Addition of sodium alginate and pectin to a carbohydrate-electrolyte solution does not influence substrate oxidation, gastrointestinal comfort or cycling performance

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Abstract

Eight well-trained cyclists ingested 68 $g \cdot h^{-1}$ of a carbohydrate-electrolyte solution with sodium alginate and pectin (CHO-ALG) or a taste and carbohydrate type-matched carbohydrate-electrolyte solution (CHO) during 120 min cycling at 55% W_{max} followed by a ~20 min time trial. $\dot{V}O_2$, $\dot{V}CO_2$ blood glucose concentration, substrate oxidation, gastrointestinal symptoms and time trial performance (CHO-ALG: 1219 ± 84 s, CHO: 1267 ± 102 s; $P = 0.185$) were not different between trials.

- Inclusion of sodium alginate and pectin in a carbohydrate drink does not influence blood glucose, substrate oxidation, gastrointestinal comfort or performance in cyclists

Key words: hydrogel, oxidation, exercise performance, gastrointestinal, cycling, sports drink

Introduction

It is well established that carbohydrate ingestion during prolonged endurance exercise enhances performance (Stellingwerff and Cox 2014). Current recommendations for exercise >2 h suggest an ingestion rate of 60-90 $g \cdot h^{-1}$ of either single or multiple carbohydrate sources (Jeukendrup 2011). When ingestion rates are high, there is increased risk of gastrointestinal issues (Pfeiffer et al. 2012), particularly if this is maintained over several hours and/ or intensity is high (e.g. a cycling criterium or a 2-3 h marathon).

To try and minimise these issues, and to increase delivery of carbohydrate to the muscles, some sports drinks manufacturers have included sodium alginate and pectin, which is designed to form a hydrogel when combined with the acidic environment in the stomach (Sutehall et al. 2018). It is hypothesised that formation of a hydrogel encapsulating the carbohydrate may enhance gastric emptying and allow carbohydrate to pass through the duodenum without activating glucose receptors. However, evidence of this is yet to be demonstrated in peer reviewed literature. Recent studies have shown no differences in blood glucose concentration, substrate oxidation, gastrointestinal (GI) comfort or exercise performance in runners (3 h at 60% $\dot{V}O_{2max}$ followed by exercise capacity test, McCubbin et al. 2019) or cyclists (98 min of varying intensity exercise followed by high intensity sprints, Baur et al. 2019). Whilst increases in mechanical motion with running presents unique challenges to the GI system, assessing the drink in prolonged steady-state cycling provides an opportunity to investigate substrate use and performance when gastric emptying is not likely to be impaired due to exercise mode and/ or intensity.

The aim of the study was to investigate if a carbohydrate-electrolyte drink containing sodium alginate and pectin would affect substrate utilisation or subjective GI responses during prolonged sub-maximal cycling and subsequent time trial performance compared to a similar

carbohydrate-electrolyte only drink. It was hypothesised that the drink containing sodium alginate and pectin would increase carbohydrate oxidation, gastrointestinal comfort and exercise performance.

Methods

Ten well-trained cyclists were recruited but two were removed due to failure to standardise exercise in the 24 h preceding the trial, meaning eight cyclists were included in the analysis. Subjects (mean ± SD: age 32 ± 5 y, body mass 74.0 ± 10.4 kg, height 1.81 ± 0.08 m, maximum power output 375 ± 53 W, peak oxygen uptake 62.1 ± 6.9 $mL \cdot kg^{-1} \cdot min^{-1}$) performed two double-blind trials in a randomised counter-balanced order, after providing written informed consent. Study approval was provided by the Loughborough University Ethics approvals (Human Participants) Sub-Committee.

Subjects attended the laboratory for a $\dot{V}O_{2peak}$ test, a familiarisation and two experimental trials, with a different drink ingested in each trial. Subjects were informed that they would be consuming a different sports drink in each trial and were not made aware of the differences between drinks. All were experienced ingesting carbohydrate gels and drinks during training and/ or racing.

