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Manuscript title: The influence of a 12 per cent carbohydrate-electrolyte beverage on self-paced soccer-specific exercise performance

Running title: Carbohydrates and soccer performance

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1 **Abstract**

2 *Objectives:* To assess the physiological and performance effects of a 12% carbohydrate-electrolyte
3 beverage consumed at practically applicable time-points (i.e., before each half) throughout simulated
4 soccer match-play.

5 *Design:* Randomised, crossover.

6 *Methods:* Fed players ($n=15$) performed 90-min of soccer-specific exercise (including self-paced
7 exercise at the end of each half). Players consumed carbohydrate-electrolyte (CHO; 60 g·500 ml⁻¹,
8 Na⁺ 205 mg·500 ml⁻¹), placebo-electrolyte (PL) or water (Wat) beverages at the end of the warm-up
9 (250 ml) and half-time (250 ml plus ad-libitum water). Blood was drawn before each half and every
10 15-min during exercise. Physical (15-m sprinting, countermovement jumps, self-paced distance,
11 acceleration/deceleration count), technical (dribbling) and cognitive (memory, attention, decision-
12 making) performance was assessed. Ratings of perceived exertion (RPE) and abdominal discomfort
13 were measured.

14 *Results:* Against Wat and PL, CHO increased (all $p<0.05$) mean accelerations $>1.5 \text{ m}\cdot\text{s}^{-2}$ during self-
15 paced exercise ($>+25\%$) and dribbling speed from 60-min onwards ($>+3\%$). Mean sprinting speed
16 improved ($+2.7\%$) in CHO versus Wat. Blood glucose increased before and during each half in CHO
17 versus PL and Wat (all $p<0.05$). A 27% decline in glycaemia occurred at 60-min in CHO. RPE was
18 comparable between trials. Cognition reduced post-exercise ($p<0.05$); this decline was not attenuated
19 by CHO. Abdominal discomfort increased during exercise but was similar between trials.

20 *Conclusions:* Using more realistic fluid ingestion timings than have been examined previously,
21 consuming a 12% carbohydrate-electrolyte beverage increased blood glucose, self-paced exercise
22 performance, and improved dribbling speed in the final 30-min of exercise compared to water and
23 placebo. Carbohydrates did not attenuate post-exercise reductions in cognition.

24

25 *Keywords:* football, skill, sucrose, maltodextrin, isomaltulose

26 **Introduction**

27 Soccer is a high-intensity intermittent sport played over two 45-min periods each separated by a half-
28 time (HT) break. Over 90-min, physical and skilled performance declines throughout the second half
29 ¹⁻³. To sustain glycaemia and fuel provision, and attenuate dehydration, 6-10% carbohydrate-
30 electrolyte beverages are recommended to maintain osmotic balance and attenuate soccer-specific
31 fatigue ^{4, 5}. Indeed, shooting performance was maintained when 6% sucrose-electrolyte beverages
32 were consumed every 15-min (carbohydrate: $\sim 59 \text{ g}\cdot\text{h}^{-1}$) during simulated match-play ¹.

33 Carbohydrate-electrolyte beverages elicit ergogenic effects when consumed regularly throughout
34 intermittent exercise ^{1, 6}. However, fluid intake during competitive soccer seldom occurs as often as
35 has previously been examined (i.e., every 15-min); consumption may only occur during scheduled
36 breaks in play (e.g., HT) ⁷. The final stages of the warm-up and the immediate time-period preceding
37 kick-off are supported empirically as fluid ingestion opportunities on match-day. As few studies have
38 sought to replicate such ingestion patterns, it is unclear whether ergogenic effects of carbohydrate-
39 electrolytes consumed throughout soccer-specific exercise persist when fluid ingestion patterns better
40 reflect competitive demands.

41 Metabolic responses (i.e., blood glucose, carbohydrate and fat oxidation) appear comparable
42 throughout intermittent exercise when equal amounts of carbohydrate ($\sim 68 \text{ g}$ ingested at $\sim 45 \text{ g}\cdot\text{h}^{-1}$) are
43 consumed in two (i.e., before each half) or six (i.e., every 15-min) boluses ⁷. Fewer ingestion
44 opportunities likely make it harder to achieve carbohydrate consumption rates shown to be ergogenic
45 (e.g., $>50 \text{ g}\cdot\text{h}^{-1}$; ^{1, 8}) without also increasing gastro-intestinal distress. Indeed, gut fullness increased
46 when fewer opportunities existed to consume carbohydrate-containing fluids ⁷. Consuming electrolyte
47 beverages that contain increased ($>10\%$) concentrations of carbohydrates may provide a practical
48 strategy for soccer players with limited opportunities to consume beverages before and during match-
49 play.

