 2014 International Association of Ultrarunners 100-km world champion, and 2013 and 2014 North American Ultra Runner of the Year, as voted by *Ultrarunning Magazine*. Each athlete has read, approved, and provided written permission for this publication, which conforms to the principle approval for case studies within the *International Journal of Sports Nutrition and Exercise Metabolism* by the Ethics Committee of the Australian Institute of Sport.

Nutritional Intake Assessments

All three ultramarathoners followed unique programs, training in different locations. Each had limited professional nutritional guidance for their race-day fueling practices, other than periodic and brief input from the author to two of the athletes. These case studies focused exclusively on nutritional intakes of ultramarathoners. Athletes were given a questionnaire featuring both specific and open-ended questions and instructions on how to report competition dietary intakes. Part of the current study's questionnaire came from a standardized competition nutrition intake and assessment questionnaire that has been used and described previously (Pfeiffer et al., 2009, 2012). Considerable correspondence (athlete contacted several times with verbal and visual instruction) was used to educate and confirm dietary intake. On completion of analysis, when necessary, further correspondence was used to verify data entries against the original records provided by the athlete. All data were collected within several months of each race, which is lengthier than normal for nutrition recall, but all athletes stressed their confidence in the data given the standardized approach they take to their nutrition race plans. The nutrition intakes of all three athletes were collected during one of the following races: the 100-mi. Western States Endurance Run (first and fourth places) in the California Sierra Nevada Mountains (5,513 m of ascent; June 28–29; 2014 temperatures: 0 °C–31.7 °C) or the Hardrock 100-miler (fourth place) in Colorado's San Juan Mountain Range (average elevation 3,400 m; 10,360 m of ascent; July 11–12; 2014 temperatures: 8 °C –22 °C). For the 100-mi. Western States Endurance Run, accurate body weight data were collected by another research team using methods described elsewhere (Hoffman & Stuempfle, 2015).

Calculations of Caloric Expenditure and Substrate Oxidation Over a 100-Kilometer Ultramarathon

Ultramarathoner 2 also participated in the 2014 International Association of Ultrarunners 100-km World Championships in Doha, Qatar. The race was run on 5-km loops (aid station every loop), with the athlete's GPS and heart rate (HR) data being uploaded to http://www.strava.com/activities/221733067. From these data,

Table 1 Anthropometric, Training, and Performance History Characteristics of Three Elite Ultramarathon Runners

Parameter	*M* ± *SD*
Age	35.3 ± 1.5
Body weight (kg)	59.5 ± 1.7
Height (cm)	171.7 ± 3.2
Years of running	22.3 ± 4.2
Years doing ultras (>50 km)	5.0 ± 2.6
No. of ultras in 2014 (>50 km)	5.3 ± 0.6
No. of ultra wins in 2014 (>50 km)	2.7 ± 0.6
Low-volume training week	117.3 ± 18.5
High-volume training week	173.3 ± 23.1
Half marathon PB	1:06:44 ± 4:03
Marathon PB	2:23:09 ± 7:38
50-km PB	3:12:20 ± 9:18
100-mi. PB	16:42:27 ± 2:27:17
HR throughout 100-mi. ultra	126.0 ± 8.5

Note. All race times reported as hr:min:s; *SD* reported as min:s. HR = heart rate; PB = personal best; ultra = ultramarathon.

caloric expenditure and substrate fuel utilization estimates for each of the 20 × 5-km loops were calculated. First, submaximal exercise EE was predicted from HR data (Keytel et al., 2005), and an exercise intensity estimate (% VO_{2max}) based on the strong linear relationship (r = .97) between increasing HR and percentage of maximal oxygen uptake (Arts & Kuipers, 1994) was calculated per 5-km loop. Given the plethora of oxidation data across varying exercise intensities (van Loon et al., 2001), coupled with CHO intake data on substrate oxidation during prolonged (3-hr) submaximal exercise (Stellingwerff et al., 2007), robust estimations of exogenous and endogenous substrate utilization were then made, considering that this athlete was neither ketogenic nor fat adapted (thus, average fat oxidation was ~0.6 g/min). Estimations were further refined by labeled CHO intake oxidation data over 5 hr of ultraendurance exercise (Jeukendrup et al., 2006), with estimations of endogenous fuel stores (muscle–liver glycogen) taken from Rapoport (2010).

Ultramarathon Nutrition Intake Strategies

Training and Fueling Preparation

Beyond running, athletes conducted varying types of endurance training (e.g., trekking, ski touring, and cycling). They reported low to high weekly running volumes of 117 ± 19–173 ± 23 km/week, respectively, with much of the weekly running occurring over several single long runs. Athletes periodically practiced their race-day fueling plans in an opportunistic, rather than strategic or structured, fashion. As one athlete stated, "It's difficult to truly practice race-day nutrition because 100 mi. [162 km] is a long way and I max out at 30 mi. [~48 km] in training." Conversely, another athlete indicated, "I will do two or three test nutrition runs in the month going into the event, and I will also test my [nutrition] plan out in preparation races."

