

## Race-Day Carbohydrate Intakes of Elite Triathletes Contesting Olympic-Distance Triathlon Events

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The aim of this study was to investigate the prerace and during-race carbohydrate intakes of elite-level triathletes contesting draft-legal Olympic-distance triathlon (ODT) events. Self-reported prerace and during-race nutrition data were collected at 3 separate ODT events from 51 elite senior and under-23 triathletes. One hundred twenty-nine observations of food and fluid intake representing actual prerace ( $n = 62$ ) and during-race ( $n = 67$ ) nutrition practices from 36 male and 15 female triathletes were used in the final analysis of this study. Female triathletes consumed significantly more carbohydrate on the morning before race start when corrected for body mass and race start time than their male counterparts ( $p < .05$ ). Male and female triathletes consumed 26% more energy (kJ/kg) and 24% more carbohydrate (g/kg) when commencing a race after midday (1:00–1:30 p.m.) than for a late morning (11:00–11:15 a.m.) race start. During the race, triathletes consumed less than 60 g of carbohydrate on 66% of occasions, with average total race intakes of  $48 \pm 25$  and  $49 \pm 25$  g carbohydrate for men and women, respectively. Given average race times of 1:57:07 hr and 2:08:12 hr, hourly carbohydrate intakes were  $\sim 25$  g and  $\sim 23$  g for men and women, respectively. Although most elite ODT triathletes consume sufficient carbohydrate to meet recommended prerace carbohydrate intake guidelines, during-race carbohydrate intakes varied considerably, with many failing to meet recommended levels.

**Keywords:** competition, carbohydrate guidelines, nutrient intakes

Triathlon events are held over a variety of distances. The four most common events are sprint (750-m swim, 20-km bike, 5-km run), Olympic (1.5-km swim, 40-km bike, 10-km run), 70.3 (1.9-km swim, 90-km bike, 21.1-km run), and Ironman (3.8-km swim, 180-km bike, 42.2-km marathon run) races. Event finishing times range from 50 to 60 min for sprint-distance triathlons to 8–17 hr for Ironman triathlon events. This range in race duration has significant physiological and nutritional implications for triathletes, which in turn influence race-day dietary practices.

Elite triathletes contest Olympic-distance triathlon (ODT) events according to the regulations set by the International Triathlon Union in a “draft-legal” format that permits competitors to ride in the slipstream of other triathletes during the cycling portion of the race. Typical race times for top finishers are approximately 1 hr 45 min to 2 hr 5 min depending on gender (men are typically  $\sim 10$  min faster than women), the environmental conditions, terrain of the cycle and run segments, and race tactics adopted by competitors.

Athletes who compete in endurance events longer than 90 min are actively encouraged to plan a preexer-

cise meal and consume carbohydrate during exercise (Rodriguez, DiMarco, & Langley, 2009). Guidelines for a preexercise meal or snack recommend that athletes consume 1–4 g carbohydrate/kg body mass 1–4 hr before exercise (Burke, Cox, Cummings, & Desbrow, 2001). Some sport nutrition experts encourage rates of carbohydrate ingestion during prolonged activities based on observations of maximal rates of exogenous carbohydrate oxidation. For example, Jeukendrup and Jentjens (2000) recommend that endurance athletes consume 1.0–1.1 g carbohydrate/min, or 60–70 g/hr. However, most official guidelines for endurance activities typically encompass a range of carbohydrate intakes starting at about 50% of this rate (e.g., 30–60 g carbohydrate/hr; Coyle, 2004; Mora-Rodriguez, Del Coso, Aguado-Jimenez, & Estevez, 2007; American College of Sports Medicine [ACSM] et al., 2007) in recognition that benefits can be seen at lower intakes (Maughan, Bethell, & Leiper, 1996).