50 The efficacy of carbohydrate-electrolyte beverages have primarily been examined using prescribed
51 exercise intensities (reviewed in: ^{9, 10}). Compared to actual match-play where players may regulate

52 their activity, omitting self-paced actions may limit the opportunity for self-selection of running
53 speeds in order to preserve peripheral physiological functioning ¹¹. A paucity of research currently
54 exists regarding the efficacy of carbohydrate-electrolyte ingestion using self-paced exercise protocols
55 ¹². Accordingly, on occasions that better reflect competitive practices, this study aimed to provide
56 carbohydrates throughout intermittent activity incorporating self-paced exercise. We hypothesised
57 that ingesting 250 ml of a 12% carbohydrate-electrolyte beverage <15-min before starting each half
58 would improve performance versus the ingestion of equivalent volumes of placebo or water
59 beverages.

60 **Methods**

61 Following ethical approval and informed consent being attained, 15 male University soccer players
62 (body mass: 75.7 ± 7.7 kg, stature: 1.81 ± 0.07 m, age: 22 ± 2 years, estimated $\dot{V}O_{2\max}$: 56 ± 2 ml·kg⁻¹·min⁻¹, >1 year playing experience) completed the study. An additional participant was recruited who
63 did not complete all experimental requirements due to issues unrelated to the study. All players
64 attended preliminary visits ($\dot{V}O_{2\max}$ estimation, procedural habituation) before three main trials
65 (water; WAT, carbohydrate-electrolyte; CHO, placebo-electrolyte; PL, separated by >7 days).
66 Players followed habitual diets (avoiding caffeine) and recorded all food consumed (analysed
67 retrospectively; Nutritics, Nutritics Ltd., Dublin, Ireland) for 48h before trials. Players consumed the
68 same evening meal the night before testing (energy content: 3.5 MJ, 101 g carbohydrates, 34 g fats, 27
69 g proteins) and refrained from strenuous physical activity for 72h before involvement. Environmental
70 conditions were comparable (all $p > 0.05$; temperature: $17.8 \pm 0.8^\circ\text{C}$, pressure: 1032 ± 23 mmHg,
71 humidity: $37 \pm 5\%$).

72
73 Preliminary trials required voiding before body mass (model 876; Seca Ltd, Birmingham, UK) and
74 stature (Portable Stadiometer; Holtain Ltd, Wales, UK) measurement. A warm-up (~20 min; light
75 aerobic activity, dynamic stretches, soccer skills, 20-m sprints) preceded the multistage fitness test
76 (MSFT) ¹³ where a level score >12 was required for further participation. A second session habituated
77 players with main trial procedures.

78 Players attended the laboratory at ~08:00 following overnight fasting. Urine osmolality (Model 3300
79 Micro-osmometer; Advanced Instruments Inc., Norwood, USA) was assessed on arrival and preceded
80 capillary blood sampling (baseline). At ~08:15, a cereal (Rice Krispies; Kellogg's, UK) and semi-
81 skimmed milk breakfast (~10% daily energy requirement) was consumed before mass and stature
82 measurements. All players drank water (Highland spring; Highland Spring Group, Scotland) with the
83 pre-exercise meal (500 ml).

84 Players remained rested for ~90 min (10:00) until blood was taken (rest). Cognition (~20 min; 10:05–
85 10:25) was assessed (COMPASS; Northumbria University, UK) ¹⁴ and mean speed and accuracy

86 scores (secondary and working memory, attention, and decision-making) and the number of correct
87 and incorrect responses (immediate and delayed word recall) were determined. Thereafter, a
88 standardised warm-up (detailed previously) was performed (10:30). A passive ten-min period
89 preceded blood sampling (pre-exercise) and maximal countermovement jump (CMJ) height was
90 assessed (10:55; OptoJump Next; Microgate SRL, Italy; three repetitions, separated by 10 s of intra-
91 set recovery; CV<4% ¹⁵) before exercise started (11:00). A 15-min passive recovery period (HT)
92 separated two 45-min halves and post-exercise assessments of CMJ height, cognition, hydration status
93 (via urine samples) and body mass preceded a standardised cool down.

94 Players performed 90-min of soccer-specific exercise (modified Soccer Match Simulation; SMS ¹⁶)
95 requiring audio-prescribed (ten blocks) and self-paced (four blocks) activity equally split across two
96 halves. The original SMS is reliable ^{2, 15, 17} and requires various intensities of running, including
97 backwards and sideward movements, over 20-m while performing 15-m sprints (Brower, USA) and
98 18-m ball dribbles. Players dribbled a ball between cones (3-m apart) towards video cameras (DCR-
99 HC96E; Sony Ltd, UK) as fast and precisely as possible. Digitisation (Kinovea version 0.8.15;
100 Kinovea Org., France) yielded speed (time taken to successfully complete) and precision (distance of
101 the ball from each cone) data with a cone being unsuccessfully negotiated if touched by the ball or not
102 completed in the required direction ¹⁷. Dribbling performance was expressed per 15-min of exercise.

