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## Sodium Intake Beliefs, Information Sources, and Intended Practices of Endurance Athletes Before and During Exercise

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**Sodium intake beliefs, information sources and intended practices of endurance athletes before and during exercise**

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## 1 **Abstract**

2 There is little information describing how endurance athletes perceive sodium intake in relation to  
3 training and competition. Using an online questionnaire, this study assessed the beliefs, information  
4 sources and intended practices regarding sodium ingestion for training and competition. Endurance  
5 athletes (n= 344) from six English-speaking countries completed the questionnaire and were included  
6 for analysis. The most cited information sources were social supports (63%), self-experimentation  
7 (56%) and media (48%). Respondents generally believed (>50% on electronic Visual Analogue Scale  
8 (VAS)) endurance athletes require additional sodium on a daily basis (median 67% (IQR 40-81%)),  
9 benefit from increased sodium in the days preceding competition (60% (30-77%)), should replace  
10 sodium losses during training (69% (48-83%)) and competition (74% (54-87%)), and would benefit  
11 from sweat composition testing (82% (65-95%)). Respondents generally believed sodium ingestion  
12 during endurance exercise prevents exercise-associated muscle cramps (75% (60-88%)) and exercise-  
13 associated hyponatraemia (74% (62-89%)). The majority (58%) planned to consciously increase  
14 sodium or total food intake (i.e. indirectly increasing sodium intake) in the days preceding  
15 competition. Most (79%) were conscious of sodium intake during competition, but only 29% could  
16 articulate a specific intake plan. A small minority (5%) reported using commercial sweat testing  
17 services, of which 75% believed it was beneficial. We conclude that endurance athletes commonly  
18 perceive sodium intake as important for their sporting activities. Many intend to consciously increase  
19 sodium intake in the days preceding and during competition, although these views appear informed  
20 mostly by non-scientific and/or non-evidence-based sources.

21

22 **Keywords:** Ultra-endurance athletes, sodium intake, hydration status

23

## 24 **Introduction**

25 During endurance exercise, muscular contractions produce heat, resulting in sweating to support  
26 thermoregulation (Sawka et al., 2007). Considering sodium is the most abundant electrolyte present in  
27 sweat, prolonged heavy sweating can cause significant sodium losses (Baker, 2017). Whilst this is  
28 broadly reflected in sport and exercise nutrition guidelines, specific sodium recommendations for  
29 athletes are lacking (Shirreffs & Sawka, 2011; Thomas et al., 2016). Despite this, numerous  
30 businesses offer sweat composition testing, which combined with purpose-built sodium supplements  
31 allow quantifiable sodium replacement. Endurance athletes commonly believe sodium intake  
32 improves performance and prevents health consequences of endurance exercise, including exercise-  
33 associated muscle cramps (EAMC) and exercise-associated hyponatraemia (EAH) (Winger et al.  
34 2011; Winger et al., 2013). Mechanisms cited include enhanced fluid absorption, maintenance of total  
35 body water, plasma volume and circulating sodium concentration (Sawka et al., 2007).

36

37 Despite this theoretical rationale, evidence that sodium replacement during exercise improves  
38 performance is scarce. A recent systematic literature review (SLR) found minimal evidence of  
39 performance benefits from sodium intake during exercise (2-13 h duration), although it was noted the  
40 quality of existing studies were poor (McCubbin & Costa, 2018a). In contrast, pre-exercise sodium  
41 loading (1500-3000 mg ingested 15-45 min prior to exercise stress) appears beneficial to performance  
42 during 1-2 h exercise durations due to expanded plasma volume, resulting in improved  
43 thermoregulation (Coles & Luetkemeier, 2005; Sims et al., 2007). In addition to performance, sodium  
44 replacement during endurance exercise may play a role in the prevention and/or management of  
45 negative exercise-associated health outcomes. The role of sodium in EAMC remains controversial,  
46 although the prevailing view is that neuromuscular fatigue is the more likely cause (Schwellnus,  
47 2009). Sodium intake during exercise can influence serum sodium concentration, although not to the  
48 same extent as fluid intake (Hew-Butler et al., 2015). It has been suggested that significant unreplaced  
49 sodium losses may contribute to asymptomatic (Noakes et al., 2005; Hoffman et al., 2013) and in  
50 some cases symptomatic (Lewis et al., 2018) hypovolaemic EAH, representing a possible rationale for

51 sodium ingestion during prolonged exercise (Hew-Butler et al., 2015). It has also been suggested  
52 sodium losses during ultra-endurance exercise may influence bone mineral content, through sodium  
53 resorption to maintain circulating concentrations (Hew-Butler et al. 2013), although implications for  
54 bone health are yet to be determined.

55

56 Whilst previous studies have investigated beliefs and strategies for sodium ingestion during endurance  
57 events (Costa et al., 2014; Costa et al., 2013; Hoffman & Stuenkel, 2014; Pfeiffer et al., 2012;  
58 Winger et al., 2013), little is known about how endurance athletes perceive the role of sodium in  
59 relation to training, before and after competition. With this in mind, the purpose of this exploratory  
60 study was to observe beliefs, information sources and intended practices of endurance athletes  
61 regarding sodium for training and competition. Based on anecdotal evidence, we hypothesised  
62 endurance athletes would; a) perceive increased daily sodium requirements; b) believe sodium  
63 ingestion during exercise improves endurance performance and reduces EAMC and EAH risk; c) plan  
64 to increase sodium intake 2-3 days before competition, and; d) deliberately ingest foods, fluids and  
65 supplements during competition for their sodium content.

66

## 67 **Methods**

### 68 *Participants*

69 This descriptive, cross sectional study, utilised an online questionnaire developed based on the  
70 principles of Desbrow and Leveritt (2007). The questionnaire was circulated internationally *via* email  
71 and social media, available in English. Respondents were endurance athletes  $\geq 18$  years of age, of any  
72 competitive level, intending to compete in endurance events  $\geq 2$ h duration in the following six months.  
73 The study was approved by the Monash University Human Research Ethics Committee (approval  
74 number 12241).