At the first visit, subjects completed a $\dot{V}O_{2peak}$ test on an electronically braked cycle ergometer (Lode Excalibur: Lode BV, Groningen, The Netherlands) using a continuous incremental protocol to determine maximal power (W_{max}) (described in Mears et al. 2018). On the second visit, subjects were familiarised with the methods used in the experimental trials. They completed 80-120 min at 55% W_{max}, ingesting tap water as per drinks in the experimental trials, to produce a fatigued state, followed by a cadence-dependent linear factor time trial, involving completing at set amount of work as quickly as possible. Target work set was calculated to last 20 min if cycling at 80% W_{max} using the formula:

$$Target\ kJ\ = \frac{(Wmax\ \times 0.8\ \times 1200s)}{1000}$$

During the time trial, subjects could see the work completed and were provided with verbal confirmation of when 25, 50 and 75% of the target had been achieved. No feedback related to time elapsed, power output, heart rate or cadence was provided. Heart rate and time to complete each 25% section were recorded. No fluid was ingested during the time trial.

In the 24 h prior to the first experimental trial, subjects recorded all food/ fluid ingested and any activity completed, replicating these patterns before the second trial. Subjects consumed a standardised breakfast (1.5 $g \cdot kg^{-1}$ body mass of carbohydrate and 8 $mL \cdot kg^{-1}$ body mass of fluid; Nutri-Grain, Kellogg's, UK; Orange Juice, Tesco, UK; Water) 90 min before arrival at the laboratory, which was between 07:30 and 09:30 (standardised within subjects).

After arriving at the laboratory, subjects sat for 10 min, before a 5 min resting gas sample (Douglas bags) and 20 μL fingertip capillary blood sample were taken and heart rate measured (Polar M400, Kempele, Finland). Subjects rated subjective feelings of headache, nausea, thirst, gastrointestinal comfort, stomach cramp, stomach fullness and stomach bloating (0= no feeling, 10= extreme feeling; values $\geq$5 classed as severe, Jeukendrup et al. 2000). Subjects completed a 5 min warm up and then cycled for 120 min at 55% W_{max} (SS). Prior to an expired gas sample collected between 19 and 20 min, subjects provided responses to gastrointestinal symptoms. During the gas collection, a 20 μL fingertip capillary blood sample was taken and heart rate and rating of perceived exertion (RPE) were recorded. This was repeated every 20 min. Drinks (143 mL, $1/7^{th}$ total volume) were consumed at 0 min and every 20 min (after measurements), providing a total of 1L over the 120 min. After 10 min rest, subjects completed the time trial, had a final blood sample and rated subjective feelings. Upon completion of both experimental trials, subjects were asked if there was a difference

between the drinks, were they fuller in a particular trial and which trial they believed they had performed better on.

Drinks were either a commercial maltodextrin and fructose drink containing sodium alginate, pectin and sodium chloride (CHO-ALG; Maurten Drink Mix 320, Maurten, Gothenburg, Sweden) or a matched carbohydrate drink (CHO), containing maltodextrin (MyProtein, Northwich, UK), fructose (Bulk Powders, Colchester, UK) and sodium chloride (table salt, Tesco, UK). One litre of water (Ashbeck still mineral water, Tesco, UK) was added to the dry ingredients of each drink, producing approximately 1150 mL. Carbohydrate ingestion rate during each trial was 68 $g \cdot h^{-1}$ provided in 500 $mL \cdot h^{-1}$.

Capillary tubes containing the blood samples were placed in Eppendorfs containing 1 mL of haemolysing solution (EKF Diagnostics, Cardiff, UK) and analysed for lactate and glucose concentrations (Biosen C-Line; EKF Diagnostics, Cardiff, UK).

Statistical analysis

Data were checked for normality of distribution using Shapiro-Wilks tests. Data containing one factor were analysed using paired t-tests. Two-way repeated measures ANOVA were used to analyse data containing two factors and were followed with post-hoc paired samples t-test with Holm-Bonferroni correction when a significant effect was detected. Cohen's *d* effect sizes (ES) were calculated on pairwise comparisons with thresholds of 0.2, 0.5 and 0.8 for small, medium and large effects respectively. Statistical significance was accepted when $P < 0.05$. Data are mean ± SD. Data were analysed using SPSS for Windows (version 23.0; SPSS Inc, Chicago, IL).