103 Performed at the end of each half, and in modification to the original SMS, self-paced exercise
104 required the same duration and pattern of activity as the audio-prescribed component. Self-paced
105 performance was determined by distance travelled (using calibrated video footage; ICC>0.99,
106 CV<1%) and accelerometry (acceleration/deceleration counts over mutually exclusive
107 thresholds; >1.5 m·s⁻², >2.5 m·s⁻², >3.5 m·s⁻²) via 10 Hz Global Positioning System units (Catapult
108 Sports, Leeds, UK). A barrier separated players exercising in pairs to minimise inadvertent pacing.

109 Capillary blood was drawn at: baseline, rest, pre-exercise, HT, and 15-, 30-, 45-, 60-, 75-, and 90-min
110 of exercise. Blood samples were analysed for lactate and glucose concentrations (Biosen C-Line, EKF
111 Diagnostics, Germany). Urine-corrected mass changes and environmental conditions (ETHG-912;

112 Oregon Scientific, USA) were determined pre- and post-exercise. Heart rate (HR) was continuously
113 recorded (Polar RS400; Polar, Finland). Abdominal discomfort ¹⁸ and ratings of perceived exertion
114 (RPE; 6-20) values ¹⁹ were obtained every 15-min.

115 Players consumed a carbohydrate-electrolyte (CHO), a flavour-matched placebo-electrolyte (PL) or a
116 water (Wat) beverage in a cross-over fashion. Randomisation (www.randomization.com) was
117 performed independently with researchers who recruited players being unaware of the allocated
118 product sequence (concealed allocation). The CHO and PL beverages were ready-to-drink
119 formulations (PepsiCo International Ltd., USA) matched for sweetness, containing comparable
120 amounts of Na⁺ (41 mg·100 ml⁻¹), and were administered double-blind. The Wat beverage contained
121 Na⁺ (0.56 mg·100 ml⁻¹). Beverages were ingested towards the end of the warm-up (250 ml) and at HT
122 (250 ml); both <15-min before each half commenced. The CHO drink was a 12% solution delivering
123 60 g of carbohydrate per 500 ml from a blend of sucrose, maltodextrin and isomaltulose. Boluses of
124 250 ml of CHO were chosen according to empirical observations and pilot testing. PLA was non-
125 caloric and taste-matched using artificial sweeteners. In trial one, water was consumed ad-libitum at
126 HT (611±265 ml) and volumes were subsequently replicated. When asked, 33% of players correctly
127 identified the CHO trial.

128 Statistical analysis was carried out using SPSS software (Version 21.0; SPSS Inc., IL). Results are
129 reported as mean ± standard deviation (SD). Performance data (e.g., 15-m sprint times) represents a
130 capture rate of 99.2%; the mean value of available data at the corresponding time-point replaced any
131 missed data. Statistical significance was set at p<0.05. A two-way repeated measures analysis of
132 variance established significant main effects in physiological and performance responses due to trial
133 (time x trial interaction effects) and/or time (timing effects). Significant main effects of condition
134 (trial effects) are only presented in cases where interaction effects are absent. Mauchly's test was
135 consulted and Greenhouse–Geisser correction applied if the assumption of sphericity was violated.
136 Partial eta-squared (η^2) values were calculated and LSD corrected post-hoc tests highlighted between-
137 trial differences. Retrospective power analyses (G*Power v3.1.9.2; Universität Düsseldorf, Germany)
138 highlighted that >80% statistical power existed for differences in blood glucose concentrations.

139 **Results**

140 Players arrived following similar ($p>0.05$) nutritional intakes (total energy: 8277 ± 1809 kJ·d⁻¹,
141 carbohydrates: 248 ± 52 g·d⁻¹, proteins: 85 ± 34 g·d⁻¹, fats: 76 ± 26 g·d⁻¹) and mean (156 ± 8 beats·min⁻¹)
142 and peak (176 ± 9 beats·min⁻¹) HR was comparable between trials ($p>0.05$).

143 Trial ($p<0.001$, $\eta^2=0.442$) and time ($p<0.001$, $\eta^2=0.494$) influenced blood glucose concentrations
144 (Figure 1A). Compared to PL, CHO raised blood glucose at pre-exercise, HT and 75-min (all $p<0.05$).
145 Relative to Wat, CHO elevated blood glucose at pre-exercise, HT, 45- and 60-min (all $p<0.05$).
146 Despite a 27% drop from HT values, blood glucose at 60-min was greater in CHO versus Wat
147 ($p=0.038$) but not PL ($p=0.125$). No differences existed between PL and Wat.