75

### 76 *Questionnaire*

77 The questionnaire was conducted using Qualtrics (Provo, Utah, USA), an online platform for  
78 questionnaire design, distribution and analysis that is well-established for exploratory research in  
79 health care settings (Ogbogu & Neczyk, 2016; Yoon et al. 2018). The questionnaire included five  
80 sections as described below. Refer to Appendix 1 for the questionnaire in full.

81 Sodium Information Sources: Participants were asked to identify the information sources that had  
82 influenced their sodium intake in respect to training and competition. These included advice from  
83 health professionals, sport-specific (coaches, managers, and trainers) and social supports (fellow  
84 athletes, friends and relatives), peer reviewed journals, media (television, magazines, internet, etc.),  
85 self-experimentation, sales and marketing (advertising material, company sales representatives and  
86 store attendants).

87 Sodium Beliefs: Two sets of questions investigated the beliefs of endurance athletes regarding the  
88 consumption of sodium before and during endurance exercise. The first set asked participants to  
89 indicate, using an electronic visual analogue scale (VAS), to what extent they agreed with statements  
90 regarding a specific need for athletes to consume more sodium day-to-day, before, during and after  
91 training and competition, and if measurement of sodium losses would be beneficial for endurance  
92 athletes. The second section asked participants to indicate to what extent they agreed that increased  
93 sodium intake would be beneficial for aspects of health (i.e., EAMC, EAH) and performance during  
94 endurance exercise, using the same VAS. In both sections the VAS ranged from 0% (strongly  
95 disagree) to 100% (strongly agree). An electronic slider commenced in the midway (50%) ~~mm~~  
96 position (neither agree or disagree), and results only recorded if the participant clicked on the slider,  
97 to prevent data being recorded as 50% due to failure to answer the question.

98 Intended Practices: Participants were asked to indicate whether they were consciously aware of the  
99 amount of sodium they consume in the days preceding competition. If so, they were then asked over  
100 what time period, and whether they deliberately planned to increase, reduce or maintain sodium intake  
101 compared to their usual day-to-day intake. They were asked to identify the foods, fluids and  
102 supplements used to achieve a specific sodium intake in preparation for competition. All participants  
103 were also asked whether they planned to change their overall food and fluid intake, regardless of

104 sodium, compared to usual intake. A second section asked participants to identify if they were  
105 consciously aware of their sodium intake during competition, and if so, if they identified a specific  
106 amount to consume. They were also asked what foods, fluid and supplements they intended to  
107 consume during a race, specifically for their sodium content.

108 **Sweat Composition Testing:** Participants were asked if they had previously had their sweat  
109 composition tested using commercial testing services (i.e., excluding research studies). Participants  
110 who had undertaken sweat testing were then asked their motivations for doing so, how the results  
111 were applied to their nutrition planning, and whether in hindsight they felt that the testing had  
112 achieved the goals they had for completing the test in the first place.

113

#### 114 *Statistical Analysis*

115 Data are presented as median (inter-quartile range, IQR) based on distribution, which was assessed  
116 using the Kolmogorov–Smirnov test. Effects of sex, geographical region and competitive level on  
117 responses were analysed. For continuous variables, sex differences were analysed using the Mann-  
118 Whitney U test, differences by region and competitive level were analysed using the Kruskal-Wallis  
119 analysis of variance by ranks, with significant outcomes analysed using the Mann-Whitney U test to  
120 determine between-group differences. For categorical data, sex, region and competitive level effects  
121 were assessed using chi-square analysis, with categories collapsed when more than 20% of cells had  
122 an expected count of less than five. Where associations were found, post-hoc analysis was performed  
123 through two by two chi square tables for all category combinations. Analysis was performed using  
124 SPSS 24.0 (IBM Corp., Armonk, New York, USA) with significance accepted at  $p \leq 0.05$ , except  
125 where adjusted as described.

126

## 127 **Results**

### 128 *Demographics*

129 Three hundred and forty-four endurance athletes ( $n=199$  males,  $n=145$  females) from Australia and  
130 New Zealand (60.0%), North America (26.5%) and the United Kingdom (UK) and Ireland (7.7%)  
131 completed the questionnaire (see Table 1). A small number of respondents ( $n=22$ ) resided elsewhere  
132 but were excluded to allow regional comparisons. Respondents were predominately competitive age-  
133 group athletes (66%), of which most (79%) mainly compete in events longer than marathon (running)  
134 or Olympic distance (triathlon), or three hours in other sports. Sports included distance running, race  
135 walking, triathlon, cycling, mountain biking, open-water swimming, adventure racing, orienteering,  
136 endurance rowing, canoeing and kayaking, endurance winter sports and ocean sailing.

137

### 138 *Information Sources*

139 Reported information sources are shown in Table 2 – the average number cited was 3.7 per  
140 participant. Social supports (particularly fellow athletes) were most cited (63%), followed by self-  
141 experimentation (56%), media (48%), health professionals (38%) and sport-specific supports (35%).  
142 Males indicated greater media influence than females ( $\chi^2= 5.3$ ,  $p< 0.05$ ), while less UK and Irish  
143 athletes sourced information from health professionals ( $\chi^2= 6.0$ ,  $p= 0.05$ ) and sport-specific supports  
144 ( $\chi^2= 10.5$ ,  $p< 0.01$ ) but more from media ( $\chi^2= 13.5$ ,  $p< 0.01$ ). More professional and aspiring  
145 professionals sourced information from health practitioners ( $\chi^2= 7.4$ ,  $p< 0.05$ ) and scientific sources  
146 (e.g. peer-reviewed journals) ( $\chi^2= 7.3$ ,  $p< 0.05$ ) compared to lower competitive levels.

