Title: Quantifying the Effect of Carbohydrate Mouth Rinsing on Exercise Performance

Running head: Carbohydrate mouth rinse review

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ABSTRACT

The purpose of this study was to review the existing literature investigating carbohydrate mouth rinsing (CMR) as an ergogenic aid by using the effect sizes and percentage change in performance of the respective studies as outcome measures. A trivial-small average overall effect size was present for the 25 studies included in the review (0.18, 95% CI = 0.10 to 0.27). Effect sizes for the sub-groups were; ≥25-min (0.25, 95% CI = 0.14 to 0.36), ≤ 180 seconds (0.06, 95% CI = -0.03 to 0.15), resistance exercise (-0.09, 95% CI -0.20 to 0.03) but the effect size is still small. A sub-analysis of ~1-h cycling time trial performance resulted in an overall effect size of 0.20 (95% CI = 0.02 to 0.38), and effect sizes for performance time and power output of 0.31 (95% CI = -0.02 to 0.64) and 0.19 (95% CI = -0.09 to 0.46) respectively. Whilst effect sizes were small the average percentage change in performance in ~1-h trials was 2.48%, which may have implications for elite performers as this is greater than the 1.30% smallest worthwhile change recommended in past research.

KEY WORDS

Carbohydrate, mouth rinse, nutrition, performance

INTRODUCTION

Amidst the research of nutritional practices to enhance exercise performance the ingestion of carbohydrates (CHO) has arguably the most support. There is a wealth of research investigating the effects of consuming CHO before, during and after exercise to support both performance and recovery, with a number narrative reviews available (6, 8, 23, 25, 38). Typically, the ergogenic benefit afforded by CHO is stronger when exercise protocols are ≥2-h in length, supposedly due to the metabolic demand of exercising for this duration. It has also been shown to help performance of shorter protocols of approximately 1-h when intensity is sufficiently high (26, 41). However, some have demonstrated that it can enhance performance in protocols of much shorter durations when metabolic demand is likely to be met by endogenous CHO stores, and therefore may not necessarily warrant exogenous feeding of CHO. In response to this several authors, Carter et al. (7) being the first, have provided evidence that simply rinsing the mouth with CHO (CMR) without ingesting it can influence performance. As the CHO is not ingested it is not possible that it supports the endogenous stores of CHO, and it has been proposed that oral receptors in the mouth may modulate central nervous system responses. Findings from Chambers et al. (9) support this theory as they reported rinsing the mouth with glucose and maltodextrin separately stimulated areas of the brain associated with motor output.

Although this nutritional strategy appears promising, and may be of interest to those who struggle with the possible GI discomfort associated with the ingestion of CHO (8), the literature to support it is still in its relative infancy. De Ataide e Silva et al. (13) performed a systematic review of research available up to May 2013 and concluded that mouth rinsing with CHO 'seems to improve performance', reporting an average improvement of 5.05 W (95% CI = 0.90 to 9.20). However, whilst such reviews are useful as they combine and synthesise findings from

a number of different papers, and it is very difficult to consider all factors in the analysis, this particular review suffers from some limitations. De Ataide e Silva et al. (13) only quantified the findings from studies where power output was the main performance outcome despite the fact that studies report a number of variables including time to completion, time to exhaustion, peak power and average power. Furthermore De Ataide e Silva et al. (13) report mean difference in power output between conditions and not effect size. The reporting of average change in power is useful in a practical sense to help practitioners understand the extent of change, but the use of this statistic alone is vague and may not provide a sufficient understanding of the efficacy of CMR on performance. The aim of this study was to review the existing literature in order to quantify the effect of CHO mouth rinse on exercise performance.