The literature is limited on how well these guidelines are incorporated into race-day fueling practices by elite triathletes. An early study investigating the nutritional habits of elite male triathletes found that only 2 of 25 reported consuming a carbohydrate-rich meal on the morning of competition (Burke & Read, 1987). Furthermore, participants reported drinking sugary (carbohydrate) fluids only during longer triathlon events (70.3 events and longer). Kimber, Ross, Mason, and Speedy (2002) assessed food and fluid intakes of 18 triathletes competing in the 1997 New Zealand Ironman triathlon.

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Hourly carbohydrate intake was higher during the cycle,  $1.5 \pm 0.6 \text{ g} \cdot \text{kg}^{-1} \cdot \text{hr}^{-1}$  and  $1.2 \pm 0.3 \text{ g} \cdot \text{kg}^{-1} \cdot \text{hr}^{-1}$  for men and women, respectively, than the run,  $0.6 \pm 0.2 \text{ g} \cdot \text{kg}^{-1} \cdot \text{hr}^{-1}$ ,  $p < .001$ , and  $0.8 \pm 0.3 \text{ g} \cdot \text{kg}^{-1} \cdot \text{hr}^{-1}$ ,  $p < .05$ ). Of interest, a positive relationship was observed for total carbohydrate intake and cycle carbohydrate intake with finishing time for female triathletes, whereas run carbohydrate intake relative to body weight and time showed a negative relationship with finishing time for men.

To date, little is known about the precompetition race-day and during-race nutrition intakes of elite-level (professional) triathletes contesting draft-legal ODT events. Athletes in these events face an increased possibility of gastrointestinal discomfort or distress associated with the ingestion of carbohydrate before or during exercise (Davis, Burgess, Slentz, Bartoli, & Pate, 1988; Rehrer, van Kemenade, Meester, Brouns, & Saris, 1992; Sullivan, 1988; Wagenmakers, Brouns, Saris, & Halliday, 1993). In addition, the lack of opportunities to consume carbohydrate-containing fluids (i.e., sports drink) or foods (i.e., sports gel or sports bar) while exercising (Jeukendrup, Jentjens, & Moseley, 2005) may prevent triathletes from meeting suggested recommendations for carbohydrate before or during a race. This may be particularly evident in draft-legal ODT events, in which nutrition strategies during the cycling leg are likely influenced by race tactics rather than the discretion of the individual athlete. Therefore, the purpose of this study was to investigate race-day prerace and during-race dietary intakes of food and fluid by male and female elite level triathletes contesting draft-legal ODT events, with specific interest in determining carbohydrate intakes before and during exercise.

## Methods

Data were collected at three separate ODT events that were part of the official Australian triathlon series. Two of the races were part of the National Accenture Triathlon series, and the third race was an International Triathlon Union World Cup event. The first of the three races doubled as the final selection race for the 2004 Australian Olympic Games triathlon team. Races were held over a 2-month period throughout February and March 2004, in Perth, Western Australia; Devonport, Tasmania; and Mooloolaba, Queensland. Race start times were 11:00 a.m. and 1:30 p.m. in Perth, 11:15 a.m. and 1:00 p.m. in Devonport, and 11:00 a.m. and 1:15 p.m. in Mooloolaba for women and men, respectively. Temperature and humidity were measured at the start of each men's and women's race. Mean race-day temperature and humidity were 28.4 °C and 38.5%, 17.2 °C and 44.0%, and 26.3 °C and 63.0% for Perth, Devonport, and Mooloolaba, respectively.

### Participant Description and Recruitment

We recruited elite senior and under-23 Australian triathletes entered in the previously mentioned races to par-

ticipate in this study. Although contesting elite races, the athletes had varied experience in racing ODT events. No attempt was made to influence or alter their race nutrition practices throughout the course of this study. Athletes were approached at race briefings on the day before the race. The purpose of the study was briefly explained, and a plain-language statement outlining participant commitments was provided. The study was undertaken with the approval of the Human Research Ethics Committee of the Australian Institute of Sport, and all participants provided their written consent before their involvement in the study.