147

### 148 *Sodium Beliefs*

149 Agreement with statements about sodium for endurance athletes are shown in Figure 1. Respondents  
150 generally agreed (>50% on VAS) endurance athletes have increased daily sodium requirements  
151 (median 67% (IQR 40-81%)), would benefit from increasing sodium intake in the days preceding  
152 competition (60% (30-77%)), should replace sweat sodium losses during training (69% (48-83%)) and  
153 racing (74% (54-87%)), after training (75% (59-88%)) and racing (80% (64-91%)), and would benefit  
154 from sweat composition testing (82% (65-95%)) although individual responses varied markedly



155 (Figure 1). There were no sex, region or competitive level differences. There was some agreement  
156 that sodium intake during exercise improved physical endurance (65% (52-77%)), but less so speed  
157 (54% (50-69%)), power (55% (50-69%)) and mental alertness (58%, 50-71%). Respondents generally  
158 agreed with statements that sodium intake helped prevent EAMC (75% (60-88%)) or reduce their  
159 severity (71% (51-84%)), and helped prevent EAH (74% (62-89%)), but with marked variation in  
160 individual responses (Figure 2). There was less agreement that sodium ingestion reduced core body  
161 temperature (53% (50-71%)), or prevented bone mineral loss during exercise (53% (50-71%)). No sex  
162 or competitive level differences were observed, however Australian and New Zealand athletes agreed  
163 more strongly ( $p < 0.01$ ) that sodium could prevent (77% (62-89%)) or treat (73% (56-86%)) EAMC  
164 compared to North American athletes (69% (52-79%) and 64% (50-78%) respectively).

165

#### 166 *Intended Practices Prior to Competition*

167 Almost half (45%) of respondents indicated being conscious of sodium intake in the days preceding  
168 competition, always or specifically for hot or longer events. Of these, 64% intended to increase, 33%  
169 maintain, and 3% reduce sodium intake during this period. There were no sex, region or competitive  
170 level effects on intended sodium intake prior to competition. Most respondents (61%) indicated they  
171 would be conscious of sodium intake 1-5 days preceding competition, 24% for less than 1 day and  
172 15% for more than 5 days. There were no sex, region or competitive level effects.

173

174 Strategies to increase sodium intake prior to competition are shown in Table 3. Females were more  
175 likely to choose high sodium foods compared to males ( $p < 0.05$ ), who were more likely to choose  
176 powdered sports and rehydration drinks ( $p < 0.05$ ). Australian and New Zealand athletes were less  
177 likely to add salt to food and fluids ( $p < 0.05$ ). There was no competitive level effect on foods chosen.  
178 Because overall food quantity may unintentionally influence sodium intake, participants were asked  
179 about overall food quantity in the days preceding competition. Almost half (41%) indicated they  
180 intend to increase overall intake in the days preceding competition; only 3% would reduce during this

181 period. A region effect was found ( $\chi^2= 13.6$ ,  $p < 0.01$ ), whereby Australian and New Zealand athletes  
182 were more likely to increase overall intake in the days preceding races ( $p < 0.01$ ), and North American  
183 athletes less likely ( $p < 0.01$ ). There were no sex or competitive level effects. Overall, 58% of  
184 respondents intend to consciously increase sodium intake, total food intake or both during this period.

185

#### 186 *Intended Practices During Competition*

187 Most respondents (79%) indicated being conscious of sodium intake during competition, an additional  
188 6% if competing in longer events or in hot ambient conditions ( $\geq 30^\circ\text{C}$ ). There were no sex or  
189 competitive level effects. However, there was a region effect ( $\chi^2= 8.470$ ,  $p < 0.05$ ), whereby UK and  
190 Irish athletes were less likely to be conscious of sodium intake than North American or Australian and  
191 New Zealand athletes (68%, 89% and 87% respectively,  $p < 0.01$ ). Of those conscious of sodium  
192 intake, only 29% articulated specific plans for how much sodium they would consume, with no sex,  
193 region or competitive level effects. These respondents described either specific hourly sodium targets  
194 in milligrams, or quantified combinations of products. The foods and fluids athletes intend to  
195 consume during a race to obtain sodium were diverse, with some sex, region and competitive level  
196 effects (Table 4).

197

#### 198 *Sweat Composition Testing*

199 Only 16 respondents (5%) reported having sweat composition tested commercially (males  $n= 10$ ,  
200 females  $n= 6$ ). Motivations included a desire to improve competition performance (69%), prevent  
201 EAMC (50%), EAH (19%), and general interest (19%). Most (75%) felt assessing sweat composition  
202 had been beneficial, 19% not beneficial and 6% unsure. Whilst the lack of responses prevented chi-  
203 square analyses, males were more likely than females to undertake sweat testing to improve  
204 performance (90% and 33%, respectively), and more likely to believe testing had been beneficial  
205 (90% and 50%, respectively).

206

## 207 Discussion

208 The purpose of this study was to describe beliefs, information sources and intended practices of  
209 endurance athletes regarding sodium intake for training and competition. In agreement with our  
210 hypotheses, respondents; a) believe daily sodium requirements are increased due to exercise, and  
211 quantifying sweat sodium losses would be beneficial; b) believe sodium intake during exercise  
212 improves endurance performance, prevents and/or attenuates EAMC and EAH; c) plan to increase  
213 either sodium or total food intake in the 1-5 days before competition; and d) plan to consume a variety  
214 of products during competition for their sodium content, but do not usually have a specific plan for  
215 the amount of sodium to consume. In addition, respondents mostly obtain information about sodium  
216 from people without sport and exercise nutrition qualifications or expertise (i.e., fellow athletes,  
217 friends and relatives, the media or self-experimentation), and whilst less than 5% had undergone  
218 commercial sweat testing, the majority of these athletes believed it was worthwhile.

219

220 Few studies have previously examined the beliefs, information sources, intended or actual sodium  
221 intakes of endurance athletes, and most are limited to sodium ingestion during competition (White &  
222 Hoffman, 2018; Hoffman & Stuempfle, 2014; (Winger, Dugas, & Dugas, 2011); Winger et al., 2013).  
223 In a recent questionnaire of ultramarathon runners, 85% believed salt tablets should be made available  
224 at races, with 65% and 58% of those stating that salt tablets prevent EAH and EAMC respectively. In  
225 addition, 43% stated that salt tablets aid hydration status (White & Hoffman, 2018). The prevalence of  
226 sodium supplementation, in addition to sodium-containing food and fluids, was 90% and 95% in  
227 questionnaire respondents competing in the 2011 and 2013 Western States Endurance Run,  
228 respectively (Hoffman & Stuempfle, 2014; Winger et al., 2013). These data are consistent with our  
229 findings in athletes across a range of endurance sports, whereby median VAS scores indicated general  
230 agreement that sodium intake during endurance exercise prevented and/or attenuated EAMC and  
231 EAH. Furthermore, over 80% of respondents specifically considered sodium intake during  
232 competition either all the time or specifically in hot or long duration events.