Reported 100-Mile Ultramarathon Dietary Intakes

Table 2 outlines the athletes' caloric, macronutrient, caffeine, and sodium intakes on race day. The prerace breakfast (~1–3 hr prerace) featured 70 ± 16 g of CHO, 29 ± 20 g of protein, and 21 ± 8 g of fat. Throughout their respective 100-mi. races, athletes consumed 1,162 ± 250 g of CHO (71 ± 20 g/hr), with minimal fat and protein intake. Total caloric intake was 5,530 ± 1,673 kcals (333 ± 105 kcals/hr). Athletes also consumed 912 ± 322 mg of caffeine and 6.9 ± 2.4 g of sodium, and two athletes consumed 12.5 g and 4.2 g, respectively, of ginger throughout their races (Table 2). Overall, commercial products accounted for 93 ± 12% of energy intake. CHO came primarily from sports drinks, gels, candies, and commercial colas. However, one athlete did mention increasing contributions of real food into his fueling plan: "I increasingly use and experiment with real food for races over 12 hours, and I do try and take in a bit of protein and fat. This largely comes down to trying to avoid flavor fatigue." A second athlete noted "at crewed aid stations, I also picked up ~1 oz salted chocolate covered almonds. They are an easy way to get some calories and protein in, especially later in the race when gels become less and less appealing." Accurate data on body mass throughout the race were collected for Ultramarathoners 2 and 3 respectively: 61.5 and 61.6 kg, dropping to 58.2 and 58.2 kg at the finish, a 5.1% and 5.8% body weight loss.

Estimation of Caloric Expenditure and Substrate Oxidation in an Ultramarathoner Over 100 Kilometers

On November 22, 2014, Ultramarathoner 2 won the International Association of Ultrarunners 100-km World Championships in Doha, Qatar, in 6:27:43 (a North American record). The athlete consumed a total of 1,800 kcals, 100% from commercial CHO gels, for an average of 58 g CHO/hr during racing. Average HR was 150 ± 5 beats/min, which he reported as "higher than normal" (most likely due to hot weather: 25–27 °C; 60% humidity). This resulted in an average predicted race %VO_{2max} intensity of 74.9 ± 2.4% (athlete reported HR_{max} of 188). This athlete demonstrated an impressively even pacing (M = 3:51 min/km, with a SD of only 5.4 s; Figure 1A). His estimated % CHO oxidation contribution to total EE was highest over the first 40 km (81%–83% of total EE) and progressively decreased to 68% throughout the race (Figure 1A). This high estimated rate of CHO oxidation coincided with the greatest estimated use of muscle glycogen (~1.4–1.8 g/min over the first 40 km). His estimated average fat oxidation was 0.62 ± 0.12 g/min. Estimates of total EE were 5,411 kcals, of which the largest contributor to EE was muscle glycogen utilization (Figure 1B). The predicted use of muscle glycogen was 1,920 kcals, which was less than the theoretical estimation for maximal muscle glycogen storage for an athlete of this weight (1,987 kcals; Rapoport, 2010).

Discussion

These case studies provide rare data and insight into the competition fueling practices of three of the world's best ultramarathoners. The major finding was that all three athletes practice nutrition strategies that provide high CHO availability throughout their races. Furthermore, substrate oxidation estimates demonstrated a very CHO- versus fat-dominant race performance while winning the 100-km World Championships.

Race-Day Nutrition Intakes

All athletes self-selected fueling strategies providing high CHO availability (71 ± 20 g CHO/hr) to fuel their impressive ultrarace performances. This CHO intake rate aligns with contemporary recommendations (~40–110 g CHO/hr) for the duration and intensity of their exer-

Table 2 Reported 100-Mile (~160-Kilometer) Race Caloric Intakes for Three Elite Ultramarathon Runners

