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Cox, Gregory R.; Snow, Rodney J.; Burke, Louise M.

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**Race-day carbohydrate intakes of elite triathletes contesting Olympic Distance
Triathlon events**

Key words: competition, carbohydrate guidelines, nutrient intakes

Gregory R. Cox^{1,2}, Rodney J. Snow², Louise M. Burke¹

¹Department of Sports Nutrition, Australian Institute of Sport, Belconnen, ACT, Australia; ²School of Exercise and Nutrition Sciences, Deakin University, VIC, Australia.

Address for correspondence: Gregory R Cox

Department of Sports Nutrition

Australian Institute of Sport

C/- Queensland Academy of Sport

PO Box 956

Sunnybank

Queensland 4109

AUSTRALIA

Email: greg.cox@ausport.gov.au

Abstract

The aim of this study was to investigate the pre-race and during-race carbohydrate intakes of elite level triathletes contesting draft-legal Olympic Distance Triathlon (ODT) events. Self reported pre-race and during-race nutrition data were collected at three separate ODT events from fifty-one elite senior and Under 23 triathletes. One-hundred and twenty-nine observations of food and fluid intake representing actual pre-race ($n=62$) 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 compared with their male counterparts ($p<0.05$). Male and female triathletes consumed 26% more energy ($\text{kJ}\cdot\text{kg}^{-1}$) and 24% more carbohydrate ($\text{g}\cdot\text{kg}^{-1}$) when commencing a race after mid-day (1.00-1.30pm) compared to a late morning (11.00-11.15am) race start. During the race, triathletes consumed less than 60 g of carbohydrate on 66% of occasions, with an average total race intake of 48 ± 25 g, and 49 ± 25 g carbohydrate for males and females, respectively. Given average race times of 1:57:07 h and 2:08:12 h, hourly carbohydrate intakes were ~ 25 g and ~ 23 g for males and females, respectively. Whilst most elite ODT triathletes consume sufficient carbohydrate to meet recommended pre-race carbohydrate intake guidelines, during-race carbohydrate intakes varied considerably with many failing to meet recommended carbohydrate intakes.

1 **Introduction**

2 Triathlon events are held over a variety of distances; the four most common events are
3 Sprint (750 m swim, 20 km bike, 5 km run), Olympic (1.5 km swim, 40 km bike, 10
4 km run), 70.3 (1.9 km swim, 90 km bike, 21.1 km run) and Ironman (3.8 km swim,
5 180 km bike, 42.2 km marathon run) races. Event finishing times range from 50-60
6 minutes for Sprint distance triathlons through to 8-17 hours for Ironman triathlon
7 events. This range in race duration has significant physiological and nutritional
8 implications for the triathlete, which in turn influences race day dietary practices.

9

10 Elite triathletes contest Olympic Distance Triathlon (ODT) events according to the
11 regulations set by the International Triathlon Union (ITU) in a “draft-legal” format
12 that permits competitors to ride in the slipstream of other triathletes during the cycling
13 portion of the race. Typical race times for top finishers are approximately 1h 45min-
14 2h 05min depending on gender (males are typically ~10 min faster than females), the
15 environmental conditions, terrain of the cycle and run segments, and race tactics
16 adopted by competitors.

17

18 Athletes who compete in endurance events greater than 90 minutes are actively
19 encouraged to plan a pre-exercise meal and consume carbohydrate during exercise
20 (Rodriguez, DiMarco, & Langley, 2009). Guidelines for a pre-exercise meal or snack
21 recommend that athletes consume 1-4 g carbohydrate.kg⁻¹ body mass, 1-4 h before
22 exercise (Burke, Cox, Cummings, & Desbrow, 2001). Some sports nutrition experts
23 encourage rates of carbohydrate ingestion during prolonged activities based on
24 observations of maximal rates of exogenous carbohydrate oxidation; for example,
25 Jeukendrup & Jentjens (2000) recommend that endurance athletes consume 1.0-1.1 g

26 carbohydrate.min⁻¹ or 60-70 g carbohydrate.h⁻¹. However, most official guidelines for
27 endurance activities typically encompass a range of carbohydrate intakes starting at
28 about 50% of this rate [e.g. 30-60 g carbohydrate.h⁻¹] (Coyle, 2004; Mora-Rodriguez,
29 Del Coso, Aguado-Jimenez, & Estevez, 2007; Sawka et al., 2007) in recognition that
30 benefits can be seen at lower intakes (Maughan, Bethell, & Leiper, 1996).