233

234 In contrast, we are not aware of any well-controlled studies that investigated intended practices or  
235 quantified sodium intake in the days preceding endurance competition, compared to typical intake.  
236 This is important because of a possible interaction between dietary sodium intake in the preceding  
237 days and the sweat sodium concentration during exercise (McCubbin & Costa, 2018b). The majority  
238 of studies found in a recent SLR compared reduced dietary sodium to usual intake (McCubbin &  
239 Costa, 2018b), whereas the findings of the present study suggest the most likely change in sodium  
240 intake in the days preceding competition is an increase. We were unable to quantify the extent of the  
241 intended increase in sodium intake prior to competition. Because it is well established that dietary  
242 records are a poor indicator of sodium intake, such a study would require collection of all urine and  
243 sweat excreted over at least three days, since sweat sodium losses reduce urinary sodium excretion  
244 (Lichten 1957), and urinary sodium excretion is a poor predictor of intake unless collected for several  
245 consecutive days (Lerchl et al., 2015). This aspect of study design would be a major imposition on  
246 endurance athletes preparing for competition, and logistically challenging for researchers.

247

248 The current study demonstrated endurance athletes are more likely to seek information from fellow  
249 athletes, friends and family, the media and self-experimentation rather than health professionals,  
250 coaches or scientific literature. This is perhaps not surprising considering health professionals,  
251 coaches and scientific literature are less available and require increased time and financial  
252 commitment. Our findings are consistent with studies on information sources for other aspects of  
253 sports nutrition such as caffeine and fluid (Desbrow & Leveritt, 2007; Winger et al., 2011; Winger et  
254 al., 2013). Unsurprisingly, professional and aspiring professional athletes were more likely to seek  
255 advice from health professionals and peer-reviewed journals, given their career relies on this advice to  
256 optimise performance, and in some cases, advice is provided at no cost through team or sponsorship  
257 arrangements.

258

259 Many of the beliefs included in the questionnaire were not supported by scientific evidence, despite  
260 general agreement from participants. Statements with the highest agreement included sodium to  
261 improve endurance performance, prevent and/or attenuate EAMC and EAH. Evidence for sodium  
262 intake during exercise to improve performance (McCubbin & Costa, 2018b), prevent or manage  
263 EAMC is scarce (Schwellnus, 2009), and the role of sodium in preventing EAH appears minimal in  
264 comparison to fluid intake management and/or behaviours (Hew-Butler et al., 2015). Given  
265 professional and aspiring professional athletes more readily consult health professionals, but did not  
266 have different beliefs about sodium, this suggests either health professionals are not providing athletes  
267 advice in accordance with current scientific literature, are referring to guidelines that do not reflect  
268 findings of individual studies (Hoffman, Bross, & Hamilton, 2016), or athlete beliefs are more  
269 strongly influenced by other information sources, despite seeking information from qualified  
270 professionals.

271  
272 Differences between sexes were minimal in the present study, except males were more likely to be  
273 influenced by non-scientific information sources and intended to consume more commercial sports  
274 nutrition products to obtain sodium compared to females. Whilst previous studies investigating beliefs  
275 and practices of sodium ingestion during exercise have included both male and female participants,  
276 we are unaware of any that have analysed the effect of sex in this way. There were also regional  
277 variations in our data, but in general most responses were remarkably similar. This may reflect  
278 commonality not only in language but sporting culture, marketing, food environment and access to  
279 sports nutrition information between Australia and New Zealand, the USA and Canada, and the UK  
280 and Ireland. These results should be interpreted with caution if extrapolating to countries with  
281 language, cultural and environmental differences.

282

283 Despite the strong belief amongst respondents that quantifying sodium losses was worthwhile, less  
284 than 5% reported doing so. This may reflect a lack of availability of sweat testing services, or that it is  
285 not prioritised amongst other factors during preparation for competition. In addition, despite 79%

286 reporting being conscious of sodium intake during competition, only 29% could articulate a specific  
287 strategy for doing so. A lack of investment by endurance athletes in quantifying sodium losses and  
288 developing replacement strategies may also reflect the absence of evidence-based guidelines to  
289 support this practice (Thomas et al., 2016). Future research should investigate the effect of targeted  
290 sodium replacement strategies during endurance exercise on health and performance outcomes and  
291 the potential role, if any, of sweat composition testing in informing this strategy.

292

### 293 *Limitations*

294 There are several limitations to our study design, mainly relating to the methods used to obtain data  
295 from participants. The nature of recruitment for online questionnaires is likely to result in self-  
296 selection bias, whereby those with strong opinions on the topic of interest are most likely to complete  
297 the questionnaire (Khazaal et al., 2014). Whilst this is likely to have been the case here, we note great  
298 variance in responses regarding sodium beliefs, as well as demographic characteristics (age and  
299 competitive level) that closely align with previously published demographic information for  
300 competitors in ultramarathon (Hoffman & Fogard, 2012) and Ironman and Ironman 70.3 triathlon  
301 events (World Triathlon Corporation, 2018). It is noted that females appear over-represented in our  
302 dataset compared to the number of entrants in endurance competitions, however the separate analysis  
303 of data by sex allows for meaningful comparisons to be made despite this discrepancy. In addition,  
304 self-selection bias is also likely to be prevalent in most other study designs within the field of sport  
305 and exercise nutrition, due to the time commitment, and in many cases inconvenience and/or potential  
306 discomfort of body fluid and tissue sampling. It is also acknowledged that the number of responses  
307 per region varied markedly, with only 28 responses from the UK and Ireland. Caution should be  
308 applied when interpreting differences by region and competitive level, although more similarities than  
309 differences were observed between sub-groups. Finally, despite the wide variability in responses, the  
310 nature of the questions means that respondents may be more likely to agree than disagree with any  
311 proposed statement (Lavrakas, 2008<sup>ref</sup>). Therefore, care should be taken when interpreting sodium  
312 beliefs data, especially where the median value was close to 50%.