Fifty-one elite senior and under-23 male and female triathletes contesting the chosen ODT events agreed to participate in this study. A combined total of 129 observations of food and fluid intake representing actual prerace ( $n = 62$ ) and during-race ( $n = 67$ ) nutrition practices from 36 male and 15 female triathletes was used in the final analysis of this study. Forty-five complete sets (observations of both prerace and during-race food and fluid intake) of data were collected across the three races. During-race carbohydrate intakes were included only from participants who completed the race, whereas all observations of prerace food and fluid intake were used in the final dietary analysis regardless of whether the participant completed the race.

### Dietary Collection Methodology

Participants were required to complete a food and fluid diary using household measures on the day of competition. They were instructed to record all food and fluids consumed on the day of the race, before race start. Verbal and written instructions were provided to each participant to ensure that foods were recorded as accurately as possible. Participants were instructed to provide a detailed description of the food, including brand name, packaging, method of preparation, and the quantity (household measures) consumed. On arrival at the race transition area, the food and fluid diary was collected by a sports dietitian (G.C.). The sports dietitian reviewed the diary immediately and clarified any discrepancies with regard to the types and quantities of foods and fluids recorded. All energy-containing foods (i.e., sports gels) and fluids (i.e., sports drink, soft drink) consumed by participants after completed food diaries were collected (i.e., during the warm-up period before race start) were noted and subsequently added to the food diary and included in the analysis of the prerace food and fluid intake. Furthermore, participants were questioned regarding drinks and gels they were likely to consume during the race to accurately determine the carbohydrate content of these items and quantify the amount of carbohydrate carried during the race (cycle and run). Commercial brands and mixing procedures of drinks were noted at this time.

Immediately before the start of the race, participants' drink bottles were taken from the bike racks in the transition area and weighed on portable food scales (Salter Microtronic electronic kitchen scale, Model 2001,

Salter Housewares Ltd., Kent, England) accurate to 2 g. Drink bottles were reweighed at the completion of the race before the athletes were able to consume any further fluid. This information was used to assess during-race intake of carbohydrate provided from sports drinks or other carbohydrate-containing drinks such as soft drinks. The brand and quantity of commercial carbohydrate-containing sports gels intended for consumption during the cycle and run legs were noted before race start, and triathletes were interviewed immediately post-race to determine the amount consumed. Athletes were specifically asked about their during-race fluid and gel intakes to determine whether any carbohydrate-containing fluid consumed (reflected by a change in drink-bottle weight pre- to post-race) was spilled and the complete contents of carbohydrate-containing sports gels consumed. During the run leg, sports gels carried by the triathletes provided the only opportunity for carbohydrate intake, because the race-sponsored aid stations provided water as the sole fluid source.

Total energy (kJ), carbohydrate (g), fat (g), protein (g), and dietary fiber (g) of all foods and fluids described in the prerace food and fluid diaries were estimated using FoodWorks professional edition (version 3.02, © 1998–2005, Xyris Software, Brisbane, Australia). Dietary analysis was performed by a sports dietitian (G.C.). All sport foods and dietary supplements were analyzed according to the manufacturers' specifications as stipulated on the product labels. Food-composition data were compiled from Nuttab 95 (AusFoods, Australian AusNut), and nutritional information from food manufacturers was entered into the standardized Australian Institute of Sport recipe database. On completion of analysis, data entries were verified against the original records provided and written comments noted by the sports dietitian (G.C.) at the time of collection.

## Statistical Analysis

Values are presented as  $M \pm SD$ . Independent  $t$  tests were used to compare body-weight differences and sex. Restricted maximum likelihood method was employed using JMP software (version 7.0.2, SAS Institute, Cary NC, USA) under the analyze/fit model platform. The model allowed comparisons between prerace and during-

race nutrient intakes, with sex, race start times (early or late), and race environmental conditions (warm race conditions in Perth and Mooloolaba and mild conditions in Devonport). Further comparisons were undertaken between during-race carbohydrate intake and carbohydrate carried and between pre- and during-race carbohydrate intakes. Statistical significance was accepted at  $p < .05$ .