METHODS

A database (SPORTDiscus, Pubmed) search for relevant peer-reviewed articles (excluding abstracts and unpublished theses/dissertations) was performed in September 2016. An original search term of *'carbohydrate OR glucose OR maltodextrin OR dextrose AND mouth rinse AND mouth wash OR exercise OR sport OR performance OR run* OR cyc*'* returned 1,075,933 and 1,492,935 entries in SPORTDiscus and Pubmed respectively. A shorter search term of 'mouth rinse OR mouth wash AND exercise' returned a more manageable 57 and 80 entries in SPORTDiscus and Pubmed respectively. Further searches consisted of entering various combinations of the following key words into Google Scholar; 'carbohydrate', 'mouth rinse', 'mouth wash', 'sport performance', 'sport', 'exercise', 'running' and 'cycling'. A manual cross-reference of relevant articles and review articles was also performed. Identified studies were included on the basis that they were performed on humans under normothermic conditions, clearly stated the type of CHO in the mouth rinse, used a placebo controlled

repeated measures design, the mouth rinse was tested using a single exercise, and the relevant raw data was available to calculate effect sizes (i.e. mean and standard deviation or standard error). The following studies were excluded from the analysis; Beaven et al. (3) because raw data was not available for the placebo condition (an attempt was made to contact the author), Rollo et al. (39) because the performance outcome was self-selected running speed which is not in itself a performance measure *per se* that could be compared to the outcomes of other studies in the same sub-analysis, Rollo et al. (40) because CMR was not compared to a placebo mouth rinse, Rollo et al (review) because it was a review article, and three studies were excluded because the mouth rinse efficacy could have been influenced by a prior exercise (1, 30, 36). An overview of the search strategy is outlined in Fig 1.

The effectiveness of the mouth rinsing was quantified by determining the effect size for each variable, which can be categorised as small (0.2), moderate (0.5) or high (0.8). This was calculated using the following equation (this equation was reversed in the case of those studies employing performance time as the performance measure, as a lower number is beneficial):

ES = (Mean of CHO – Mean of placebo) ÷ SD of placebo

Some studies reported the standard error of the mean rather than the standard deviation. Standard deviation was calculated from these studies using the following equation:

$SD = s_{\bar{x}} \times \sqrt{n}$

A weighted effect size was then calculated to account for changes in individual sample sizes as used by Matson and Tran (31) and Peart et al. (33) :

106 $Weighted\ ES = \sum[(ES)(n)] \div \sum n$

107

108 The most common exercise protocol of a ~1-h cycling time trial with ~6% CHO was used by
109 8/25 studies, therefore a sub-analysis on these studies was conducted to allow a comparison of
110 findings from a similar exercise. As both power and time to completion were used as
111 performance measures for the ~1-h cycling time trials a further sub-analysis on these was
112 performed. Percentage changes in performance were analysed in this further sub-analysis and
113 interpreted as recommended by Hopkins (20).

114

115 **RESULTS**

116 Table 1 describes the 25 included articles that allowed the analysis of 56 effect sizes (Table 2).
117 The overall effect size for the influence of CMR on performance exclusive of other factors was
118 0.18 (weighted = 0.18) and the small effect size for exercises that lasted longer than 25-min
119 (0.25) was on average higher than the trivial effect size for shorter exercises lasting under 3-
120 min (0.06). No statistical comparison was made between the groups due to the differing sample
121 sizes, but of note is that the upper 95% CI for shorter exercise was almost identical to the lower
122 95% CI for longer exercises, suggesting a possible difference. There was an average negative
123 effect size for resistance exercises, with the majority of the 95% CI lower than null. The most
124 common exercise protocol of a 1-h cycling time trial with ~6% CHO was used by 8/25 studies,
125 therefore a sub-analysis of these studies was conducted to allow a comparison of findings from
126 a similar exercise (Table 2). The overall effect size of these studies was 0.20, and the upper
127 95% CI approached moderate and reached moderate-large effect sizes for power output and
128 time to completion respectively.