313

314 **Conclusion**

315 From analysis of 344 responses to an online questionnaire across six English-speaking countries, we  
316 found endurance athletes commonly believe they have increased sodium needs before, during and after  
317 training and competition. Many endurance athletes intend to deliberately increase sodium intake before  
318 and during competition. These beliefs and intentions appear to be informed mostly by non-scientific  
319 information sources, although it has been noted that reliance on sports nutrition guidelines may lead to  
320 athletes receiving similar advice from health professionals. There remains a significant need for better  
321 evidence to inform sodium intake guidelines, that outline (if deemed relevant) specific sodium intake  
322 strategies to optimise performance and prevent adverse health outcomes in the short, or long-term for  
323 endurance athletes.

324

325

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328 design, and the participants from around the world who took the time to complete the questionnaire.  
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330 all data. Data interpretation and manuscript preparation were undertaken by AM, GC and RC. All  
331 authors approved the final version of the paper.

332

**333 Conflicts of interest**

334 All authors have no conflicts of interest to declare.

335

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458 **Table 1.** Participant characteristics

	Total				Male				Female			
	Australia/ New Zealand	USA/ Canada	UK/ Ireland	Total	Australia/ New Zealand	USA/ Canada	UK/ Ireland	Total	Australia/ New Zealand	USA/ Canada	UK/ Ireland	Total
<i>Number of participants (n)</i>	219	97	28	344	136	50	13	199	83	47	15	145
<i>Age (median (IQR))</i>	43 (14)	39 (18)	42 (9.5)	42 (15)	43 (14)	39 (18)	42 (9.5)	43 (16)	43 (11.5)	36 (14)	40 (10)	40 (14)
<i>Years competing (median (IQR))</i>	6 (8)	12 (14)	8 (8)	8 (11)	7 (11)	14.5 (19.25)	8 (12)	10 (14)	5 (7)	10 (10)	8 (7)	7 (8)
<i>Competitive Level:</i>												
<i>Professional</i>	0.9%	4.1%	0.0%	1.7%	0.0%	4.0%	0.0%	1.0%	2.4%	4.3%	0.0%	2.8%
<i>Aspiring Professional</i>	4.1%	5.2%	10.7%	4.9%	4.4%	8.0%	15.4%	6.0%	3.6%	2.1%	6.7%	3.4%
<i>Competitive age-group athlete</i>	65.3%	73.2%	42.9%	65.7%	72.1%	80.0%	46.2%	72.4%	54.2%	66.0%	40.0%	56.6%
<i>Training regularly for health &amp; fitness</i>	28.8%	16.5%	46.4%	26.7%	22.1%	8.0%	38.5%	19.6%	39.8%	25.5%	53.3%	36.6%
<i>Training irregularly for health &amp; fitness</i>	0.9%	1.0%	0.0%	0.9%	1.5%	0.0%	0.0%	1.0%	0.0%	2.1%	0.0%	0.7%
<i>Event participation:</i>												
<i>Events &lt; 3h or less than marathon or Olympic distance (running and triathlon)</i>	16.4%	27.8%	32.1%	20.9%	11.0%	16.0%	15.4%	12.6%	25.3%	40.4%	46.7%	32.4%
<i>Events &gt; 3h or greater than marathon or Olympic distance (running and triathlon)</i>	83.6%	72.2%	67.9%	79.1%	89.0%	84.0%	84.6%	87.4%	74.7%	59.6%	53.3%	67.6%

460  
461**Table 2.** Sources of information about sodium consumption before, during and after endurance exercise by sex, region and performance level

	<i>Total</i>	<i>Australia/ New Zealand</i>	<i>USA/ Canada</i>	<i>UK/ Ireland</i>	<i>Association between region and information source <math>\chi^2</math> (p)</i>	<i>Male</i>	<i>Female</i>	<i>Association between sex and information source <math>\chi^2</math> (p)</i>	<i>Health and Fitness</i>	<i>Competitive Age Group</i>	<i>Professional/ aspiring professional</i>	<i>Association between training level and information source <math>\chi^2</math> (p)</i>
Number of participants (n)	344	219	97	28		199	145		95	226	23	
Never considered the use of sodium with sport	8.1%	10.0%	3.1%	10.7%	4.3 (0.117)	7.0%	9.7%	0.8 (0.380)	9.5%	7.5%	8.7%	0.4 (0.839)
Health Professionals	37.8%	37.9%	43.3%	17.9% <sup>ab</sup>	6.0 (0.05)	35.7%	40.7%	0.9 (0.344)	30.5%	38.5%	60.9% <sup>cd</sup>	7.4 (0.025)
Sport-specific supports	34.6%	36.1%	39.2%	7.1% <sup>ab</sup>	10.5 (0.005)	32.7%	37.2%	0.8 (0.378)	31.6%	35.0%	43.5%	1.2 (0.550)
Social supports	63.4%	63.0%	69.1%	46.4%	4.8 (0.09)	61.3%	66.2%	0.9 (0.352)	58.9%	65.9%	56.5%	1.9 (0.386)
Peer reviewed journals	29.7%	27.4%	32.0%	39.3%	2.0 (0.375)	32.2%	26.2%	1.4 (0.232)	21.1%	31.4%	47.8% <sup>c</sup>	7.3 (0.025)
Media	48.0%	42.5%	51.5%	78.6% <sup>ab</sup>	13.5 (0.001)	53.3%	40.7%	5.3 (0.021)	46.3%	50.4%	30.4%	3.5 (0.175)
Sales & Marketing	21.5%	21.5%	21.6%	21.4%	0.001 (1.000)	22.6%	20.0%	0.3 (0.560)	15.8%	23.0%	30.4%	3.2 (0.199)
Self-experimentation	55.8%	55.7%	57.7%	50.0%	0.5 (0.768)	57.3%	53.8%	0.4 (0.519)	49.5%	58.8%	51.2%	2.5 (0.284)

462

463

464

<sup>a</sup> Significantly different from Australia/New Zealand ( $p < 0.05$ ), <sup>b</sup> significantly different from USA/Canada ( $p < 0.05$ ), <sup>c</sup> significantly different from Health and Fitness ( $p < 0.05$ ), <sup>d</sup> significantly different from Competitive Age Group ( $p < 0.05$ ).