## Results

### Participant Characteristics

The participant pool involved high-level athletes including several World Champions at senior, under-23, and junior elite levels. Mean prerace body mass of male triathletes ( $68.6 \pm 5.5$  kg) was significantly higher than that of female triathletes ( $59.3 \pm 6.1$  kg) participating in this study ( $p < .01$ ).

### Prerace and During-Race Dietary Intakes

The results of prerace food and fluid intake nutrient analysis reported by elite male and female Olympic-distance triathletes are summarized in Table 1. Reported prerace intakes reflect all food and fluid consumed on the morning of the race, before the race start, including items consumed during and after the warm-up. When corrected for body mass, there were no differences in energy (kJ/kg), protein (g/kg), fat (g/kg), or fiber (g/kg) of prerace meal and snack intakes between male and female triathletes. Of interest, female triathletes consumed significantly more carbohydrate, when corrected for body-mass differences, than their male counterparts on the morning of the race ( $p < .05$ ).

Figure 1 demonstrates the distribution of prerace carbohydrate intakes expressed relative to body mass (g/kg) reported by male and female triathletes in this study. Typically, triathletes consumed 2.1–3.0 g/kg of carbohydrate during the day, before race start. Two male triathletes consumed less than 1.0 g/kg, despite race start times of 11:15 a.m. or later.

Reported prerace intakes of energy (kJ/kg), carbohydrate (g/kg), and protein (g/kg) were significantly higher ( $p < .05$ ) for late race start times than for early start times

**Table 1 Race-Day Prerace Nutrient-Intake Analysis for Elite Male and Female Triathletes Contesting Olympic-Distance Triathlon Events,  $M \pm SD$ , Range**

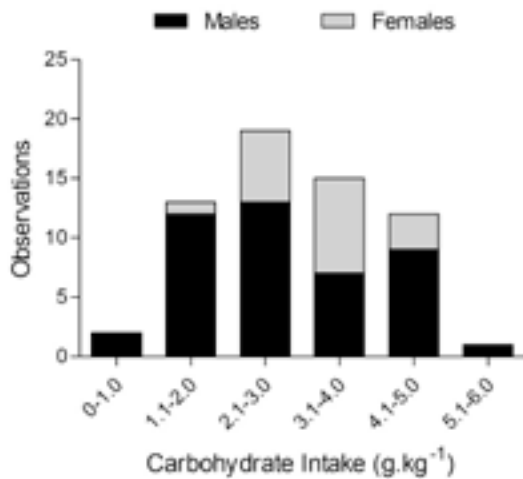
	Energy (kJ/kg BM)	CHO (g)	CHO (g/kg BM)	Fat (g/kg BM)	Protein (g/kg BM)	Fiber (g/kg BM)
Men ( $n = 44$ )	$71 \pm 27$ 18–128	$198 \pm 81$ 60–370	$2.9 \pm 1.2$ 0.9–5.3	$0.3 \pm 0.2$ 0.0–0.9	$0.5 \pm 0.3$ 0.1–1.2	$0.2 \pm 0.1$ 0.1–0.4
Women ( $n = 18$ )	$75 \pm 16$ 40–104	$195 \pm 52$ 102–321	$3.3 \pm 0.8^*$ 1.9–4.9	$0.2 \pm 0.2$ 0.0–0.8	$0.5 \pm 0.2$ 0.2–1.0	$0.2 \pm 0.1$ 0.1–0.4
Combined ( $N = 62$ )	$72 \pm 24$ 18–128	$197 \pm 73$ 60–370	$3.0 \pm 1.1$ 0.9–5.3	$0.3 \pm 0.2$ 0.0–0.9	$0.5 \pm 0.2$ 0.1–1.2	$0.2 \pm 0.1$ 0.1–0.4

Note. BM = body mass; CHO = carbohydrate.

\* $p < .05$ .

(Table 2). Athletes consumed 26% more energy (kJ/kg) and 24% more carbohydrate (g/kg) when commencing a race after midday (1:00–1:30 p.m.) than with a late morning (11:00–11:15 a.m.) race start. No significant differences in fat or fiber intake were noted.