DISCUSSION

The average effect sizes reported in this study can be classified as trivial-small, and some of the lower 95% CI marginally cross 0, suggesting a trivial chance of a negative impact upon performance. However, it must also be noted that some of the upper 95% CI reach 0.64 suggesting that there may be a moderate benefit for some individuals. Table 2 identifies that the higher effect sizes are typically in exercises lasting 25-min or greater, and there has been a particular focus on cycling time trials of approximately 1-h administering ~6% CHO. A number of studies implementing this protocol have reported small-moderate effect sizes of 0.3 to 0.5 (7, 9, 19, 29, 35), however the average effect size is only small (Table 2). This may be influenced by the small effect size reported by Beelen et al. (4), but is more than likely due to the small negative effect size shown by Ispoglou et al. (21). In fact, if Ispoglou et al. (21) are removed from the analysis the mean effect size for time trial performance increases from 0.31 to 0.41, demonstrating the impact that this study has on the final effect size. There are some methodological differences between these studies such as pre-participation fasting times. The low effect size reported by Beelen et al. (4) was attributed to participants being in a fed state, and other authors have shown that effect sizes are higher when CMR is used in a fasted state (17, 29). However this cannot explain the negative effect size from Ispoglou et al. (21) as participants performed the trial following a 3-h fast, similar to the 2-4 h fast used in other studies (7, 19, 29). Unfortunately, the number of differing fasting protocols and relatively small number of studies in resulting sub-groups did not allow for a sub-analysis for the effect of fasting on CMR efficacy. There is also some disparity between studies for duration of the rinse (typically 5 or 10 seconds). However, this also cannot explain the much lower effect in the Ispoglou et al. (21) study as the 5-s rinse used was comparable to Carter et al. (7) and Gam et al. (19). Another consideration is that the true effect of the CMR in many of these studies is

unclear as very few compare CMR to a control condition. Gam et al. (19) argued that a control condition is essential in future work as whilst they reported a significant difference between CMR and a placebo, they found that a control was just as beneficial compared to the placebo (their effect size reduces from 0.33 to 0.17 when CMR is compared to control rather than a placebo). It could be the case that the action of rinsing the mouth may impact upon performance by interrupting the participant, and this small decline in performance may be off-set by the CHO content i.e. performance returned to control conditions as opposed to being improved. Further work is needed to compare CMR to a control, perhaps in more ecological settings where small interruptions may have a greater practical consequence.

Whilst effect sizes were on average trivial-small it should be considered that at the elite level a small effect may be practically significant in competition. Although some studies observed 'physically active' participants, a strength of the current body of research is that the majority of studies observed participants specifically trained for the task (Table 1.). In fact, all of the studies in the ~1-h cycling time trial sub-group analysis apart from Devenney et al. (15) recruited cyclists or triathletes, and although the effect size was small the average improvement in time to completion was 2.48% (Table 2). To put this into context Hopkins (20) suggests that the smallest worthwhile change for cycling time trial time to completion is 1.3%, and other authors have reported less substantial improvements in performance of 0.16% (14) and 2.34% (24) for the same task when CHO was ingested. Moreover, Pottier et al. (35) actually observed significant improvements in 1-h cycling time trial performance when using a mouth rinse, but not when ingesting the CHO.

Resistance exercises had on average a negative effect size with most of the 95% CI range being below 0, suggesting a potentially adverse effect upon performance. However, it should be considered that this has been based on only two studies (11, 32), and the performances between conditions in these studies were almost identical (Table 1). The average negative effect size is likely due to participants performing one less repetition in a repetition to fatigue exercise in Clarke et al. (11), which was within the reported normal variation for the outcome. Therefore, whilst there is no evidence to support CMR for resistance exercise, there is also not enough evidence to portray it as being detrimental.

It is evident that more work is needed in the area to standardise testing procedures to facilitate practitioner and athlete interpretation of findings. In particular, it would be of benefit to see more comparisons to a control condition. The current evidence suggests that CMR is not ergogenic for very short duration exercises lasting less than 3-min, and that CMR may be more beneficial for exercises of approximately 1-h but the effect sizes are variable (see CIs in Table 2). It is worth noting that whilst the effect sizes are on average trivial-small they may be higher than the smallest worthwhile change for elite performers.

PRACTICAL APPLICATIONS

The evidence reviewed in this paper suggests that the average performance enhancement afforded by CMR is trivial-small, but may be greater than the smallest worthwhile effects for elite athletes. It is unclear if the small effects would provide any meaningful benefit to sub-elite performers, however it should be considered that the average effect is not necessarily true for every athlete and the broad confidence intervals suggest that CMR may be worth

experimenting with on an individual basis. Athletes whose events last 25-60 min may be more likely to observe an ergogenic effect than those taking part in shorter more anaerobic events and/or resistance exercises. For events and activities lasting more than 60 min the cost-benefit relationship to withholding the ingestion of CHO should be considered. Finally, although not included as a sub-analysis in this review some authors have suggested that CMR is more effective when in a fasted state. Once again the cost-benefit relationship should be considered for competing in a fasted state, but practitioners may wish to consider CMR if training in a low glycogen state.