31

32 There is limited literature on how well these guidelines are incorporated into the race-
33 day fuelling practices by elite triathletes. An early study investigating the nutritional
34 habits of elite male triathletes found that only two triathletes (n=25) reported
35 consuming a carbohydrate rich meal on the morning of competition (Burke & Read,
36 1987). Furthermore, subjects reported drinking sugary (carbohydrate) fluids only
37 during longer triathlon events (70.3 events and above). Kimber et al. (2002) assessed
38 food and fluid intakes of 18 triathletes competing in the 1997 New Zealand Ironman
39 triathlon. Hourly carbohydrate intake was higher during the cycle (1.5 ± 0.6 g.kg⁻¹.h⁻¹
40 and 1.2 ± 0.3 g.kg⁻¹.h⁻¹) compared to the run (0.6 ± 0.2 g.kg⁻¹.h⁻¹, $p<0.001$ and 0.8 ± 0.3
41 g.kg⁻¹.h⁻¹ $p<0.05$) for males and females, respectively. Of interest, a positive
42 relationship was observed for total carbohydrate intake and cycle carbohydrate intake
43 with finishing time for female triathletes, whereas run carbohydrate intake relative to
44 body weight and time showed a negative relationship with finishing time for males.

45

46 To date, little is known about the pre-competition race day and race nutrition intakes
47 of elite level (professional) triathletes contesting draft-legal ODT events. Athletes
48 contesting these events face an increased possibility for gastrointestinal discomfort or
49 distress associated with the ingestion of carbohydrate before or during exercise
50 (Davis, Burgess, Slentz, Bartoli, & Pate, 1988; Rehrer, van Kemenade, Meester,

51 Brouns, & Saris, 1992; Sullivan, 1988; Wagenmakers, Brouns, Saris, & Halliday,
52 1993). In addition, the lack of opportunities for consuming carbohydrate containing
53 fluids (i.e. sports drink) or foods (i.e. sports gel or sports bar) while exercising
54 (Jeukendrup, Jentjens, & Moseley, 2005), may prevent triathletes from meeting
55 suggested recommendations for carbohydrate before or during a race. This may be
56 particularly evident in draft-legal ODT events where nutrition strategies during the
57 cycling leg are likely influenced by race tactics rather than the discretion of the
58 individual athlete. Therefore, the purpose of this study was to investigate race day pre-
59 race and during-race dietary intakes of food and fluid by male and female elite level
60 triathletes contesting draft-legal ODT events, with specific interest to determine
61 carbohydrate intakes before and during exercise.

62

63 **Methods**

64 Data were collected at three separate ODT events that were part of the official
65 Australian triathlon series. Two of the races were part of the National Accenture
66 Triathlon series, while the third race was an ITU World Cup event. The first of the
67 three races, doubled as the final selection race for the 2004 Australian Olympic
68 Games Triathlon team. Races were held over a two-month period throughout
69 February and March, 2004, in Perth, Western Australia; Devonport, Tasmania; and
70 Mooloolaba, Queensland. Race start times were 11.00am and 1.30pm in Perth;
71 1.00pm and 11.15am in Devonport; 11.00am and 1.15pm in Mooloolaba for females
72 and males, respectively. Temperature and humidity was measured at the start of each
73 male and female race. Mean race day temperature and humidity were 28.4°C and
74 38.5%; 17.2°C and 44.0%; 26.3°C and 63.0% for Perth, Devonport and Mooloolaba,
75 respectively.