The triathletes commonly reported consuming carbohydrate from sports gels (84% of observations) and drinks (69% of observations) during races. Reported during-race intakes of carbohydrate for male and female triathletes



**Figure 1** — Race-day, prerace carbohydrate intakes (g/kg) for elite male and female triathletes contesting Olympic-distance triathlon events.

are summarized in Table 3. Absolute and relative amounts of carbohydrate consumed from carbohydrate-containing drinks and sports gels during the race are presented. Furthermore, the amount of carbohydrate consumed from the available supplies was analyzed (i.e., the amount of carbohydrate consumed relative to the total carried by the athlete was calculated as a percentage). Seventy-two percent of carbohydrate carried during the race was consumed, which explained 91% of the variance observed in during-race carbohydrate intakes ( $p < .001$ ). No sex differences were observed for during-race carbohydrate intakes, and the amount of carbohydrate consumed during the race was not influenced by prerace carbohydrate intake. However, athletes consumed more carbohydrate ( $p < .05$ ) during races in warm weather conditions ( $53 \pm 25$  g) than in mild weather conditions ( $41 \pm 21$  g). This difference resulted from a greater intake of carbohydrate ( $p < .05$ ) from carbohydrate-containing drinks ( $25 \pm 22$  g and  $14 \pm 17$  g for warm and mild conditions, respectively). During warm-weather races, athletes carried more ( $p < .05$ ) carbohydrate ( $33 \pm 25$  g) from carbohydrate-containing drinks during the cycle than those in the races held in milder environmental conditions ( $19 \pm 19$  g).

Figure 2 demonstrates the distribution of during-race carbohydrate intakes for male and female triathletes in this study. Triathletes consumed less than 30 g of carbohydrate during the race from carbohydrate-containing drinks and sports gels on 25% of observations. One athlete consumed less than 10 g of carbohydrate on two separate occasions.

**Table 2** Race-Day Prerace Nutrient-Intake Analysis for Elite Triathletes Contesting Olympic-Distance Triathlon Events Starting Early (11:00–11:15 a.m.) and Late (1:00–1:30 p.m.),  $M \pm SD$ , Range

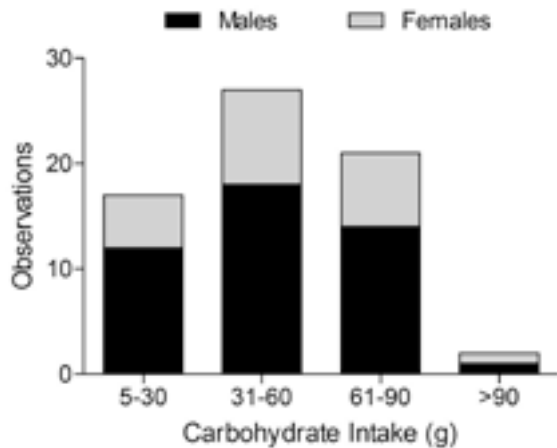
	Energy (kJ/kg BM)	CHO (g)	CHO (g/kg BM)	Fat (g/kg BM)	Protein (g/kg BM)	Fiber (g/kg BM)
Early ( $n = 30$ )	$64 \pm 21$ 18–103	$170 \pm 63$ 60–328	$2.7 \pm 1.0$ 0.9–4.6	$0.3 \pm 0.2$ 0.0–0.8	$0.4 \pm 0.2$ 0.1–1.0	$0.2 \pm 0.1$ 0.1–0.4
Late ( $n = 32$ )	$80 \pm 24^{**}$ 28–128	$222 \pm 75^{**}$ 89–370	$3.3 \pm 1.1^{**}$ 1.4–5.3	$0.4 \pm 0.2$ 0.0–0.9	$0.6 \pm 0.3^*$ 0.1–1.2	$0.2 \pm 0.1$ 0.1–0.4

Note. BM = body mass; CHO = carbohydrate.

\* $p < .05$ . \*\* $p < .01$ .