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Table 1. Summary of research articles used for analysis (chronological order)

Study	Subjects	Exercise *(CHO rinse)*	Effect Size	% change	$P \leq 0.05$
Carter et al. (7)	7 male and 2 female cyclists	~ 1-h cycling TT (914 kJ) *(6.4% maltodextrin)*	Time = 0.40 AP = 0.15	2.93% 2.70%	Y Y
Whitham and McKinney (43)	7 recreationally active males	15-min (65% $\dot{V}O_2$ max) followed by 45-min running TT *(6.4% maltodextrin)*	Distance = 0.02	0.26%	N
Beelen et al. (4)	14 male endurance athletes	~ 1-h cycling TT (1053 kJ) *(6.4% maltodextrin)*	Time = -0.08 AP = -0.06	-0.54% -0.38%	N N
Chambers et al (9)	8 male cyclists 6 male and 2 female participants (activity level not specified)	~ 1-h cycling TT (914 kJ) *(6.4% glucose)* ~ 1-h cycling TT (837 kJ) *(6.4% maltodextrin)*	Time = 0.32 Time = 0.42	1.95% 3.10%	Y Y
Pottier et al. (35)	12 triathletes (sex not specified)	~ 1-h cycling TT (975 kJ) *(6% isotonic carbohydrate-electrolyte solution)*	Time = 0.47	3.74%	Y
Rollo et al. (37)	10 male runners	1-h running TT *(6.4% isotonic carbohydrate-electrolyte solution)*	Distance = 0.29	1.48%	Y
Chong et al. (10)	14 male cyclists	30-s maximal cycle sprint *(6.4% isotonic carbohydrate-electrolyte solution)* 30-s maximal cycle sprint *(7.1% glucose)*	PP = -0.10 AP = 0.06 PP = -0.13 AP = 0.00	-1.01% 0.47% -1.18% -	N N N N
Fares and Kayser (17)	13 non-athletic males	60% Wmax cycle to exhaustion following a controlled breakfast *(6.4% maltodextrin)* 60% Wmax cycle to exhaustion following an overnight fast *(6.4% maltodextrin)*	TEX = 0.17 TEX = 0.37	3.36% 10.39%	Y Y
Painelli et al. (32)	12 recreationally strength trained males	1-RM bench press (*6.4% dextrose)*	KG = 0.00	-	N
Bortolotti et al. (5)	9 under-15 soccer players	Repeated sprint ability test *(6% maltodextrin)*	Mean = 0.02 Best = -0.02	0.08% -0.08%	N N
Dorling and Earnest (16)	8 active males	Repeated sprint ability test *(6.4% maltodextrin)* Loughborough Intermittent Shuttle Test *(6.4% maltodextrin)*	Mean = 0.12 Mean = -0.10	0.58% -0.57%	N N
Gam et al. (19)	10 male cyclists	~ 1-h cycling TT (1000 kJ) *(6.4% maltodextrin)*	Mean = 0.33	5.33%	Y
Lane et al. (29)	12 male cyclists	1-h cycling TT following a controlled breakfast *(10% maltodextrin)* 1-h cycling TT following an overnight fast *(10% maltodextrin)*	AP = 0.29 AP = 0.43	1.75% 3.19%	Y Y
Wright and Davison (44)	7 physically active males	90-min treadmill TT *(6% carbohydrate-electrolyte solution)* 90-min treadmill TT *(12% carbohydrate-electrolyte solution)*	Distance = 0.41 Distance = 0.59	4.79% 6.71%	Y Y
Phillips et al. (34)	12 physically active males	30-s maximal cycle sprint *(6.4% maltodextrin)*	PP = 0.14	2.29%	Y