76 ***Description of subjects and subject recruitment process***

77 We recruited elite senior and Under 23 Australian triathletes entered in the
78 abovementioned races to participate in this study. Although contesting elite races,
79 athletes had varied experience in racing ODT events. No attempt was made to
80 influence or alter their race nutrition practices throughout the course of this study.
81 Athletes were approached at race briefings on the day prior to the race. The purpose
82 of the study was briefly explained and a plain language statement outlining subject
83 commitments was provided. The study was undertaken with the approval of the
84 Human Research Ethics Committee of the Australian Institute of Sport and all
85 subjects provided their written consent prior to their involvement in the study.

86
87 Fifty-one elite senior and Under 23 male and female triathletes contesting the chosen
88 ODT events, agreed to participate in this study. A combined total of 129 observations
89 of food and fluid intake representing actual pre-race ($n=62$) and during-race ($n=67$)
90 nutrition practices from 36 male and 15 female triathletes, were used in the final
91 analysis of this study. Forty-five complete sets (observations of both pre-race and
92 during-race food and fluid intake) of data were collected across the three races.
93 During-race carbohydrate intakes were included only from subjects who completed
94 the race, whereas all observations of pre-race food and fluid intake were used in the
95 final dietary analysis regardless if the subject completed the race.

96

97 ***Dietary collection methodology***

98 Subjects were required to complete a food and fluid diary using household measures
99 on the day of competition. Subjects were instructed to record all food and fluids
100 consumed on the day of the race, prior to race start. Verbal and written instructions

101 were provided to each subject to ensure foods were recorded as accurately as possible.
102 Subjects were instructed to provide a detailed description of the food, including brand
103 name, packaging, method of preparation, and the quantity (household measures) of
104 food consumed. On arrival at the race transition area, the food and fluid diary was
105 collected by a Sports Dietitian (GC). The Sports Dietitian reviewed the diary
106 immediately upon collection, and clarified any discrepancies with regards to the types
107 and quantities of foods and fluids recorded. All energy containing foods (i.e. sports
108 gels) and fluids (i.e. sports drink, soda/soft drink) consumed by subjects after
109 completed food diaries were collected (i.e. during the warm-up period before race
110 start), were noted and subsequently added to the food diary and included in the
111 analysis of the pre-race food and fluid intake. Furthermore, subjects were questioned
112 regarding drinks and gels likely to be consumed during the race in order to accurately
113 determine the carbohydrate content of these items and quantify the amount of
114 carbohydrate carried during the race (cycle and run). Commercial brands and mixing
115 procedures of drinks were noted at this time.

116

117 Immediately prior to the start of the race, subjects' drink bottles were taken from the
118 bike racks in the transition area and weighed on portable food scales (Salter
119 Microtronic Electronic Kitchen Scale, Model 2001, Salter Housewares Limited.,
120 Kent, England), accurate to 2 g. Drink bottles were reweighed at the completion of the
121 race before the athletes were able to consume any further fluid. This information was
122 used to assess during-race intake of carbohydrate provided from sports drinks or other
123 carbohydrate-containing drinks such as soda/soft drink. The brand and quantity of
124 commercial carbohydrate-containing sports gels intended for consumption during the
125 cycle and run legs were noted prior to race start, and triathletes were interviewed

126 immediately post-race in order to determine the amount consumed. Athletes were
127 specifically asked about their during-race fluid and gel intakes in order to determine
128 whether any carbohydrate containing fluid consumed (reflected by a change in drink
129 bottle weight pre/post race) was spilt and the complete contents of carbohydrate-
130 containing sports gels consumed. During the run leg, sports gels carried by the
131 triathletes provided the only opportunity for the intake of carbohydrate, since the race-
132 sponsored aid stations provided water as the sole fluid source.