**Table 3** During-Race Carbohydrate (CHO) Intake for Elite Male and Female Triathletes Contesting Olympic-Distance Triathlon Events,  $M \pm SD$ , Range

	Total CHO consumed (g)	Total CHO carried (g)	Available CHO consumed (%)	CHO consumed from drink (g)	Available drink CHO consumed (%)	CHO consumed from gel (g)	Available gel CHO consumed (%)
Men ( $n = 45$ )	$48 \pm 25$ 5–108	$60 \pm 29$ 12–131	$80 \pm 23$ 23–100	$21 \pm 2$ 0–108	$72 \pm 26$ 14–100	$26 \pm 18$ 0–64	$82 \pm 33$ 0–100
Women ( $n = 22$ )	$49 \pm 25$ 18–118	$64 \pm 33$ 18–142	$81 \pm 20$ 31–100	$19 \pm 19$ 0–64	$77 \pm 16$ 44–91	$30 \pm 16$ 0–64	$83 \pm 26$ 23–100
Combined ( $N = 67$ )	$48 \pm 25$ 5–118	$62 \pm 30$ 12–142	$80 \pm 22$ 23–100	$21 \pm 21$ 0–108	$73 \pm 23$ 14–100	$27 \pm 17$ 0–64	$82 \pm 30$ 0–100



**Figure 2** — During-race carbohydrate intakes (g) for elite male and female triathletes contesting Olympic-distance triathlon events.

## Discussion

This is the first study to report race-day food and fluid intake practices of elite-level triathletes contesting draft-legal ODT events to assess prerace and during-race carbohydrate intakes. Mean prerace carbohydrate intake of male and female triathletes in the current study was approximately 3 g/kg. Observed prerace dietary practices ensured that athletes met current guidelines that encourage them to consume 1–4 g carbohydrate/kg 1–4 hr before exercise (Burke et al., 2001). In addition to scheduling breakfast and a snack throughout the morning before the race, triathletes in this study commonly consumed carbohydrate in the form of sports drinks, energy drinks, or sports gels after their warm-up immediately before the event to add to their prerace carbohydrate intake.

Studies have shown that intake of a substantial amount of carbohydrate (~100–300 g) 2–4 hr before exercise can improve endurance-exercise capacity (Schabort, Bosch, Weltan, & Noakes, 1999; Wright, Sherman, & Dernbach, 1991) and enhance performance of an exercise task undertaken at the end of a standardized endurance protocol (Neufer et al., 1987; Sherman et al., 1989) compared with an overnight fast. These observed benefits are believed to result from an increase in muscle glycogen and/or increase in liver glycogen concentrations (Casey et al., 2000). Given that liver glycogen is substantially reduced after an overnight fast, consuming a carbohydrate-rich meal may increase these reserves and help maintain blood glucose levels throughout exercise (Hargreaves, Hawley, & Jeukendrup, 2004). This is of practical significance to elite triathletes because the introduction of the draft-legal cycling format into elite ODTs has resulted in highly variable workloads during the cycling stages compared with nondrafting events (Bentley, Cox, Green, & Laursen, 2008). Variable-intensity cycling has been shown to elevate carbohydrate oxidation during the

early stages of exercise and increase total plasma glucose oxidation during a prolonged endurance cycling protocol (Palmer, Borghouts, Noakes, & Hawley, 1999; Palmer, Noakes, & Hawley, 1997).

A unique feature of elite ODT racing is that races typically commence around midday. In our study, race start times varied from 11:00 a.m. to 1:30 p.m., which contrasts with start times of age-group and long-course triathlon events, which typically start at 6:00–7:00 a.m. Lindeman (1990) reported that 40% of participants contesting a short-course triathlon (1.3-km swim, 40-km cycle, and 10-km run) that started at 7:30 a.m. omitted breakfast on the morning of the event. By contrast, triathletes in our study had significantly greater intakes of energy and carbohydrate before races scheduled after midday (Table 2). As might be expected, a later race start provided athletes with more time and opportunities to eat; it was typical for athletes in our study to schedule two meals or substantial snacks before afternoon race starts. The observed difference in prerace nutrient intakes between our study and that of Lindeman provides direct support that race start time can influence prerace nutrition habits of athletes contesting endurance competition. Therefore, sport nutrition professionals should consider race start time when interpreting current prerace nutrition guidelines for carbohydrate intake.