148 ***** INSERT FIGURE 1 NEAR HERE *****

149 Blood lactate concentrations increased ($p<0.001$, $\eta^2=0.781$) but were similar between trials ($p=0.228$,
150 $\eta^2=0.090$). A main condition effect ($p=0.021$, $\eta^2=0.240$; Figure 1B) indicated that blood lactate values
151 in PL were lower than CHO ($p=0.020$) and Wat ($p=0.044$). No differences existed between CHO and
152 PL ($p=0.505$).

153 Urine osmolality reduced pre- to post-exercise (826 ± 181 mOsmol·kg⁻¹ vs. 490 ± 205 mOsmol·kg⁻¹;
154 $p<0.001$, $\eta^2=0.807$) but was not affected by trial ($p=0.219$, $\eta^2=0.103$). Body mass loss was comparable
155 ($p=0.429$, $\eta^2=0.059$) across trials (1.6 ± 0.3 kg, $2.2\pm0.3\%$). Although abdominal discomfort (Figure 1C)
156 increased ($p<0.001$, $\eta^2=0.418$), no trial effects occurred ($p=0.166$, $\eta^2=0.094$). Similarly, RPE (Figure
157 1D) was comparable between trials ($p=0.684$, $\eta^2=0.050$). Values increased from 0-15-min ($p<0.001$,
158 $\eta^2=0.674$).

159 Sprint speed (Figure 2A) reduced ($p<0.001$, $\eta^2=0.650$) similarly across trials ($p=0.924$, $\eta^2=0.031$).
160 However, condition effects highlighted that 15-m sprints were fastest ($p=0.002$, $\eta^2=0.365$) for CHO
161 versus Wat ($+2.7\%$, $p=0.004$) but not PL ($p=0.078$). Mean 15-m sprint speeds were also faster in PL
162 versus Wat ($p=0.018$). Mean CMJ height (33.7 ± 5.0 cm) was not influenced by trial ($p=0.257$,
163 $\eta^2=0.093$) or time ($p=0.060$, $\eta^2=0.231$).

164

***** INSERT FIGURE 2 NEAR HERE *****

165 Self-paced distance covered decreased by 15-m in the second half (1428±31-m vs. 1413±45-m;
166 $p=0.010$, $\eta^2=0.388$). Although comparable ($p=0.142$, $\eta^2=0.130$), the between-half decrements
167 observed in PL (-18-m) and Wat (-26-m), appeared attenuated by CHO (+1-m). The number of self-
168 paced accelerations >1.5 , >2.5 and >3.5 $m \cdot s^{-2}$ were not affected by trial (all $p>0.05$) or time (all
169 $p>0.05$); being, 7 ± 4 , 2 ± 2 , 1 ± 2 , respectively. A main condition effect highlighted that CHO increased
170 the mean number of self-paced accelerations >1.5 $m \cdot s^{-2}$ (9 ± 4 , $p=0.027$, $\eta^2=0.227$) versus PL (7 ± 4)
171 and Wat (6 ± 4) by +25% ($p=0.038$) and +36% ($p=0.029$), respectively. No differences existed between
172 Wat and PL ($p=0.481$) for the mean number of self-paced accelerations >1.5 $m \cdot s^{-2}$. The number of
173 self-paced decelerations >1.5 , >2.5 and >3.5 $m \cdot s^{-2}$ were unaffected by trial (all $p>0.05$) or time (all
174 $p>0.05$); being, 6 ± 4 , 1 ± 1 , 1 ± 1 , respectively.

175 Dribbling speed varied according to trial ($p=0.042$, $\eta^2=0.154$) and time ($p=0.008$, $\eta^2=0.252$).
176 Dribbling speeds were similar between PL and WAT (all $p>0.05$), but CHO improved dribbling speed
177 from 60-min onwards versus both PL and Wat ($p<0.040$; Figure 2B). Trial did not influence dribbling
178 precision ($p=0.597$, $\eta^2=0.056$) and success ($p=0.055$, $\eta^2=0.117$) but timing throughout exercise did
179 ($p=0.048$, $\eta^2=0.163$; $p=0.033$, $\eta^2=0.156$, respectively); dribbles at 75-90-min were ~8% more accurate
180 versus 0-15-min (38 ± 6 cm; $p=0.011$) and 6% more successful ($p=0.008$) than 60-75-min ($91 \pm 11\%$).

181 Table 1 presents the cognition data. Reaction times in choice decision making, numeric working
182 memory, and picture recognition improved post-exercise, but such responses occurred in the context
183 of lower correct answers. The number of correct responses on delayed word recall tasks were also
184 lower post-exercise but cognition was unaffected by drink (all $p>0.05$).