Sinclair et al. (42)*	11 male recreational cyclists	30-min cycling TT *(6.4% maltodextrin)*	Distance = 0.55 AP = 0.73	5.88% 6.36%	Y Y
Clarke et al. (11)	15 recreationally resistance-trained males	1-RM bench press *(6% maltodextrin)* Reps to fatigue at 60% 1-RM *(6% maltodextrin)* Total weight lifted *(6% maltodextrin)*	KG = 0.24 Total = -0.2 KG = -0.01	4.44% -4.76% -0.18%	N N N
Fraga et al. (18)	6 endurance trained men	Run to exhaustion at 85% $\dot{V}O_2$ max (*8% dextrose*)	TEX = 0.80 Distance = 0.64	25.09% 24.68%	Y Y
Ispoglou et al. (21)	9 male cyclists	~ 1-h cycling TT *(4% carbohydrate-electrolyte solution)* ~ 1-h cycling TT *(6% carbohydrate-electrolyte solution)* ~ 1-h cycling TT *(8% carbohydrate-electrolyte solution)*	Time = -0.20 AP = -0.11 Time = -0.41 AP = -0.18 Time = -0.25 AP = -0.14	-1.29% -1.21% -2.26% -2.03% -1.61% -1.62%	N N N N N N
Jeffers et al. (22)	9 male cyclists/triathletes	45-min cycle at 70% Wmax followed by a 15-min TT *(6.4% maltodextrin)*	AP = 0.00	-	N
Bastos-Silva et al. (2)	13 physically active males	Cycle to exhaustion 110% PPO *(6.4% maltodextrin)* Cycle to exhaustion 80% respiratory compensation point *(6.4% maltodextrin)*	TEX = 0.54 TEX = 0.74	8.07% 14.62%	Y Y
Clarke et al. (12)	15 healthy men	5-km running TT (3% maltodextrin) 5-km running TT (6% maltodextrin) 5-km running TT (12% maltodextrin)	Time = -0.16 Time = -0.13 Time = -0.05	-2.70% -1.94% -0.82%	N N N
Devenney et al. (15)	12 recreationally active males	~ 1-h cycling TT *(6% maltodextrin)* ~ 1-h cycling TT *(16% maltodextrin)*	Time = 0.50 AP = 0.48 Time = 0.58 AP = 0.61	5.62% 7.06% 6.32% 7.91%	Y Y Y Y
Kasper et al. (27)	8 recreationally active males	High-intensity running protocol *(10% maltodextrin)*	TEX = 0.73	30.77%	Y
Kulaksiz et al. (28)	9 recreational cyclists	20-km cycling TT *(3% maltodextrin)* 20-km cycling TT *(6% maltodextrin)* 20-km cycling TT *(12% maltodextrin)*	Time = 0.03 AP = 0.05 Time = 0.02 AP = 0.23 Time = 0.21 AP = 0.00	0.25% 0.49% 0.25% 2.38% 2.24% -	N N N N N N

*Analysis only includes the 10-s rinse trial as raw data was not available for the 5-s rinse trial; AP =average power; PP = peak power; TEX = time to exhaustion; Wmax = watt max; PPO = peak power output; TT = time trial; KG =kilograms; reps = repetitions; 1-RM = one rep max; Y = yes; N = no.

Table 2. Summary of Effect Sizes

Measure	No. of ES	Effect size				
		Mean	SD	95% CI	Weighted ES	% change
Overall	56	0.18	0.30	0.10, 0.27	0.18	-
Resistance exercise	4	-0.09	0.07	-0.20, 0.03	-0.09	-
≤180 seconds	15	0.06	0.17	-0.03, 0.15	0.06	-
≥25-min	37	0.25	0.34	0.14, 0.36	0.25	-
1-h cycling TT with ~6% CHO (overall)	14	0.20	0.31	0.02, 0.38	0.21	-
1-h cycling TT time with ~6% CHO (time to completion)	8	0.31	0.25	-0.02, 0.64	0.31	2.48%
1-h cycling TT power with ~6% CHO (power output)	6	0.19	0.27	-0.09, 0.46	0.21	1.93%

≥25-min most of these studies were over 30-min but the threshold was set at 25-min to allow the inclusion of Clarke et al. (12). 1-h cycling TT includes Beelen et al. (4), Carter et al. (7), Chambers et al. (4), Gam et al. (19), Ispoglou et al. (21), Lane et al. (29), Pottier et al. (35). ES = effect size, TT = time trial, CHO = carbohydrate, CI = confidence intervals.