Carbohydrate ingestion during endurance exercise (>90 min duration) has been consistently shown to improve exercise capacity and performance in single-modality exercise tasks (Angus, Hargreaves, Dancey, & Febbraio, 2000; Coggan & Coyle, 1987, 1988; Coyle, Coggan, Hemmert, & Ivy, 1986; Coyle et al., 1983; Langenfeld, Seifert, Rudge, & Bucher, 1994; McConell, Klotz, & Hargreaves, 1996; Mitchell et al., 1989; Tsintzas, Liu, Williams, Campbell, & Gaitanos, 1993; Wilber & Moffatt, 1992; Wright et al., 1991). The observed benefits of carbohydrate ingestion during prolonged exercise are most likely a result of the maintenance of blood glucose concentrations and carbohydrate oxidation in the latter stages of exercise (Coggan & Coyle, 1987, 1988; Coyle & Montain, 1992; Mitchell et al., 1989).

Triathletes who participated in this study typically failed to meet the current guidelines for carbohydrate intake during endurance exercise. The American College of Sports Medicine suggests that athletes consume 30–60 g/hr of carbohydrate in events greater than 90 min in duration (ACSM et al., 2007). In 66% of observations, triathletes consumed less than 60 g of carbohydrate during the race, with an average total race intake of  $48 \pm 25$  and  $49 \pm 25$  g for men and women, respectively. Given average race times of 1:57:07 hr and 2:08:12 hr, hourly carbohydrate intakes were ~25 g and ~23 g for men and women, respectively. Despite failing to meet suggested carbohydrate intake guidelines during exercise, athletes in this study typically consumed carbohydrate-containing drinks and sports gels during the event. The more carbohydrate athletes carried during the race, the more they consumed. This finding is in contrast to earlier studies that reported that athletes typically consume only water

during shorter duration triathlon events (Burke & Read, 1987; Lindeman, 1990). Likely explanations for higher during-race carbohydrate intakes among athletes in the current study include a greater awareness of the benefits of consuming carbohydrate during exercise, increased access to sports drinks and sports foods at races, increased popularity of sports gels as an alternative source of carbohydrate to sports drinks, sponsorship arrangements, and promotion of sports drinks and sports foods through various media (i.e., triathlon magazines, Internet, and television commercials).

Athletes contesting long-course triathlon events consume more carbohydrate than was observed in our study. Kimber et al. (2002) reported carbohydrate intakes of  $81.8 \pm 14.9$  and  $62.3 \pm 18.7$  g/hr for male and female Ironman competitors, respectively. Lower rates of carbohydrate ingestion in our study likely reflect the limited time available for carbohydrate ingestion (Jeukendrup et al., 2005), reduced gastrointestinal tolerance at higher intensities of exercise (Bentley et al., 2008), and race nutrition strategies adopted by individual athletes. Whether it would be beneficial to consume more carbohydrate during an ODT event than we observed among our participants cannot be addressed by the design of our study. However, it has previously been shown that carbohydrate intakes below the recommended range can enhance endurance-exercise performance (Maughan et al., 1996). Furthermore, in nonendurance activities lasting ~60 min in which muscle fuel stores are not limiting, there is evidence that consuming very small amounts of carbohydrate—even the use of a carbohydrate mouth wash—can provide benefits to the central nervous system to reduce perception of effort and enhance pacing (Carter, Jeukendrup, & Jones, 2004; Chambers, Bridge, & Jones, 2009). This may have some relevance to a triathlon, in which different activities (swimming, cycling, and running) and muscle groups contribute to the total exercise time and may not be individually limited by fuel availability. In other words, although the ODT fulfills the general criteria of an endurance sport, we are currently uncertain whether it truly fits all the expected nutritional characteristics.