185

***** INSERT TABLE 1 NEAR HERE *****

186 **Discussion**

187 The primary aim of this study was to examine the physiological and performance effects of a 12%
188 carbohydrate-electrolyte drink consumed <15-min before starting each half of soccer-specific
189 exercise. Carbohydrate ingestion improved soccer dribbling speed and self-paced exercise
190 performance versus equivalent volumes of water and placebo. Relative to water, mean 15-m sprints
191 were faster following carbohydrate ingestion. These data support previous observations where
192 beneficial effects of exogenous energy provision result from consuming beverages more frequently
193 than possible in soccer match-play (i.e., every 15-min). This was the first study to investigate the
194 physiological and performance effects of providing appropriate quantities of carbohydrate and
195 electrolytes in a manner which better replicates current practice in competitive soccer.

196 Improved sprinting (speed: +2.7% vs. Wat), soccer dribbling (speed: >+3% vs. Wat and PL) and self-
197 paced exercise (mean number of self-paced accelerations >1.5 m·s⁻²: >+25% vs. Wat and PL)
198 performance occurred throughout CHO; reflecting previous observations when carbohydrate was
199 consumed in beverages ⁶, gels ²⁰, or mouth rinses ¹². Despite improved high-intensity performance in
200 CHO, no between-trial effects were observed for RPE. As RPE is thought to inform team sport pacing
201 strategies ²¹, players could be exercising at higher intensities in CHO but not rating such exercise as
202 being more challenging. The strategy of carbohydrate provision used in this study aligns to current
203 recommendations ⁵ while also employing a logistically feasible feeding pattern.

204 Throughout self-paced exercise, players replicated the activity pattern performed in the audio-
205 prescribed component. Any additional distance above the ~1440-m normally covered throughout two
206 blocks of the SMS would initially have consisted of walking (as three 20-m walks commence each
207 4.5-min exercise block). Such low intensity activity may have muted the manifestation of more
208 substantial between-trial differences in the *extra* self-paced exercise performed; likely explaining the
209 similarity of the overall distances covered. That said, although non-significant, CHO (+1-m) appeared
210 beneficial in attenuating the between-half decrements observed in PL (-18-m) and Wat (-26-m). To

211 contextualise, a between-half difference of 26-m represents a ~1.8% reduction in the ~1440-m
212 distance required by two audio-paced blocks of the SMS.

213 Previous studies report a speed-accuracy trade-off when skills were performed throughout soccer-
214 specific exercise ^{1,2}. Although no effects of CHO on cognition were observed, cognitive indices were
215 impaired by 90-min of soccer-specific exercise (Table 1). As mental fatigue has been implicated in
216 the reduction of soccer-specific performance ²², our findings support that intermittent exercise
217 compromises aspects of technical, physical and cognitive performance even when players follow
218 standard pre-game preparations. Notably, heart rate, sprint speed, body mass changes and blood
219 lactate responses were reflective of match-play and previous studies using the SMS ^{1,2,16}.

220 A 500 ml blend of sucrose, isomaltulose and maltodextrin was consumed in a 12% carbohydrate-
221 electrolyte solution. The influence of each type of carbohydrate cannot be discerned due to the
222 absence of single-source trials. Sports drink formulations often include electrolytes and two or more
223 carbohydrates due to the increased oxidation rates seen when multiple sources (e.g., glucose and
224 fructose) are consumed ²³. Ingesting Na⁺ allows replacement of electrolyte losses occurring in sweat,
225 maintenance of osmotic thirst and a continued drive to drink ²⁴. As dehydration is a candidate
226 mechanism of fatigue in intermittent sprint performance ²⁵, electrolyte differences between the Wat
227 (Na⁺: 0.56 mg·100 ml⁻¹) and CHO and PL (both Na⁺: 41 mg·100 ml⁻¹) beverages may plausibly
228 explain the differences in 15-m sprint speeds observed.

229 While the exact mechanisms are unclear, exogenous energy provision from carbohydrates during
230 exercise improves performance and likely involves maintenance of blood glucose concentrations and
231 carbohydrate oxidation rates, sparing of endogenous glycogen stores and, potentially, stimulation of
232 reward centres via oropharyngeal receptor activation ²⁶. Relative to both Wat and PL, elevated blood
233 glucose concentrations occurred in CHO immediately before, and throughout each 45-min half
234 (Figure 1A). As the brain is primarily reliant on blood glucose concentrations as a fuel for cognition,
235 the increased blood glucose concentrations at 60- and 75-min may offer an explanation for the
236 improved dribbling speed observed ²⁷. Likewise, the absence of between-trial differences in blood

237 glucose concentrations at 90-min may explain the lack of detectable post-exercise cognition effects
238 for CHO. However, in the absence of cerebral glucose measurement, these proposed mechanisms
239 should be interpreted with caution. Nevertheless, this study supports findings of impaired physical,
240 technical and cognitive performance in the latter stages of soccer-specific exercise and the
241 enhancement of selected physical and technical performance markers following carbohydrate
242 supplementation ^{1, 6, 20}.