465 **Table 3:** Foods chosen for their sodium content in the days prior to competition.

466

	<i>Total</i>	<i>Australia/ New Zealand</i>	<i>USA/ Canada</i>	<i>UK/ Ireland</i>	<i>Association between region and food choice <math>\chi^2</math> (p)</i>	<i>Male</i>	<i>Female</i>	<i>Association between sex and food choice <math>\chi^2</math> (p)</i>	<i>Health and Fitness</i>	<i>Competitive Age Group</i>	<i>Professional/ aspiring professional</i>	<i>Association between training level and food choice <math>\chi^2</math> (p)</i>
Number of participants (n)	151	93	43	15		88	63		35	101	15	
Regular foods high in sodium	32.5%	28.0%	37.2%	46.7%	2.7 (0.261)	25.0%	42.9%	5.3 (0.021)	25.7%	36.6%	20%	2.6 (0.274)
Added salt to food and fluids	40.4%	32.3%	55.8% <sup>a</sup>	46.7% <sup>a</sup>	7.0 (0.029)	34.1%	49.2%	3.5 (0.062)	31.4%	43.6%	40.0%	1.6 (0.451)
Sports, rehydration and electrolyte drinks (ready to drink)	24.5%	20.4%	34.9%	20.0%	3.5 (0.174)	21.6%	28.6%	1.0 (0.325)	31.4%	24.8%	6.7%	3.5 (0.175)
Sports, rehydration and electrolyte drinks (made from powder)	41.1%	40.9%	48.8%	20.0%	3.8 (0.148)	48.9%	30.2%	5.3 (0.021)	31.4%	42.6%	53.3%	2.4 (0.306)
Sports, rehydration and electrolyte drinks (dissolvable tablets)	37.7%	36.6%	37.2%	46.7%	0.6 (0.752)	34.1%	42.9%	1.2 (0.273)	37.1%	34.7%	60.0%	3.6 (0.167)
Salt or electrolyte tablets or capsules	28.5%	28.0%	34.9%	13.3%	2.6 (0.277)	30.7%	25.4%	0.5 (0.478)	28.6%	26.7%	40.0%	1.1 (0.569)

467 <sup>a</sup> Significantly different from Australia/New Zealand (p < 0.05), <sup>b</sup> significantly different from USA/Canada (p < 0.05), <sup>c</sup> significantly different from Health  
468 and Fitness (p < 0.05), <sup>d</sup> significantly different from Competitive Age Group (p < 0.05).

469 **Table 4:** Foods chosen for their sodium content during competition.

	<i>Total</i>	<i>Australia/ New Zealand</i>	<i>USA/ Canada</i>	<i>UK/ Ireland</i>	<i>Association between region and food choice <math>\chi^2</math> (p)</i>	<i>Male</i>	<i>Female</i>	<i>Association between sex and food choice <math>\chi^2</math> (p)</i>	<i>Health and Fitness</i>	<i>Competitive Age Group</i>	<i>Professional/ aspiring professional</i>	<i>Association between training level and food choice <math>\chi^2</math> (p)</i>
Number of participants (n)	344	219	97	28		199	145		95	226	23	
Sports Drinks	57.8%	55.3%	67.0%	46.4%	5.3 (0.070)	57.8%	57.9%	0.001 (0.979)	60.0%	57.5%	52.2%	0.5 (0.781)
Rehydration Drinks	28.5%	33.8%	20.6% <sup>a</sup>	14.3% <sup>a</sup>	8.9 (0.012)	31.2%	24.8%	1.6 (0.199)	31.6%	27.4%	26.1%	0.6 (0.728)
Electrolyte capsules and tablets	50.9%	50.7%	51.5%	50.0%	0.02 (0.988)	50.3%	51.7%	0.07 (0.787)	48.4%	52.2%	47.8%	0.5 (0.788)
Energy Gels	67.7%	68.5%	69.1%	57.1%	1.6 (0.461)	67.8%	67.6%	0.002 (0.960)	62.1%	69.5%	73.9%	2.1 (0.352)
Energy bars/chews/foods	41.9%	42.0%	44.3%	32.1%	1.3 (0.515)	47.2%	34.5%	5.6 (0.018)	46.3%	40.3%	39.1%	1.1 (0.582)
Vegemite	8.4%	12.8%	0.0% <sup>a</sup>	3.6% <sup>a</sup>	15.2 (< 0.001)	6.0%	11.7%	3.5 (0.061)	14.7%	6.2% <sup>c</sup>	4.3%	6.9 (0.032)
Homemade, savoury snacks & coconut water	12.8%	13.7%	11.3%	10.7%	0.5 (0.789)	12.1%	13.8%	0.3 (0.635)	15.8%	11.9%	8.7%	1.3 (0.534)

470 <sup>a</sup> Significantly different from Australia/New Zealand ( $p < 0.05$ ), <sup>b</sup> significantly different from USA/Canada ( $p < 0.05$ ), <sup>c</sup> significantly different from Health  
471 and Fitness ( $p < 0.05$ ), <sup>d</sup> significantly different from Competitive Age Group ( $p < 0.05$ ).



472 **Figure Legends**

473

474 **Figure 1.** Level of agreement of endurance athletes regarding aspects of sodium intake and sweat  
475 sodium measurement for training and competition. Level of agreement is scored on a Visual Analogue  
476 Scale (VAS), where 50% indicates neither agreement nor disagreement with the stated effect.

477

478 **Figure 2.** Level of agreement of endurance athletes regarding the effect of sodium intake during  
479 endurance exercise on aspects of physiological function and health outcomes. Level of agreement is  
480 scored on a Visual Analogue Scale (VAS), where 50% indicates neither agreement nor disagreement  
481 with the stated effect. EAMC: exercise-associated muscle cramps, EAH: exercise-associated  
482 hyponatraemia, BMC: bone mineral content.