Parameter	Athlete 1	Athlete 2	Athlete 3	*M* ± *SD*
100-mi. PB (hr)	19.50	15.73	14.88	16.70 ± 2.46
No. of aid stations	14	24	24	21 ± 6
Caloric intake metrics				
Total caloric intake (kcals)	6,442	3,600	6,549	5,530 ± 1,673
Calories/hr (kcals/hr)	330	228	440	333 ± 105
CHO intake metrics				
Total CHO intake (g)	1,189	900	1,398	1,162 ± 250
CHO/hr (g)	61	57	94	71 ± 20
CHO/aid station (g)	85	41	64	63 ± 22
Estimated % CHO solution	9.1	8.4	18.7	12.1 ± 5.8
CAFF intake metrics				
Total CAFF intake (mg)	850	1,260	625	912 ± 322
CAFF/hr (mg)	44	80	42	55 ± 22
CAFF/BW/hr (mg/kg/hr)	0.75	1.20	0.72	0.9 ± 0.27
CAFF/aid station (mg)	61	57	28	49 ± 18
Sodium intake metrics				
Total sodium intake (mg)	5,250	9,691	5,780	6,907 ± 2,426
Sodium/hr (mg)	269	616	388	426 ± 176
Sodium/aid station (mg)	375	441	263	359 ± 90
Other				
Total ginger intake (g)	12.5	0.0	4.2	5.6 ± 6.4
% intake as commercial products	80	100	100	93 ± 12

Note. BW = body weight; CAFF = caffeine; CHO = carbohydrate; PB = personal best.

cise (Jeukendrup, 2011; Stellingwerff & Cox, 2014). When comparing this CHO intake rate with previously published ultramarathon data, an interesting pattern emerges. Of the nine studies measuring nonelite or amateur ultramarathon finisher dietary intakes (n = 82 subjects), the average CHO intake rate was only 41 g/hr (Eden & Abernethy, 1994; Glace et al., 2002a, 2002b; Moran et al., 2011; Noakes et al., 1988; Stuempfle et al., 2011, 2013). Conversely, in the elite ultramarathon data (n = 6 athletes), the average was much higher at 61 g CHO/hr (Fallon et al., 1998; Rontoyannis et al., 1989; Sengoku et al., 2015). This 20-g CHO/hr can quickly result in large energy and CHO deficits (~330–550 g CHO or 1,300–2,200 kcals over 15–25 hr of racing). This finding is supported by previous nutrition intake data in triathletes, which found a significant positive correlation between CHO intake rate and performance in an Ironman race (Pfeiffer et al., 2012). Whether elite ultraendurance athletes are partially successful as a result of their fueling intakes or whether they would be successful regardless cannot be ascertained from current data. However, the plethora of placebo-controlled double-blind positive CHO and endurance performance studies have suggested that the athletes' success is at least partially due to their fueling (high CHO) strategies (Jeukendrup, 2011; Stellingwerff & Cox, 2014). In further support of success due to a high CHO fueling strategy, Yannis Kouros, considered to be the best ultrarunner of all time (every world record from 100 to 1,000 miles), averaged an impressive 96 g CHO/hr of racing over a 5-day 960-km race (96% of energy intake as CHO totaling 13,340 g of CHO consumed; Rontoyannis et al., 1989).

In the current case studies, two ultramarathoners also consumed significant amounts of ginger to help keep the stomach settled. Ginger has a long history with considerable clinical evidence in the prevention of nausea, dizziness, and vomiting symptoms, especially involving motion sickness (Langner et al., 1998). Interestingly, given that the prevalence of gastrointestinal (GI) distress is 30%–80% in ultraendurance event participants (Hoffman & Fogard, 2011; Pfeiffer et al., 2012; Stuempfle et al., 2013), the two athletes using ginger had no serious GI side effects. Ginger consumption could perhaps be an effective intervention to minimize exercise-induced GI issues, although this author is unaware of data to support this.

The athletes in these case studies relied on individualized trial-and-error and personal experiences to develop and execute their competition fueling interventions. Each