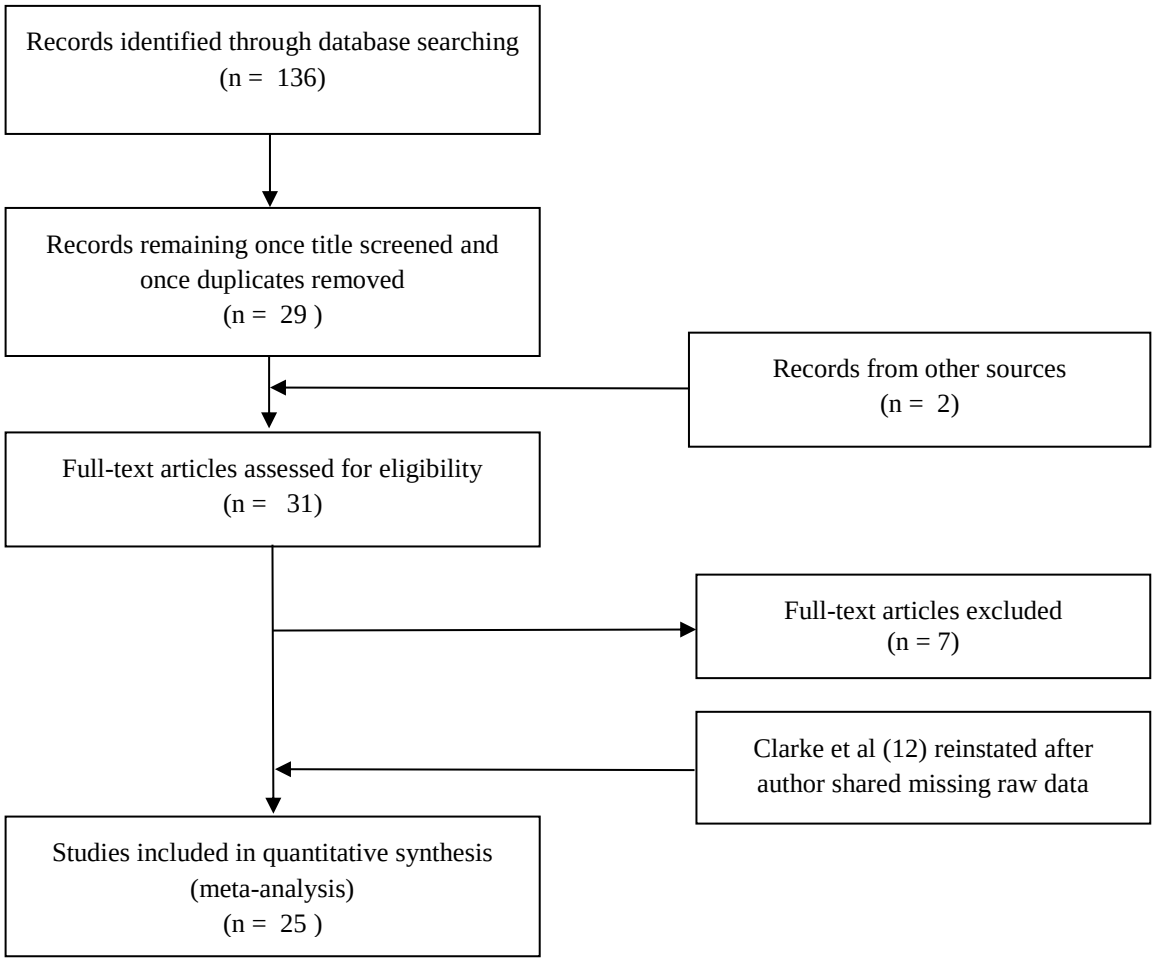

Fig 1. Study selection process