243 Carbohydrate-electrolyte beverages ingested before and throughout each half of soccer-specific
244 exercise have been shown to elicit transient reductions in glycaemia at 45-60-min which persists for
245 most of the second half ^{1, 6}. This exercise-induced rebound glycaemic response also occurs when
246 carbohydrates in the form a 12% beverage are provided less frequently (i.e., <15-min before
247 commencing each half). This response probably reflects differences between the physiological effects
248 of carbohydrates consumed in passive (i.e., HT; insulin secretion attempts to normalise blood glucose
249 concentrations) versus active (i.e., warm-up; counter-regulatory hormones dampen the insulin
250 response) states combined with post-exercise insulin-independent glucose uptake. Notably, mean
251 glucose concentrations in the second half of CHO exceeded those observed in PL at 75-min; a novel
252 finding versus previous work ^{1, 6}. While the effects of rapid reductions in glycaemia are unclear in
253 team sports, evidence from primarily cycling studies do not support negative effects of rebound
254 hypoglycaemia on physical performance markers ²⁸.

255 **Conclusions**

256 Providing 60 g of carbohydrate via ingestion of a 12% beverage at the end of the warm-up and at half-
257 time (with ad-libitum water intake) improved aspects of dribbling (i.e., speed) and self-paced soccer-
258 specific exercise performance in the latter stages of soccer-specific exercise when compared to
259 equivalent volumes of water and placebo. Further studies which better reflect the drinking practices
260 and timing of carbohydrate intake during competitive soccer are required.

261 **Practical Implications**

- 262 • Soccer-specific exercise impaired physical, technical and cognitive performance despite
263 players starting exercise in a fed state.
- 264 • Drinking 250 ml of a 12% carbohydrate-electrolyte beverage towards the end of the
265 warm-up and at half-time (plus ad-libitum water ingestion), provided a practical hydro-
266 nutritional strategy for soccer players without further compromising abdominal
267 discomfort when compared to water.
- 268 • If carbohydrate-electrolyte beverages are recommended for the purposes of maintaining
269 blood glucose concentrations, practitioners should be cognisant of transient reductions in
270 glycaemia that occurred throughout the initial stages of the second half despite
271 carbohydrate-electrolyte consumption.

