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Citation: Peart, Daniel, Graham, Michael, Blades, Callum and Walshe, Ian (2020) The effect of carbohydrate mouth rinsing on multiple choice reaction time during amateur boxing. *International Journal of Sports Physiology and Performance*, 15 (5). pp. 720-723. ISSN 1555-0265

Published by: Human Kinetics

URL: <https://doi.org/10.1123/ijsp.2019-0485> <<https://doi.org/10.1123/ijsp.2019-0485>>

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1 **Title:** The effect of carbohydrate mouth rinsing on multiple choice reaction time during
2 amateur boxing.

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4 **Submission type:** Original investigation

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16
17 **Preferred running head:** Carbohydrate mouth rinsing and reaction time

18
19 **Abstract word count:** 214

20
21 **Text-only word count:** 2061

22
23 **Number of tables:** 2
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49 **Abstract**

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Purpose: To examine whether the use of a carbohydrate mouth rinse (CMR) can improve multiple choice reaction time (MCRT) in amateur boxers during sparring.

Methods: Eight male amateur boxers (age 22 ± 3 years, stature 1.78 ± 0.07 m, mass 73.6 ± 14.2 kg) with at least 18 months experience in the sport volunteered. All participants attended a familiarisation session, followed by an experimental (CMR; 6% dextrose) and placebo (PLAC) trial completed in a random order. Participants undertook 3 x 2-min of sparring against an ability and size (stature and mass) matched opponent. MCRT and perceived exertion was measured before round 1, and then after each round. The respective mouth rinse was administered in a 25-ml solution for 10-s before each round. Magnitude based inferences were used to compare the results from each round (mean difference \pm 90% confidence limits).

Results: The CMR was unlikely to have a beneficial effect on MCRT compared to PLAC (5 ± 9.5 , 4 ± 3.4 , -1 ± 8.5 lights for each round respectively), and had a possibly harmful effect on perceived exertion in round one (10 ± 20). There was an unlikely harmful effect on perceived exertion in rounds two (1 ± 12) and three (9 ± 23).

Conclusions: There is no evidence to support the use of CMR during sparring in amateur boxers.

Key words: Cognitive, combat, nutrition, perceived exertion, ergogenic aid

99 **Introduction**

100
101 The concept of holding an ergogenic aid in the buccal cavity for a short period of time
102 without swallowing, also known as mouth rinsing, was first described by Carter et al. ¹. In
103 this study cyclists used a carbohydrate mouth rinse (CMR) at regular intervals during a time
104 trial, resulting in improved performance compared to a placebo rinse. The mechanism of
105 action is unlikely to be metabolic as the carbohydrate is not ingested, but rather due to
106 stimulation of the central nervous system. This idea is supported by data from Chambers et al
107 ² who identified that a CMR can activate areas of the brain associated with reward and
108 regulation of motor activity. A recent review identified that this method can improve time
109 trial performance by approximately 2-3%, but shorter anaerobic exercises may not benefit by
110 as much ³. Gam et al. ⁴ has criticised some of the research in this area for comparing an
111 experimental mouth rinse only to a placebo. They observed that whilst the presence of
112 carbohydrate afforded an ergogenic benefit compared to a sweetened placebo, there were no
113 improvements compared to a non-rinse control. The act of rinsing itself may have a negative
114 effect on performance by interrupting the athlete or affecting their breathing. Nevertheless,
115 the presence of carbohydrate appears to have masked this possible negative effect on
116 performance, therefore implementing the practice into a sport where the act of rinsing will
117 not hinder their performance could be of benefit.