Results

Time to complete the time trial was not different between trials (CHO-ALG: 1219 ± 84 s, CHO: 1267 ± 102 s; $P = 0.185$; ES = 0.44, figure 1). Pacing was not different across each 25% segment or between trials (time x trial interaction, $P = 0.555$). Mean blood glucose ($P = 0.166$; ES = 0.26) and lactate ($P = 0.525$; ES = 0.15) concentrations were not different between trials during SS exercise (table 1), however blood lactate concentrations did rise in both trials following completion of the TT (time effect, $P = 0.003$). $\dot{V}O_2$, $\dot{V}CO_2$, carbohydrate oxidation, fat oxidation, RER and HR were not different between trials during SS exercise (all ES < 0.03; table 1). RPE was slightly increased during SS in CHO-ALG ($P = 0.021$).

Subjective responses to GI symptoms were not different between trials during SS, except for stomach fullness which was higher in CHO-ALG (3.2 ± 1.2 vs. 2.8 ± 0.9, $P = 0.020$). During SS, the highest incidence of severe symptoms ($\geq$ 5 out of 10) were recorded for thirst (CHO-ALG: 27/48 timepoints; CHO: 22/48 timepoints). For stomach fullness, 9/48 (CHO-ALG) and 3/48 (CHO) timepoints were severe, whilst for stomach bloating 2/48 timepoints were rated severe during the CHO trial. When questioned after completion of both trials, four out of the eight subjects stated they perceived a difference between the drinks but were not aware of the contents. When asked to describe which trial they felt they had a fuller stomach, four felt no difference between trials, one felt fuller on CHO, and three felt fuller during CHO-ALG.

Discussion

The main finding of this study was that, contrary to the hypothesis, including sodium alginate and pectin in a carbohydrate-electrolyte drink ingested during 120 min steady-state cycling did not affect subsequent cycling time trial performance compared to a carbohydrate-electrolyte drink. Additionally, there was no difference between drinks for substrate oxidation, blood glucose/ lactate concentrations or subjective GI symptoms during the 120 min steady state cycle.

The results of this study were similar to those observed by McCubbin et al. (2019) in runners and Baur et al. (2019) in cyclists despite the slightly reduced carbohydrate intake in our study. Both studies found no difference in glucose concentrations, carbohydrate and fat oxidation and subsequent exercise performance when comparing similar drinks. Although the fate of the ingested carbohydrate cannot be determined from these studies, the current and previous studies suggest that addition of sodium alginate and pectin to drinks ingested during exercise does not influence exogenous carbohydrate utilisation. As performance in all studies were not different between drinks, it was likely that the contributions were not different as any sparing of endogenous stores would likely have contributed to an enhanced exercise performance.

Increased gastric emptying has been proposed as one of the potential benefits of including sodium alginate and pectin in drinks consumed during exercise, through the formation of a hydrogel (Sutehall et al. 2018). Gastric emptying was not measured in the current study, however the similar concentrations of blood glucose and carbohydrate oxidation rates in both trials would suggest gastric emptying and intestinal absorption were not different and therefore did not affect rate of glucose appearance into the blood and uptake into the muscles. The amount of carbohydrate consumed in this study was within the range recommended for

exercise of 2-3 h (Jeukendrup, 2011) but was towards the lower end of this when using multiple transportable carbohydrates. Whilst this may be considered a limitation, as one might expect less stress on the GI system, McCubbin et al. (2019) and Baur et al. (2019), found no differences when providing higher amounts of CHO (90 and 78 $g \cdot h^{-1}$ respectively). Therefore, it is yet to be seen whether the proposed advantages of CHO-ALG are only observed when ingestion rates are higher than current recommendations (i.e. 90+ $g \cdot h^{-1}$). Further examination of gastric emptying rate and the impact on oxidation rates is required using appropriate measurement techniques that are not potentially confounded by the hydrogel formation.