272

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279

280 **References**

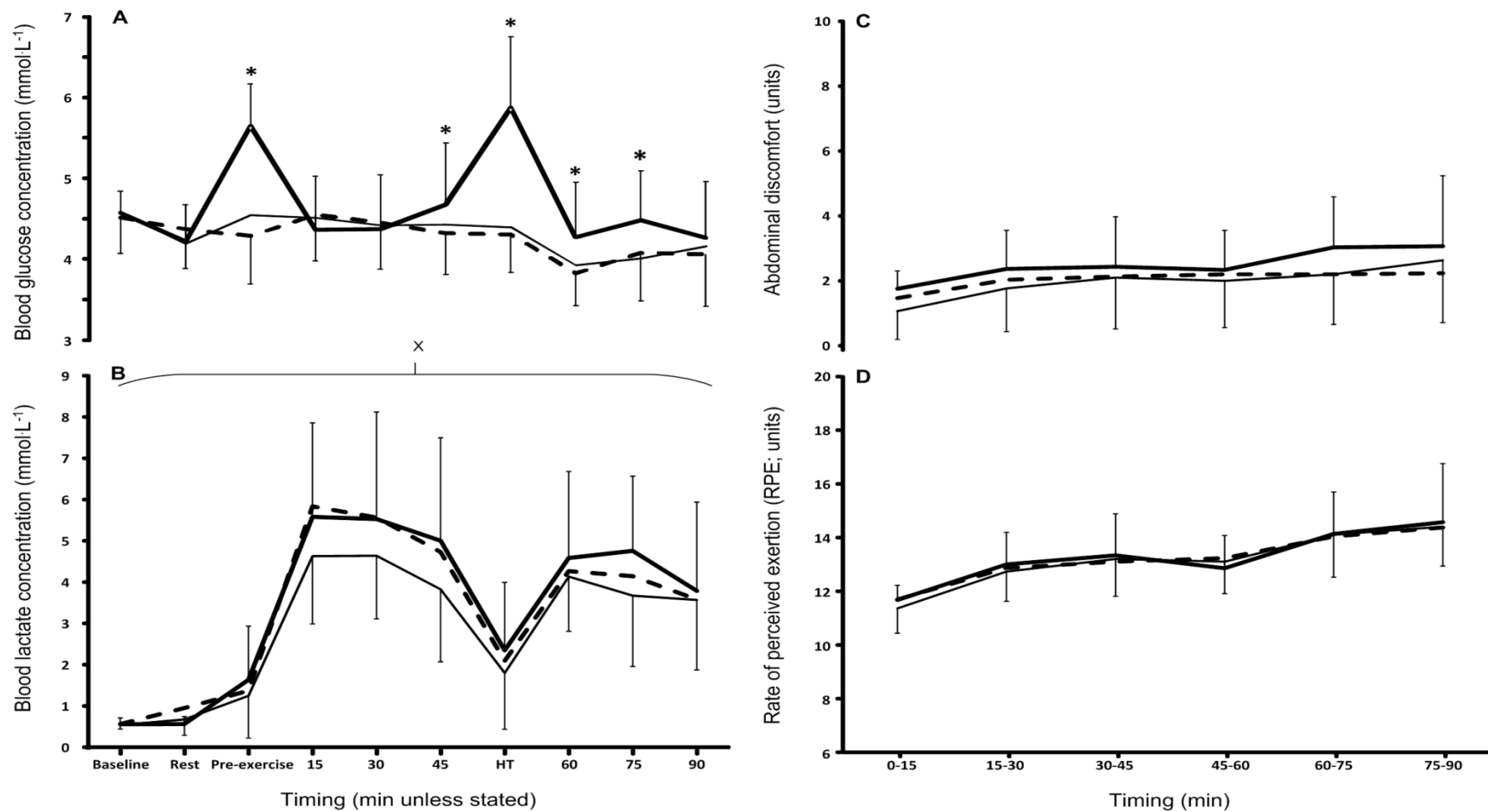
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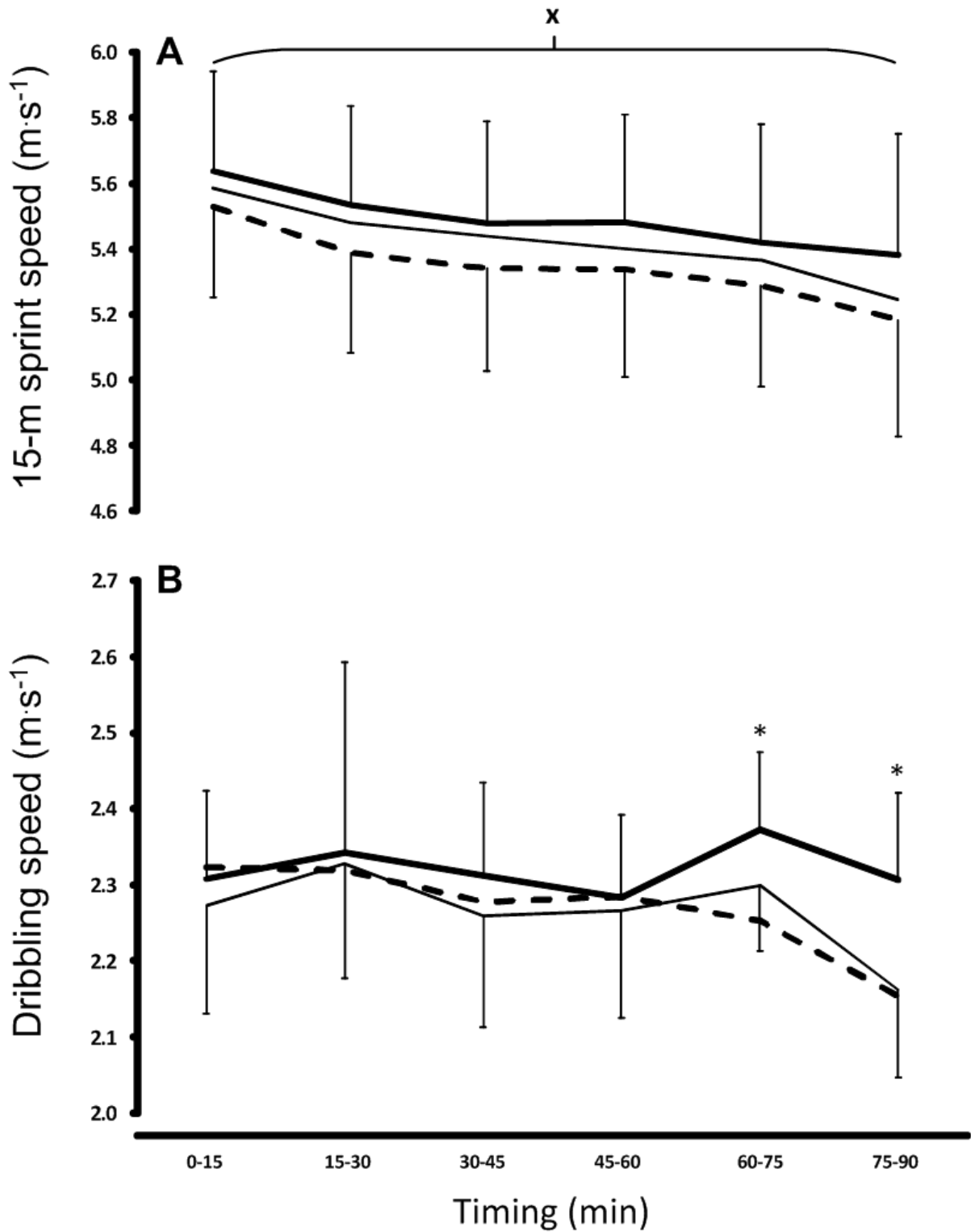
345 Table 1: Cognitive performance (mean \pm SD) throughout carbohydrate-electrolyte (CHO), placebo-electrolyte (PL) and water (Wat) trials. * represents significant time effect