118
119 Combat sports typically consist of a set number of rounds interspersed by short rest periods.
120 Such periods may offer an opportunity for athletes to perform a mouth rinse without
121 hindering their performance during active rounds. These sports would also arguably benefit
122 from an attenuation in cognitive as well as physical decline due to fatigue, in order to beat an
123 opponent ⁵. Rinsing the mouth with a carbohydrate solution has been shown to enhance
124 reaction time (RT) at rest (Sanders et al, 2012), improve temporal performance during
125 exercise ⁶, reduce exercise induced declines in cognitive function ⁷, and reduce perception of
126 fatigue in latter stages of exercise ⁶. This could be a result of an inhibition in stress hormone
127 release ⁷, a moderation of self-control ⁸, or an increase in brain activity in areas associated
128 with attention ^{2,6}. Therefore, whilst the evidence for carbohydrate mouth rinsing benefitting
129 short term exercise is limited to a small number of recent articles investigating isolated
130 anaerobic tasks such as vertical jumping and resistance exercises ^{9,10}, the potential benefits
131 for cognition warrants research into its applicability for combat sports.

132
133 The purpose of this study was to investigate the effects of a CMR on multiple choice reaction
134 time (MCRT) in amateur boxers.

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136
137 **Method**

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139 **Participants**

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141 Eight male amateur boxers (age 22 ± 3 years, stature 1.78 ± 0.07 m, mass 73.6 ± 14.2 kg)
142 with at least 18 months experience in the sport volunteered to take part in the study. All
143 participants were in preparation for an upcoming competitive bout, with visits taking place in
144 three consecutive weeks that were four, three and two weeks out from competition. The
145 institutional ethics committee approved all experimental procedures, and all participants
146 provided written informed consent. Prior to sparring, all participants had completed a full
147 medical according to England Boxing regulations

148

Experimental Design

Participants completed three visits to their regular training facility following a four hour fast. Visit one acted as a full familiarisation to the protocol, and visits two and three were the experimental and placebo trials completed in a randomised order. During each visit, participants completed an individual, standardised 15-min warm up, followed by 3 x 2-min rounds of sparring against an opponent, under the supervision of an England Boxing level two coach. The boxers were paired based on being within two competitive bouts of each other and within the same weight division recognized by England Boxing. The MCRT test took place before round one, and in the rest periods between each round. Participants conducted a mouth rinse immediately after each MCRT, and rated their perception of overall exertion using the CentiMax scale (CR100)¹¹. Both fighters in each bout received the same condition.

Mouth Rinse

Participants rinsed their mouth for 10-s each time with 25 ml of a carbohydrate solution (CMR) (6% dextrose), placebo (0.5% artificial sweetener, Tesco UK), or water (familiarisation).

Multiple Choice Reaction Time (MCRT)

The MCRT was programmed using an automated reaction light system (Witty System, Microgate, Italy), arranged as a four light system with the order of lights set to random. Participants had to react to each light by tapping the surface, which subsequently triggered the next light to appear. The aim was to tap and turn off as many lights as possible during a 40-s period. The lights were arranged in a diamond shape, with the highest sensor 170 cm from the floor, and another 39.5 cm lower on the same vertical line. Two remaining lights were on a horizontal line 18.5 cm lower than the top sensor, 21 cm either side of the vertical line. These placements were used to match the approximate height of head and body shots, and to be approximately shoulder width apart. Pilot work with five participants resulted in a coefficient of variance of 3% over three visits, with a minimal worthwhile change of seven lights between rounds (one more than the upper 95% confidence interval of the typical error).

Data Analysis

Differences (mean \pm 90% Confidence Limits) between visits for each round were quantified using magnitude based inferences (MBI). Reproducibility data from pilot work identified that six people would be suitable to detect a difference of seven lights between rounds with 80% power, based on within and between subject standard deviations of 6 and 10 respectively. Both the MBI analysis and sample size estimation were completed using custom-made spreadsheets (Will Hopkins; www.sportsci.org). The percent chances of an effect being beneficial, trivial or harmful was interpreted using the following qualitative terms; <0.5%, most unlikely or almost certainly not; 0.5 to 5%, very unlikely; 5 to 25%, unlikely or probably not; 25 to 75%, possibly; 75 to 95%, likely or probably; 95 to 99.5%, very likely; >99.5%, most likely or almost certainly¹².