Subjective responses to symptoms of gastrointestinal comfort, except for stomach fullness, were not different between trials. Gastrointestinal symptoms of comfort have been negatively correlated with the amount of carbohydrate ingested (Pfeiffer et al. 2012). In the current study there was a greater sensation of stomach fullness in CHO-ALG, possibly due to the hydrogel forming in the stomach but this was marginal and probably not caused by differences in gastric emptying (Camps et al. 2016).

Conclusion

Inclusion of sodium alginate and pectin in a carbohydrate-electrolyte solution did not influence time trial performance, blood glucose concentration, substrate oxidation or perceptual measures of GI comfort. Further investigation of gastric emptying rates during exercise and exogenous carbohydrate oxidation rates would increase understanding of how sodium alginate and pectin addition to sports drinks may impact substrate metabolism and performance.

Conflict of interest and disclosure

No external funding was obtained for the current study. LJJ has previously received funding from PepsiCo Inc. and Volac International, performed consultancy for PepsiCo Inc. and Lucozade, Ribena Suntory and received conference fees from PepsiCo Inc. and Danone Nutricia. In all cases, monies have always been paid to LJJs institution and not directly to LJJ.

References

Baur, D.A., Toney, H.R., Saunders, M.J., Baur, K.G., Luden, N.D., and Womack, C.J. 2019. Carbohydrate hydrogel beverage provides no additional cycling performance benefit versus carbohydrate alone. Eur. J. Appl. Physiol. doi:10.1007/s00421-019-04240-4.

Camps, G., Mars, M., De Graaf, C., and Smeets, P.A. 2016. Empty calories and phantom fullness: a randomized trial studying the relative effects of energy density and viscosity on gastric emptying determined by MRI and satiety. Am. J. Clin. Nutr. 104(1): 73-80. doi:10.3945/ajcn.115.129064.

Jeukendrup, A.E. 2011. Nutrition for endurance sports: Marathon, triathlon, and road cycling. J. Sports Sci. **29**(S1): S91-9. doi:10.1080/02640414.2011.610348.

Jeukendrup, A.E., Vet-Joop, K., Sturk, A., Stegen, J.H., Senden, J., Saris, W.H., et al. 2000. Relationship between gastro-intestinal complaints and endotoxemia, cytokine release and the acute-phase reaction during and after a long-distance triathlon in highly trained men. Clin Sci. **98**: 47-55.

McCubbin, A.J., Zhu, A., Gaskell, S.K., and Costa, R.J.S. 2019. Hydrogel carbohydrate-electrolyte beverage does not improve glucose availability, substrate oxidation, gastrointestinal symptoms or exercise performance, compared with a concentration and nutrient-matched placebo. Int. J. Sport Nutr. Exerc. Metab. doi: 10.1123/ijsnem.2019-0090.

Mears, S.A., Dickinson, K., Bergin-Taylor, K., Dee, R., Kay, J., and James, L.J. 2018. Perception of breakfast ingestion enhances high-intensity cycling performance. Int. J. Sports Physiol. Perf. **13**:504-509. doi:10.1123/ijspp.2017-0318.

Pfeiffer, B., Stellingwerff, T., Hodgson, A.B., Randell, R., Pottgen, K., Res., P., et al. 2012. Nutritional intake and gastrointestinal problems during competitive endurance events. Med. Sci. Sports. Exerc. **44**(2): 344-351. doi:10.1249/MSS.0b013e31822dc809.

Stellingwerff, T., and Cox, G.R. 2014. Systematic review: Carbohydrate supplementation on exercise performance or capacity of varying durations. Appl. Physiol. Nutr. Metab. **39**(9): 998-1011. doi:10.1139/apnm-2014-0027.

Sutehall, S., Muniz-Pardos, B., Bosch, A.N., Di Gianfrancesco, A., and Pitsiladis, Y.P. 2018. Sports drinks on the edge of a new era. Curr. Sports Med. Rep. **17**(4): 112-116. doi:10.1249/JSR.0000000000000475.

Table 1. Mean whole-body oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), respiratory exchange ratio (RER), substrate oxidation rates and blood glucose/ lactate concentrations during the steady-state (SS) exercise period (20-120 min) and post time trial (TT).