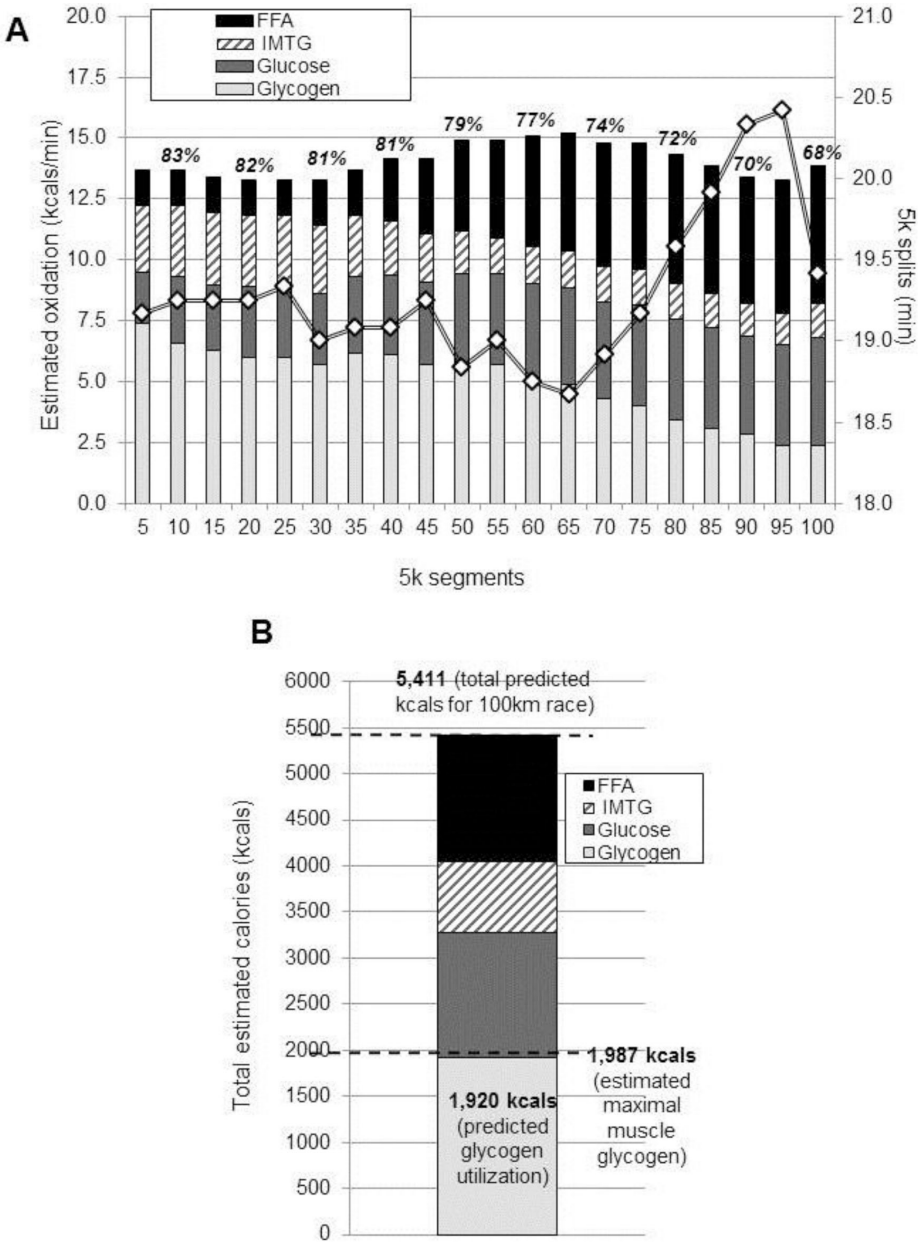

Figure 1 — (A) Running 5-km splits (line; minutes) and estimated oxidation of exogenous and endogenous substrates and % carbohydrate oxidation (bars) and (B) total estimated caloric and substrate requirements of elite Ultramarathoner 2 while winning the 100-km World Championships. FFA = free fatty acids; IMTG = intramyocellular triglycerides; kcals = nutritional calories.

ultramarathoner highlighted the necessity for in-race flexibility in nutrition intake to adjust to specific race circumstances (e.g., weather, altitude, GI tolerance, tactics).

Predicted Carbohydrate Dominance to Fuel Performance

Oxidation estimates for Ultrarunner 2 demonstrated a very CHO-dominant race performance while winning the 100-km World Championships. In this race, he ran for approximately 6.5 hr at an estimated 74% of VO_{2max}, which resulted in a predicted 74.9 ± 2.4% CHO oxidation contribution to total EE. This predicted % VO_{2max} intensity extrapolates and aligns well with previous directly measured data (O'Brien et al., 1993; Rontoyannis et al., 1989; Sengoku et al., 2015). Furthermore, his 58 g CHO/hr intake was enough to allow him to finish with a very small amount of muscle glycogen left (as predicted in Figure 1B). The fact that he won the race with a significant increase in speed over the final 5-km segment (Figure 1A) also supports this predicted postrace muscle glycogen level. Mechanistically, it has long been

known that CHO-dominant oxidation is more efficient and economical than fat oxidation (Krogh & Lindhard, 1920). In fact, just shifting the respiratory quotient from 0.90 (~66% CHO oxidation) to 0.95 (~83% CHO) will theoretically improve 2-hr elite marathon performance, as a result of improved economy, by 60–90 s (Andrew Jones, unpublished calculations, 2014 presentation). Finally, significant fat adaptation has been shown to downregulate CHO metabolism and actually compromise higher intensity performance (Burke & Kiens, 2006).

In conclusion, these world-class ultrarunners practice fueling strategies that maximize CHO intake for optimal race performances. Despite having limited professional nutritional input into their fueling approaches, all athletes' individual intakes for CHO and sodium were congruent with contemporary evidence-based recommendations.

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