The reproducibility of the MCRT was examined using the pre-bout scores in visits two and three in order to make the meaningful change specific to our sample. This resulted in a meaningful change for number of lights tapped to be eight, and the average RT between

199 lights to be 0.16 seconds. The meaningful change for RPE was set as a 38.6% change from
200 the placebo result, according to reproducibility data from Scott et al. ¹³. This equated to 10 for
201 round one, 14 for round two, and 17 for round three.

202

203 **Results**

204

205 Mean and standard deviation for each variable in each round is available in Table 1, and the
206 group comparisons and inferences are in Table 2. There were no clear differences between
207 groups for any of the variables, apart from a possibly harmful effect of CMR on RPE in
208 round one.

209

210 **Discussion**

211

212 The purpose of this study was to examine if the addition of carbohydrate to a mouth rinse
213 used between rounds could improve MCRT in amateur boxers. The main findings were that a
214 CMR had no effect on MCRT or perceived exertion.

215

216 Carbohydrate ingestion has been shown to improve reaction time during exercise ^{14,15},
217 possibly by delaying the onset of fatigue. Similarly, previous work has shown that
218 carbohydrate does not necessarily need to be ingested, as a CMR can also improve cognitive
219 function during exercise ⁷. However, we are unable to concur, as there were no clear
220 differences between conditions in the present study. This may be because there was no
221 apparent change in RT through the rounds, whereas Konishi et al. ⁷ saw an exercise induced
222 reduction in RT in their study using 65-min of running. Moriarty et al. ¹⁶ followed a number
223 of amateur boxers through one to three bouts over seven days, and observed that RT pre-bout
224 only changed if a concussion was evident. Our findings add to this, exhibiting that RT is
225 stable across three rounds in amateur boxers. Therefore, the exercise stimulus may not have
226 been strong enough to identify a difference between groups. However, CMR has been shown
227 to improve RT at rest, possibly by enhancing motivation via stimulation of the anterior
228 cingulate cortex and the striatum ⁸. This means that an exercise-induced decrement in RT
229 should not have been necessary to see an ergogenic effect. It may be that the participants in
230 this study were already operating at an optimal level of arousal and motivation due to the
231 competitive nature of the exercise task. Conversely, other authors have also reported no
232 positive effects of a carbohydrate mouth rinse on RT ¹⁷, suggesting that an ergogenic effect is
233 not guaranteed.

234

235 Previous work examining the effects of CMR on RPE during exercise has reported either no
236 change or a benefit ⁶, with no studies observing a harmful effect. In the current study,
237 perceived exertion was marginally higher under the CMR condition in each round, and the
238 intervention had a possibly harmful effect in round one. Scrutiny of the results identifies that
239 this difference is mainly the result of one participant who reported a 57-point difference
240 between conditions. It is not clear why this is the case, but it is a risk associated with using
241 subjective measurements to quantify workload in combat sports ¹⁸. A particular event such
242 as a late punch may have influenced participants' perceived exertion in this study. The
243 absence of an objective measure to accompany perceived exertion is a limitation of the
244 current study, as is the absence of session RPE ¹⁹.

245

246 The current study benefits from a number of factors that enhance its ecological validity, such
247 as the fact that trained amateur boxers performed a familiar translatable task in a familiar
248 environment. Furthermore, each fighter was in preparation for an upcoming competition.