133

134 Total energy (kJ), carbohydrate (g), fat (g), protein (g) and dietary fibre (g) of all
135 foods and fluids described in the pre-race food and fluid diaries were estimated using
136 FoodWorks Professional Edition, Version 3.02, © 1998-2005 (Xyris Software,
137 Brisbane, Australia). Dietary analysis was performed by a Sports Dietitian (GC). All
138 sports foods and dietary supplements were analysed according to the manufacturers'
139 specifications as stipulated on the product labels. Food composition data were
140 compiled from Nuttab 95; AusFoods; Australian AusNut and nutritional information
141 from food manufacturers entered into the standardised Australian Institute of Sport
142 Recipe database. On completion of analysis, data entries were verified against the
143 original records provided and written comments noted by the Sports Dietitian (GC) at
144 the time of collection.

145

146 *Statistical Analysis*

147 Values are presented as mean \pm SD. Independent t-tests were used to compare body
148 weight differences and sex. Restricted maximum likelihood (REML) method was
149 employed using JMP software (Version 7.0.2, SAS Institute, Cary NC, USA) under the
150 Analyse/Fit Model platform. The model allowed comparisons between pre-race and

151 during-race nutrient intakes; with sex, race start times (early or late) and race
152 environmental conditions (Warm race conditions – Perth and Mooloolaba; Mild race
153 conditions – Devonport). Further comparisons were undertaken between during-race
154 carbohydrate intake and carbohydrate carried; and, pre- and during-carbohydrate
155 intakes. Statistical significance was accepted at $p < 0.05$.

156

157 **Results**

158 *Subject Characteristics*

159 Despite the inherent distractions in collecting information immediately prior to a race,
160 the subject pool involved high level athletes including several World Champions at
161 senior, under 23 and junior elite levels. Mean pre-race body mass for male triathletes
162 (68.6 ± 5.5 kg) was significantly higher than that of female triathletes (59.3 ± 6.1 kg)
163 participating in this study ($p < 0.01$).

164

165 *Pre-race and during-race dietary intakes*

166 The results of pre-race food and fluid intakes nutrient analysis (mean \pm SD; range)
167 reported by elite male and female Olympic distance triathletes are summarised in
168 Table 1. Reported pre-race intakes reflect all food and fluid consumed on the morning
169 of the race, prior to the race start, including items consumed during and after the
170 warm-up. When corrected for body mass, no differences existed in energy ($\text{kJ}\cdot\text{kg}^{-1}$),
171 protein ($\text{g}\cdot\text{kg}^{-1}$), fat ($\text{g}\cdot\text{kg}^{-1}$) or fibre ($\text{g}\cdot\text{kg}^{-1}$) of pre-race meal and snack intakes
172 between male and female triathletes. Of interest, female triathletes consumed
173 significantly more carbohydrate when corrected for body mass differences than their
174 male counterparts on the morning of the race ($p < 0.05$).

175

176 Figure 1 demonstrates the distribution of pre-race carbohydrate intakes expressed
177 relative to body mass ($\text{g}\cdot\text{kg}^{-1}$) reported by male and female triathletes in this study.
178 Typically, triathletes consumed between 2.1-3.0 $\text{g}\cdot\text{kg}^{-1}$ of carbohydrate during the day,
179 prior to race start. On two occasions, male triathletes consumed less than 1.0 $\text{g}\cdot\text{kg}^{-1}$,
180 despite race start times of 11.15am or later.

181

182 Reported pre-race intakes of energy ($\text{kJ}\cdot\text{kg}^{-1}$), carbohydrate ($\text{g}\cdot\text{kg}^{-1}$) and protein ($\text{g}\cdot\text{kg}^{-1}$)
183 were significantly higher ($p<0.05$) for late race start times compared with early race
184 start times (Table 2). Athletes consumed 26% more energy ($\text{kJ}\cdot\text{kg}^{-1}$) and 24% more
185 carbohydrate ($\text{g}\cdot\text{kg}^{-1}$) when commencing a race after mid-day (1.00-1.30pm)
186 compared to a late morning (11.00-11.15am) race start. No significant differences in
187 fat or fibre intakes were noted.