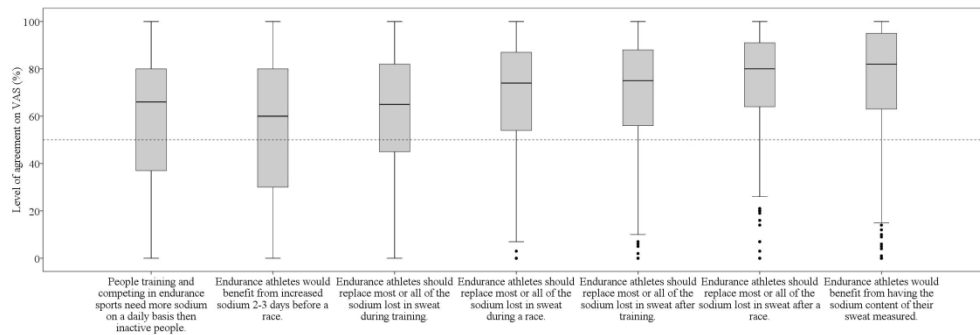


Figure 1. Level of agreement of endurance athletes regarding aspects of sodium intake and sweat sodium measurement for training and competition. Level of agreement is scored on a Visual Analogue Scale (VAS), where 50% indicates neither agreement nor disagreement with the stated effect.

893x317mm (72 x 72 DPI)

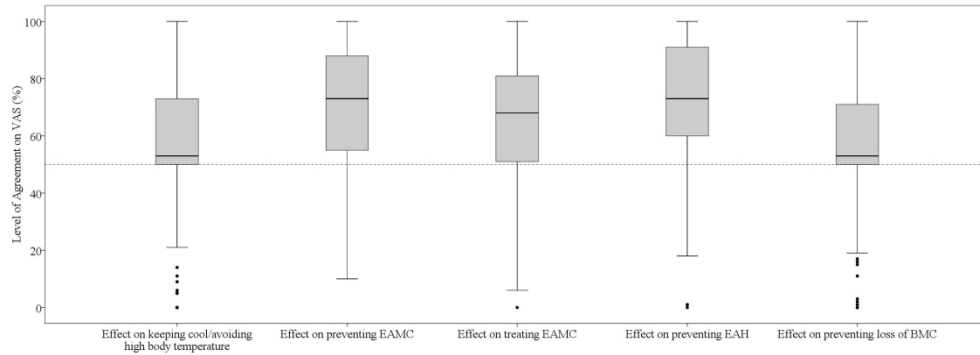


Figure 2. Level of agreement of endurance athletes regarding the effect of sodium intake during endurance exercise on aspects of physiological function and health outcomes. Level of agreement is scored on a Visual Analogue Scale (VAS), where 50% indicates neither agreement nor disagreement with the stated effect. EAMC: exercise-associated muscle cramps, EAH: exercise-associated hyponatraemia, BMC: bone mineral content.

847x301mm (72 x 72 DPI)

1 **Supplementary Appendix – Endurance Athlete Questionnaire**

2

3 **Demographics**

4 Q1 What is your sex?  Male  Female

5

6 Q2 What is your age in years? \_\_\_\_\_

7

8 Q3 Which sport/sports do you currently train and compete in? \_\_\_\_\_

9

10 Q4 For how many years have you been competing in endurance sports? \_\_\_\_\_

11

12 Q5 How would you best describe yourself and your level of training?

13  Professional athlete, training regularly

14  Aspiring professional athlete, training regularly

15  Actively competitive age group athlete, training regularly

16  Interest in general health and fitness, training regularly

17  Interest in general health and fitness, training sometimes

18

19 **Sodium Information Sources**

20 Q26 From the following list, please select any individual(s) or information sources that have

21 influenced whether you choose/do not choose to consume a certain amount of sodium or sodium-

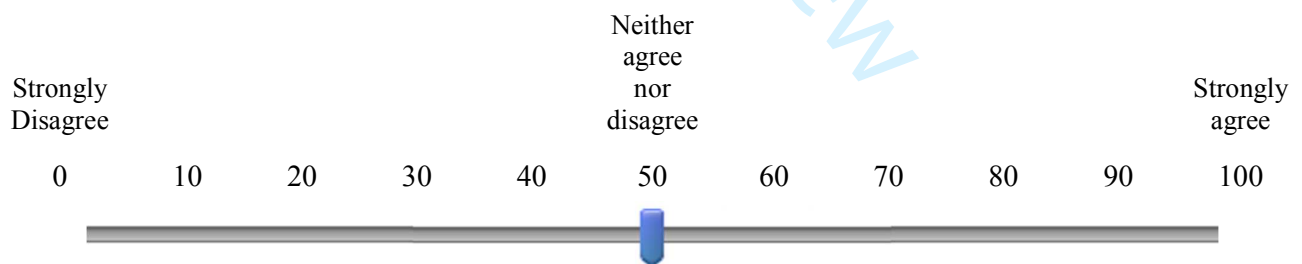
22 containing products relating to your endurance training or competition (*please tick all responses that*

23 *apply to you – more than one answer is allowed*).

- 24  I've never considered the use of sodium with sport
- 25  Doctor/Physician  Pharmacist  Dietitian or Nutritionist
- 26  Coach  Trainer  Manager
- 27  Parent  Relative  Fellow athlete
- 28  Friend  Health food store attendant
- 29  TV/radio  Journal Articles
- 30  Food &/or supplement company advertising
- 31  Magazines  Internet  Self researched/experimented
- 32  Other \_\_\_\_\_

33

34

35 **Sodium Beliefs**36 *Please click and drag the sliders to indicate how much you agree with each of the following*37 *statements:*

38 Q6 People training and competing in endurance sports need to eat more salt/sodium/electrolytes on a

39 day-to-day basis compared to people who are not exercising.

40

41 Q7 Endurance sport competitors would benefit from increasing the amount of salt/sodium they  
42 consume in the 2-3 days before a race.