	SS (20-120 min)			TT		
	CHO-ALG	CHO	*P*	CHO-ALG	CHO	*P*
$\dot{V}O_2$ ($L \cdot min^{-1}$)	2.96 ± 0.35	2.95 ± 0.37	0.942	-	-	-
$\dot{V}CO_2$ ($L \cdot min^{-1}$)	2.70 ± 0.37	2.69 ± 0.35	0.738	-	-	-
RER	0.91 ± 0.03	0.91 ± 0.02	0.857	-	-	-
Carbohydrate oxidation ($g \cdot min^{-1}$)	2.59 ± 0.60	2.56 ± 0.44	0.772	-	-	-
Fat oxidation ($g \cdot min^{-1}$)	0.42 ± 0.15	0.42 ± 0.12	0.793	-	-	-
Heart rate ($b \cdot min^{-1}$)	147 ± 10	145 ± 7	0.224	182 ± 9	181 ± 12	0.825
RPE	13 ± 1	12 ± 1	0.021	19 ± 1	19 ± 1	0.591
Blood glucose conc. ($mmol \cdot L^{-1}$)	4.73 ± 0.35	4.85 ± 0.40	0.166	5.10 ± 1.67	4.16 ± 0.76	0.160
Blood lactate conc. ($mmol \cdot L^{-1}$)	2.08 ± 0.89	1.92 ± 0.81	0.525	6.42 ± 2.93	5.44 ± 2.83	0.420

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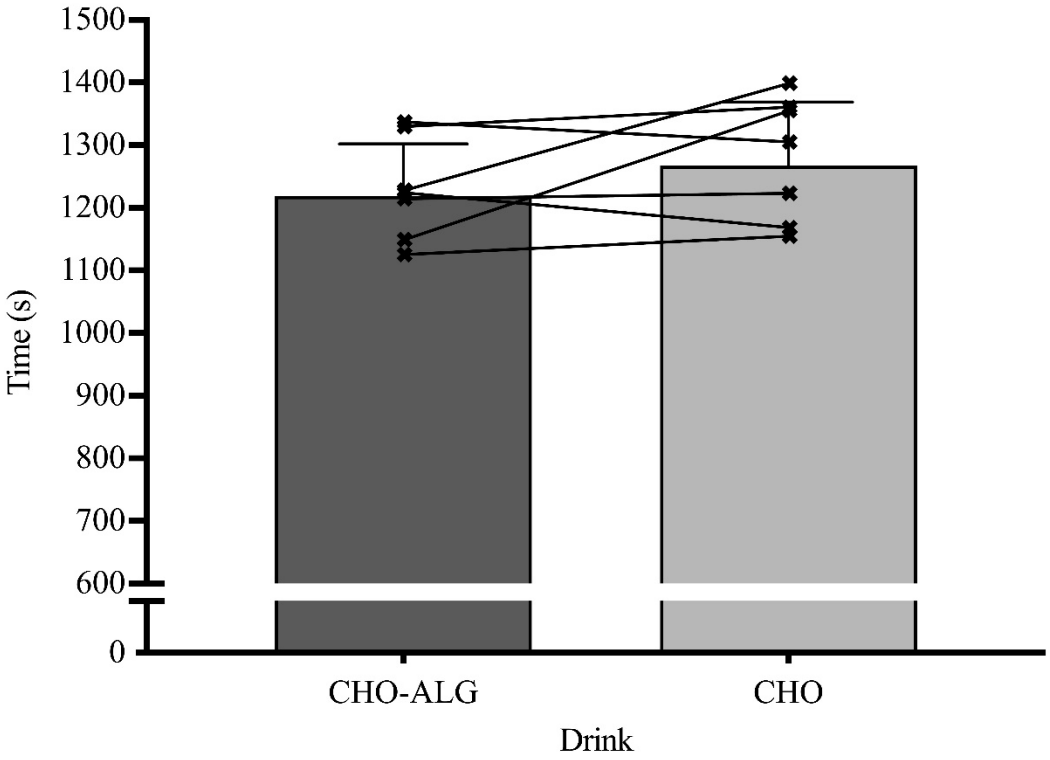
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