188

189 The triathletes commonly reported the consumption of carbohydrate from sports gels
190 (84% of observations) and drinks (69% of observations) during races. Reported
191 during-race intakes of carbohydrate for male and female triathletes are summarised in
192 Table 3 (mean \pm SD; range). Absolute and relative amounts of carbohydrate
193 consumed from carbohydrate-containing drinks and carbohydrate-containing sports
194 gels during the race are presented. Furthermore, the amount of carbohydrate
195 consumed from the available supplies was analysed (i.e. the amount of carbohydrate
196 consumed relative to the total carried by the athlete was calculated as a percentage).
197 Seventy-two percent of carbohydrate carried during the race was consumed, which
198 explained 91% of the variance observed in during-race carbohydrate intakes
199 ($p<0.001$). No sex differences were observed for during-race carbohydrate intakes and
200 the amount of carbohydrate consumed during the race was not influenced by pre-race

201 carbohydrate intake. However, athletes consumed more carbohydrate ($p < 0.05$) during
202 races in warm weather conditions (53 ± 25 g) compared to races in mild weather
203 conditions (41 ± 21 g). This difference was due to a greater intake of carbohydrate
204 ($p < 0.05$) from carbohydrate-containing drinks (25 ± 22 g and 14 ± 17 g for warm and
205 mild conditions, respectively). During warm weather races, athletes carried more
206 ($p < 0.05$) carbohydrate (33 ± 25 g) from carbohydrate-containing drinks during the
207 cycle compared to races held in milder environmental conditions (19 ± 19 g).

208

209 Figure 2 demonstrates the distribution of during-race carbohydrate intakes for male
210 and female triathletes in this study. Triathletes consumed less than 30 g of
211 carbohydrate during the race from carbohydrate containing drinks and sports gels on
212 25% of observations. One athlete consumed less than 10 g of carbohydrate on two
213 separate occasions.

214

215 **Discussion**

216 This is the first study to report race-day food and fluid intake practices of elite level
217 triathletes contesting draft-legal ODT events to assess pre-race and during-race
218 carbohydrate intakes. Mean pre-race carbohydrate intakes of male and female
219 triathletes in the current study were approximately $3 \text{ g} \cdot \text{kg}^{-1}$. Observed pre-race dietary
220 practices ensured athletes met current guidelines, which encourage athletes to
221 consume $1\text{-}4 \text{ g} \text{ carbohydrate} \cdot \text{kg}^{-1}$, $1\text{-}4$ h before exercise (Burke et al., 2001). In
222 addition to scheduling breakfast and a snack throughout the morning before the race,
223 triathletes in this study commonly consumed carbohydrate in the form of sports
224 drinks, energy drinks or sports gels following their warm-up, immediately prior to the
225 event to add to their pre-race carbohydrate intake.

226 Studies have shown that the intake of a substantial amount of carbohydrate (~100-300
227 g) 2-4 h before exercise can improve endurance exercise capacity (Schabort, Bosch,
228 Weltan, & Noakes, 1999; Wright, Sherman, & Dernbach, 1991) and enhance
229 performance of an exercise task undertaken at the end of a standardised endurance
230 protocol (Neufer et al., 1987; Sherman et al., 1989) compared with an overnight fast.
231 These observed benefits are believed to result from an increase in muscle glycogen
232 and/or increase in liver glycogen concentrations (Casey et al., 2000). Given liver
233 glycogen is substantially reduced after an overnight fast, the consumption of a
234 carbohydrate-rich meal may increase these reserves and contribute to maintenance of
235 blood glucose levels throughout exercise (Hargreaves, Hawley, & Jeukendrup, 2004).
236 This is of practical significance to elite triathletes as the introduction of the draft-legal
237 cycling format into elite ODT has resulted in highly variable workloads during the
238 cycling stages compared with non-drafting events (Bentley, Cox, Green, & Laursen,
239 2008). Variable intensity cycling has been shown to elevate carbohydrate oxidation
240 during the early stages of exercise and increase total plasma glucose oxidation during
241 a prolonged endurance cycling protocol (Palmer, Borghouts, Noakes, & Hawley,
242 1999; Palmer, Noakes, & Hawley, 1997).