The cycling leg of an ODT event presents the most opportunity for carbohydrate intake and better tolerance for fluid and food (i.e., sports gel) intake than the swim and run. In our study, despite failing to meet hourly carbohydrate intake recommendations during exercise, all triathletes consumed some carbohydrate during the cycle leg. Athletes used carbohydrate-containing drinks (sports drinks) and sports gels routinely during the cycle. In contrast, carbohydrate was consumed during the run in only 20% of observations, in the form of a carbohydrate-containing sports gel. Sports gels were used in 85% of during-race observations by athletes in this study. Athletes relied on them as their only source of carbohydrate in 32% of during-race observations and in combination with sports drinks in 53% of observations. Sports gels provide a compact, reliable carbohydrate alternative to carbohydrate-containing drinks, particularly for athletes who dislike consuming sweet fluids while racing.

In our study, observed carbohydrate intakes in triathletes contesting ODT events held in warm environmental conditions (Mooloolaba and Perth races) were 23% greater than those observed in races in mild conditions (Devonport race). This difference was the result of greater amounts of carbohydrate-containing drinks' being consumed in warm weather conditions. This finding suggests that athletes consume more carbohydrate by virtue of increasing their fluid intake, with no specific intent to increase carbohydrate intake. This is of practical significance to sport nutrition professionals because different strategies need to be implemented and sources of carbohydrate (drinks vs. gels) prioritized when counseling athletes contesting ODT events in varying environmental conditions. Failure to account for environmental conditions when advising athletes on race nutrition strategies will result in markedly different during-race carbohydrate intakes.

A primary finding from the current study was the large variation in the observed prerace and during-race carbohydrate intakes of participating athletes (see Figures 1 and 2). There are several factors that are likely to influence athletes' race-day carbohydrate intake, such as their routine nutrition practices in training, relative experience at racing ODT events, tolerance of food and fluids on race day, organization and access to suitable options, the dynamics of the race and subsequent opportunities for intake, previous experience of gastrointestinal upset while racing, previous nutrition education, and personal perceptions regarding the importance of carbohydrate before and during competition.

Current sport nutrition guidelines encourage endurance athletes to exercise under conditions of high carbohydrate availability by incorporating adequate carbohydrate before and during exercise in daily training and competition (Rodriguez et al., 2009). The findings of this study suggest that ODT athletes typically meet current sport nutrition guidelines for preexercise carbohydrate but fail to meet suggested carbohydrate intake guidelines during actual competition for endurance activity. To determine the significance of these findings for metabolism and performance for endurance-trained athletes, it is important to consider the interaction between preexercise and during-exercise carbohydrate ingestion (Hawley & Burke, 1997). It is possible that consuming carbohydrate during exercise overrides the likely benefits associated with consuming a preexercise carbohydrate meal (Febbraio, Chiu, Angus, Arkinstall, & Hawley, 2000). However, the reverse could also be true; the benefits of a preexercise carbohydrate-containing meal may override the likely benefits associated with consuming carbohydrate during exercise (Beelen, Berghuis, Ballak, Jeukendrup, & van Loon, 2009; Desbrow, Anderson, Barrett, Rao, & Hargreaves, 2004). Findings from this study provide no evidence that athletes adjust their during-race carbohydrate intakes in response to prerace intake of carbohydrate.

In conclusion, athletes in the current study consumed adequate carbohydrate in their preexercise meal to meet

current sport nutrition guidelines, with later timing of the race start appearing to support this practice. However, the findings of this study demonstrate the difficulty faced by athletes in meeting current guidelines for carbohydrate intake during exercise in high-intensity endurance competition, in which opportunities for intake and tolerance of ingesting carbohydrate-containing drinks and sports gels are reduced. Further research is warranted to investigate the possible benefits to performance of consuming higher rates of carbohydrate than observed in this study. Given the challenges triathletes may face in meeting suggested competition nutrition guidelines, they are best advised to seek the assistance of a sport nutrition expert to devise a pre-race and race nutrition strategy to optimize their competition performance.

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