Component	Variable	Trial	Pre-exercise	Post-exercise	Time x trial interaction (p), η^2	Time effect (p), η^2
Choice decision making	% correct	PL	96 \pm 2	95 \pm 4	0.417, 0.061	0.044*, 0.259
		CHO	96 \pm 3	95 \pm 3		
		Wat	97 \pm 3	96 \pm 3		
	Reaction time (ms)	PL	396 \pm 50	379 \pm 39	0.599, 0.027	0.016*, 0.349
		CHO	400 \pm 63	383 \pm 57		
		Wat	399 \pm 42	391 \pm 50		
Rapid visual information processing	% correct	PL	55 \pm 24	50 \pm 23	0.072, 0.171	0.560, 0.025
		CHO	51 \pm 22	54 \pm 21		
		Wat	54 \pm 20	54 \pm 21		
	Reaction time (ms)	PL	498 \pm 37	491 \pm 51	0.244, 0.096	0.091, 0.191
		CHO	515 \pm 62	488 \pm 37		
		Wat	494 \pm 41	487 \pm 37		
Numeric working memory	% correct	PL	96 \pm 3	93 \pm 8	0.471, 0.052	0.037*, 0.274
		CHO	97 \pm 4	94 \pm 7		
		Wat	96 \pm 4	96 \pm 4		
	Reaction time (ms)	PL	891 \pm 224	812 \pm 217	0.912, 0.007	<0.001*, 0.634
		CHO	849 \pm 226	787 \pm 193		
		Wat	877 \pm 244	802 \pm 169		
Picture recognition	% correct	PL	88 \pm 13	87 \pm 12	0.413, 0.061	0.034*, 0.284
		CHO	88 \pm 8	85 \pm 15		
		Wat	90 \pm 10	84 \pm 16		
	Reaction time (ms)	PL	873 \pm 135	837 \pm 154	0.160, 0.123	<0.001*, 0.638
		CHO	928 \pm 208	812 \pm 164		
		Wat	884 \pm 105	820 \pm 106		
Word recognition	% correct	PL	79 \pm 7	77 \pm 8	0.580, 0.038	>0.99, <0.001
		CHO	76 \pm 8	78 \pm 8		
		Wat	77 \pm 10	77 \pm 11		
	Reaction time (ms)	PL	942 \pm 197	855 \pm 173	0.561, 0.040	0.002*, 0.512
		CHO	954 \pm 167	832 \pm 146		
		Wat	1035 \pm 248	885 \pm 168		
Immediate word recall	Number correct	PL	7 \pm 2	7 \pm 2	0.327, 0.077	0.119, 0.165
		CHO	7 \pm 2	6 \pm 3		
		Wat	8 \pm 2	7 \pm 2		
	Number incorrect	PL	1 \pm 1	1 \pm 1	0.622, 0.033	0.622, 0.033
		CHO	1 \pm 1	1 \pm 1		
		Wat	0 \pm 1	1 \pm 1		
Delayed word recall	Number correct	PL	5 \pm 2	5 \pm 2	0.525, 0.045	<0.001*, 0.570
		CHO	5 \pm 2	4 \pm 2		
		Wat	6 \pm 2	4 \pm 2		
	Number incorrect	PL	1 \pm 1	1 \pm 1	0.908, 0.007	0.719, 0.010
		CHO	1 \pm 1	1 \pm 1		
		Wat	1 \pm 1	1 \pm 1		



346

347 Figure 1: Mean \pm SD blood glucose concentrations (A), blood lactate concentrations (B), abdominal discomfort values (C) and rating of perceived exertion
 348 values (D) throughout placebo-electrolyte (PL; thin black line), carbohydrate-electrolyte (CHO; bold black line) and water (Wat; dashed line) trials. *
 349 represents significant between-trial differences at corresponding time-point. X represents main effect of condition. HT represents half-time.



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351 Figure 2: Mean \pm SD 15-m sprint speed (A) and dribbling speed (B) throughout placebo-electrolyte

352 (PL; thin black line), carbohydrate-electrolyte (CHO; bold black line) and water (Wat; dashed line)

353 trials. * represents significant between-trial differences at corresponding time-point. X represents

354 main effect of condition.