243

244 A unique feature of elite ODT racing is that race start times typically commence
245 around mid-day. In our study, race start times varied from 11.00am to 1.30pm, which
246 contrasts with start times of age-group and long course triathlon events which are
247 typically 6.00-7.00am. Lindeman (1990) reported that 40% of participants contesting
248 a short-course triathlon (1.3km swim, 40km cycle and 10km run) which started at
249 7.30 am, omitted breakfast on the morning of the event. By contrast, triathletes in our
250 study consumed significantly greater intakes of energy and carbohydrate before races

251 scheduled after mid-day (Table 2). As might be expected, a later race start provided
252 athletes with more time and opportunities to eat; it was typical for athletes in our
253 study to schedule two meals or substantial snacks prior to afternoon race starts. The
254 observed difference in pre-race nutrient intakes between our study and that of
255 Lindeman (1990), provides direct support that race start time can influence pre-race
256 nutrition habits of athletes contesting endurance competition. Therefore, sports
257 nutrition professionals should consider race start time when interpreting current pre-
258 race nutrition guidelines for carbohydrate intake.

259

260 Carbohydrate ingestion during endurance exercise (>90 min duration) has been
261 consistently shown to improve exercise capacity and performance in single modality
262 exercise tasks (Angus, Hargreaves, Dancy, & Febbraio, 2000; Coggan & Coyle,
263 1987, 1988; Coyle, Coggan, Hemmert, & Ivy, 1986; Coyle et al., 1983; Langenfeld,
264 Seifert, Rudge, & Bucher, 1994; McConell, Klotz, & Hargreaves, 1996; Mitchell et
265 al., 1989; Tsintzas, Liu, Williams, Campbell, & Gaitanos, 1993; Wilber & Moffatt,
266 1992; Wright et al., 1991). The observed benefits of carbohydrate ingestion during
267 prolonged exercise are most likely due to the maintenance of blood glucose
268 concentrations and carbohydrate oxidation in the latter stages of exercise (Coggan &
269 Coyle, 1987, 1988; Coyle & Montain, 1992; Mitchell et al., 1989).

270

271 Triathletes who participated in this study typically failed to meet the current
272 guidelines for carbohydrate intake during endurance exercise. The American College
273 of Sports Medicine suggests that athletes consume 30-60 g.h⁻¹ of carbohydrate in
274 events greater than 90 min duration (Sawka et al., 2007). Sixty-six percent of
275 observations, triathletes consumed less than 60 g of carbohydrate during the race, with

276 an average total race intake of 48 ± 25 g carbohydrate and 49 ± 25 g carbohydrate for
277 males and females, respectively. Given average race times of 1:57:07 h and 2:08:12 h,
278 hourly carbohydrate intakes were ~ 25 g and ~ 23 g for males and females,
279 respectively. Despite failing to meet suggested carbohydrate intake guidelines during
280 exercise, athletes in this study typically consumed carbohydrate-containing drinks and
281 sports gels during the event. The more carbohydrate carried during the race, the more
282 athletes consumed. This finding is in contrast to earlier studies which reported that
283 athletes typically consume water only during short (i.e. ODT events) duration
284 triathlon events (Burke & Read, 1987; Lindeman, 1990). Likely explanations for
285 higher during-race carbohydrate intakes amongst athletes in the current study include:
286 a greater awareness of the benefits of consuming carbohydrate during exercise;
287 increased access to sports drinks and sports foods at races; increased popularity of
288 sports gels as an alternate source of carbohydrate to sports drinks; sponsorship
289 arrangements; and, promotion of sports drinks and sports foods through various media
290 avenues (i.e. triathlon magazines, internet, and television commercials).