43

44 Q8 During training, endurance athletes should aim to replace most or all of the salt/sodium lost in  
45 sweat.

46

47 Q9 During a race, endurance athletes should aim to replace most or all of the salt/sodium lost in  
48 sweat.

49

50 Q10 After training, endurance athletes should aim to replace most or all of the salt/sodium lost in  
51 sweat.

52

53 Q12 After a race, endurance athletes should aim to replace most or all of the salt/sodium lost in sweat.

54

55 Q13 Endurance athletes would benefit from having the amount of sodium measured in their sweat.

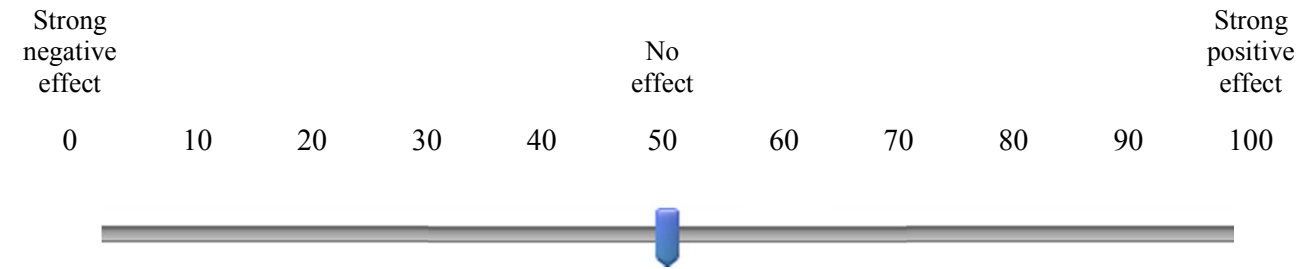
56

57 *If you were to specifically increase the amount of salt/sodium you consume on a day-to-day basis in*  
58 *training (compare to a period of time when you are not training), what effect do YOU THINK it would*  
59 *have on the following aspects of exercise performance? Click and drag the sliders to indicate your*  
60 *response:*

61

62

63



64 Q14 Endurance during exercise of more than 1 hour

65

66 Q15 Speed in exercise of more than 1 hour

67

68 Q16 Power in exercise of more than 1 hour

69

70 Q17 Concentration/alertness

71

72 Q18 Keeping cool or avoiding high body temperature

73

74 Q19 Preventing muscle cramping during exercise

75

76 Q20 Reducing the severity of muscle cramping once it has started

77

78 Q21 Preventing hyponatraemia (low blood sodium) during exercise

79

80 Q22 Preventing loss of bone minerals during exercise

81

82 **Intended Practices**

83 *The following questions are about your use of sodium in the days and hours leading up to an*  
84 *endurance race or competition. If you do not consciously focus on the amount of sodium in the days*  
85 *or hours before competition, answer no to the first question and skip ahead to the next section.*

86

87 Q27 In the days leading up to a race (that will have a duration of more than 2 hours), would you be  
88 aware of consuming a certain amount of salt/sodium from food, fluids or supplements?

89  Yes  No

90  Sometimes (please provide comments) \_\_\_\_\_

91

92 Q28 Would you plan to eat more, less or the same amount of salt/sodium in the days leading up to a  
93 race compared to day-to-day when you are training?

94  I would plan to consume MORE sodium in the days before a race compared to when I'm training

95  I would plan to consume LESS sodium in the days before a race compared to when I'm training

96  I would plan to consume THE SAME AMOUNT of sodium in the days before a race compared to  
97 when I'm training

98

99 Q29 How long before a race (that will have a duration of more than 2 hours) would you be aware of  
100 consuming a certain amount of sodium from food, fluids or supplements (answer can be in hours,  
101 days or weeks)? \_\_\_\_\_

102

103



104 Q30 What foods, drinks or supplements do you plan to consume to increase the amount of salt/sodium  
105 in the lead up to a race? (can choose more than one)

106  Eat more regular foods that are higher in salt/sodium

107  Adding salt (table salt, sea salt, rock salt, etc.) to food/drinks

108  Sports, rehydration or other electrolyte drinks (bottled)

109  Sports, rehydration or other electrolyte drinks (made from powder)

110  Sports, rehydration or other electrolyte drinks (dissolvable tablets)

111  Salt/electrolyte capsules or tablets

112  Other – please specify: \_\_\_\_\_

113

114 Q31 Regardless of sodium, would the overall amount of food you plan to eat change in the days  
115 leading in to an endurance race or competition, compared to your day-to-day diet in training?

116  I would eat MORE food overall

117  I would eat LESS food overall

118  I would eat about THE SAME amount of food overall

119

120 *This section relates to your consumption of sodium/salt DURING competition*

121

122 Q32 DURING a race (that will have a duration of more than 2 hours), would you be aware of  
123 consuming sodium from food, fluids or supplements?

124  Yes  No

125  Sometimes (please provide comments) \_\_\_\_\_

126

127 Q33 How much sodium would you aim to take (can answer in milligrams (mg) OR amounts of certain  
128 foods and drinks OR based on a percentage of expected losses)?

129  Specify amount here \_\_\_\_\_, OR

130  I'm not sure

131

132 Q34 Please tick all of the sodium-containing products you are planning to consume immediately  
133 before and during your next race/event

134  The sports drink provided by the race organisers

135  The gels provided by the race organisers

136  The energy bars/chews provided by the race organisers

137  My own sports drink (sold as a sports product, not a rehydration product)

138  My own rehydration drink (sold as a rehydration formula, not a sports product)

139  My own dissolvable electrolyte tablets

140  Salt or electrolyte tablets/capsules

141  My own homemade drink formula (please provide details if possible)

142  Energy gels I purchased myself

143  Energy bars/chews I purchased myself

144  Coconut water (plain or flavoured)

145  Vegemite sandwich

146  Other \_\_\_\_\_

147

148 **Commercial Sweat Testing Experiences**

149 Q35 Have you PREVIOUSLY had your sweat tested to measure the amount of  
150 salt/sodium/electrolytes in it (not including research studies)?

151  Yes  No

152

153 Q36 If yes, what was your main goal or motivation for having your sweat tested (can choose more  
154 than 1 answer)?

155  To improve my performance in training and/or competition

156  To reduce the risk of muscle cramping during training and/or competition

157  To reduce the risk of hyponatraemia during training and/or competition

158  Other: \_\_\_\_\_

159

160 Q37 Do you feel that the results of your sweat test allowed you to better reach the goal/s stated in  
161 question 24 (above)?

162  Yes  No  Not Sure