249 However, by the nature of increasing ecological validity, there are some limitations we must
250 acknowledge. Firstly the open nature of the exercise task meant that workload could not be
251 controlled and therefore it cannot be discounted that workload may have been different
252 between visits. An objective measurement of workload such as heart rate alongside perceived
253 exertion could have provided more insight, but this was not possible for logistical reasons.
254 We attempted to minimise the difference between conditions by pairing each participant with
255 somebody that they had experience sparring against, and taking advice from the coach to
256 ensure that participants were matched for size (mass and stature), experience and ability.
257 Secondly, previous authors have suggested that mouth rinsing may have negative
258 implications for performance as it interrupts an athlete's action and breathing ⁴. Boxing was
259 selected as the sport in this study due to the natural rest points between rounds, so minimising
260 any possible negative effect of mouth rinsing identified in studies comparing placebo to a
261 control ⁴. However, boxing is a sport in which it is difficult to quantify performance. Siegler
262 and Hirscher ²⁰ attempted to measure performance by scoring rounds during a competitive
263 fight, however the score may be influenced as much by the opponent as the fighter being
264 observed. RT was included as the outcome in this study as; (i) it could be measured in a
265 closed environment without interference from the opponent, (ii) making fast motor actions
266 under time pressure is an integral aspect of combat sports ⁵, and (iii) others have improved
267 RT using a CMR intervention ^{7,8}.

268

269 **Practical Application**

270

271 Our findings provide no evidence to support the use of a CMR during a sparring session that
272 replicates a 3 x 2-min round bout, but it is unknown whether a CMR may be beneficial during
273 longer training sessions, or during periods of progressive weight loss in preparation for
274 competition. The MCRT used in this study had high repeatability, and the absence of a
275 change in RT within a bout adds to previous literature showing no change between bouts
276 unless a concussion is evident ¹⁶, so future research could look at using RT as a tool for
277 coaches to screen their athletes.

278

279 **Conclusion**

280

281 In conclusion, there is no evidence that the use of a CMR in between rounds improves
282 MCRT.

283

284 **Acknowledgments**

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286 The authors would wish to thank the participants who volunteered for the study, and
287 Northumbria University Boxing Club for allowing us to use their facilities.

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299 **References**

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351 Table 1 Reaction time and perceived exertion in each round (mean \pm SD)
 352

	Round 1	Round 2	Round 3
Reaction time (no. lights)			
PLAC	72 \pm 11	74 \pm 9	77 \pm 10
CMR	77 \pm 6	78 \pm 7	77 \pm 8
Reaction time (s)			
PLAC	0.55 \pm 0.12	0.54 \pm 0.04	0.55 \pm 0.06
CMR	0.52 \pm 0.05	0.53 \pm 0.09	0.52 \pm 0.05
Perceived exertion (CR100)			
PLAC	26 \pm 17	36 \pm 19	45 \pm 26
CMR	36 \pm 26	37 \pm 22	54 \pm 25

353
 354 Table 2. Magnitude based inferences of differences between conditions
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Variable	Comparison	Difference between groups (% mean; 90%CL)	Likelihood (%) of intervention being beneficial / trivial / harmful	Clinical inference
Reaction time (no. lights)	R1 CMR to PLAC	5 \pm 9.5	28.3 / 69.9 / 4.3	Unclear
	R2 CMR to PLAC	4 \pm 3.4	3.0 / 97.0 / 0.0	Very unlikely beneficial, most unlikely harmful
	R3 CMR to PLAC	-1 \pm 8.5	4.2 / 87.6 / 8.1	Unlikely harmful, very unlikely beneficial
Reaction time (s)	R1 CMR to PLAC	-0.03 \pm 0.12	3.5 / 95.6 / 0.9	Very unlikely harmful, very unlikely beneficial
	R2 CMR to PLAC	-0.01 \pm 0.16	5.1 / 91.2 / 3.6	Very unlikely harmful, unlikely beneficial
	R3 CMR to PLAC	-0.03 \pm 0.06	0.2 / 99.8 / 0.0	Most unlikely harmful, most unlikely beneficial
RPE	R1 CMR to PLAC	10 \pm 20	1.4 / 48.6 / 50.0	Possibly harmful, unlikely beneficial
	R2 CMR to PLAC	1 \pm 12	0.0 / 100.0 / 0.0	Most unlikely harmful, most unlikely beneficial
	R3 CMR to PLAC	9 \pm 23	0.3 / 85.6 / 14.0	Unlikely harmful, most unlikely beneficial

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