291
292 Triathletes contesting long course triathlon events consume higher rates of
293 carbohydrate than that observed in our study. Kimber et al (2002) reported
294 carbohydrate intakes of 81.8 ± 14.9 g.h⁻¹ and 62.3 ± 18.7 g.h⁻¹ for male and female
295 Ironman competitors, respectively. Lower rates of carbohydrate ingestion in our
296 study, likely reflect the limited time available for ingestion of carbohydrate
297 (Jeukendrup et al., 2005), reduced gastrointestinal tolerance at higher intensities of
298 exercise (Bentley et al., 2008) and race nutrition strategies adopted by individual
299 athletes. Whether it would be beneficial to consume higher carbohydrate intakes
300 during an ODT event than we observed among our subjects cannot be addressed by

301 the design of our study. However, it has previously been shown that carbohydrate
302 intakes below the recommended range can enhance endurance exercise performance
303 (Maughan et al., 1996). Furthermore, in non-endurance activities lasting ~ 60 mins
304 where muscle fuel stores are not limiting, there is evidence that the consumption of
305 very small amounts of carbohydrate – even the use of a carbohydrate mouth wash-
306 can provide benefits to the central nervous system to reduce the perception of effort
307 and enhance pacing (Carter, Jeukendrup, & Jones, 2004; Chambers, Bridge, & Jones,
308 2009). This may have some relevance to a triathlon where different activities and
309 muscle groups (e.g. swimming, cycling and running) contribute to the total exercise
310 time and may not be individually limited by fuel availability. In other words, although
311 the ODT fulfils the general criteria of an endurance sport, we are presently uncertain
312 whether it truly fits all the expected nutritional characteristics.

313

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

326 In our study, observed carbohydrate intakes from triathletes contesting ODT events
327 held in warm environmental conditions (Mooloolaba and Perth races) were 23%
328 greater than those observed in races contested in mild conditions (Devonport race).
329 This difference was due to greater amounts of carbohydrate-containing drinks being
330 consumed when racing in warm weather conditions. This finding suggests that
331 athletes consume more carbohydrate by virtue of increasing their fluid intake, with no
332 specific intent to increase carbohydrate intake. This is of practical significance to
333 sports nutrition professionals as different strategies need to be implemented, and
334 sources of carbohydrate (drinks versus gels) prioritised when counselling athletes
335 contesting ODT events in varying environmental conditions. Failure to account for
336 environmental conditions when advising athletes with regards to race nutrition
337 strategies will result in markedly different during-race carbohydrate intakes.

338

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

348

349 Current sports nutrition guidelines encourage endurance athletes to exercise under
350 conditions of high carbohydrate availability by incorporating adequate carbohydrate

351 before and during exercise in daily training and competition (Rodriguez et al., 2009).
352 The findings of this study suggest that ODT athletes typically meet current sports
353 nutrition guidelines for pre-exercise carbohydrate, however fail to meet suggested
354 carbohydrate intake guidelines during actual competition for endurance activity. In
355 order to determine the significance of these findings on metabolism and performance
356 for endurance trained athletes, it is important to consider the interaction that exists
357 between pre-exercise carbohydrate feeding and during exercise carbohydrate
358 ingestion (Hawley & Burke, 1997). It is possible that consuming carbohydrate during
359 exercise, overrides the likely benefits associated with consuming a pre-exercise
360 carbohydrate meal (Febbraio, Chiu, Angus, Arkinstall, & Hawley, 2000). However,
361 the reverse could also be true; the benefits of a pre-exercise carbohydrate-containing
362 meal may override the likely benefits associated with consuming carbohydrate during
363 exercise (Beelen, Berghuis, Ballak, Jeukendrup, & van Loon, 2009; Desbrow,
364 Anderson, Barrett, Rao, & Hargreaves, 2004). Findings from this study, provide no
365 evidence that athletes adjust their during-race carbohydrate intakes in response to pre-
366 race intake of carbohydrate.

367

368 In conclusion, athletes in the current study consumed adequate carbohydrate in their
369 pre-exercise meal to meet current sports nutrition guidelines, with the later timing of
370 the race start appearing to support this practice. However, the findings of this study
371 demonstrate the difficulty faced by athletes in meeting current guidelines for
372 carbohydrate intake during exercise in high intensity endurance competition where
373 opportunities for intake and tolerance of ingesting carbohydrate-containing drinks and
374 sports gels are reduced. Further research is warranted to investigate the possible
375 benefits on performance of consuming higher rates of carbohydrate than observed in

376 this study. Given the challenges a triathlete may face in meeting suggested
377 competition nutrition guidelines, athletes are best advised to seek the assistance of a
378 sports nutrition expert in order to devise a pre-race and race nutrition strategy to
379 optimise their competition performance.

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Table 1: Race day, pre-race nutrient intake analysis for elite male and female triathletes contesting Olympic distance triathlon events.

	Energy (kJ/kg BM)	CHO (g)	CHO/BM (g/kg BM)	Fat/BM (g/kg BM)	Protein/BM (g/kg BM)	Fibre/BM (g/kg BM)
<i>Males (n=44)</i>						
Mean ± SD	71 ± 27	198 ± 81	2.9 ± 1.2	0.3 ± 0.2	0.5 ± 0.3	0.2 ± 0.1
Range	18-128	60-370	0.9-5.3	0.0-0.9	0.1-1.2	0.1-0.4
<i>Females (n=18)</i>						
Mean ± SD	75 ± 16	195 ± 52	3.3 ± 0.8*	0.2 ± 0.2	0.5 ± 0.2	0.2 ± 0.1
Range	40-104	102-321	1.9-4.9	0.0-0.8	0.2-1.0	0.1-0.4
<i>Combined (n=62)</i>						
Mean ± SD	72 ± 24	197 ± 73	3.0 ± 1.1	0.3 ± 0.2	0.5 ± 0.2	0.2 ± 0.1
Range	18-128	60-370	0.9-5.3	0.0-0.9	0.1-1.2	0.1-0.4

CHO = carbohydrate; BM = body mass; * p <0.05.

Table 2: Race day, pre-race nutrient intake analysis for elite triathletes, contesting Olympic distance triathlon events starting early (11.00-11.15am) and late (1.00-1.30pm).

	Energy (kJ/kg BM)	CHO (g)	CHO/BM (g/kg BM)	Fat/BM (g/kg BM)	Protein/BM (g/kg BM)	Fibre/BM (g/kg BM)
<i>Early (n=30)</i>						
Mean ± SD	64 ± 21	170 ± 63	2.7 ± 1.0	0.3 ± 0.2	0.4 ± 0.2	0.2 ± 0.1
Range	18-103	60-328	0.9-4.6	0.0-0.8	0.1-1.0	0.1-0.4
<i>Late (n=32)</i>						
Mean ± SD	80 ± 24**	222 ± 75**	3.3 ± 1.1**	0.4 ± 0.2	0.6 ± 0.3*	0.2 ± 0.1
Range	28-128	89-370	1.4-5.3	0.0-0.9	0.1-1.2	0.1-0.4

CHO = carbohydrate; BM = body mass; * p < 0.05; ** p < 0.01.

Table 3: During-race carbohydrate intake for elite male and female triathletes contesting Olympic distance triathlon events.

	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 (%)
Males (n=45)							
Mean ± SD	48 ± 25	60 ± 29	80 ± 23	21 ± 22	72 ± 26	26 ± 18	82 ± 33
Range	5-108	12-131	23-100	0-108	14-100	0-64	0-100
Females (n=22)							
Mean ± SD	49 ± 25	64 ± 33	81 ± 20	19 ± 19	77 ± 16	30 ± 16	83 ± 26
Range	18-118	18-142	31-100	0-64	44-91	0-64	23-100
Combined (n=67)							
Mean ± SD	48 ± 25	62 ± 30	80 ± 22	21 ± 21	73 ± 23	27 ± 17	82 ± 30
Range	5-118	12-142	23-100	0-108	14-100	0-64	0-100

CHO = carbohydrate.

Figure Legends

Figure 1. Race day, pre-race carbohydrate intakes ($\text{g}\cdot\text{kg}^{-1}$) for elite male and female triathletes contesting Olympic distance triathlon events.

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