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Effects of milk ingestion on prolonged exercise capacity in young, healthy men

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Abstract

Objective: The effects of fluid intake during prolonged exercise have been extensively studied but at present there exists little information on the effects of milk-based drinks on the response to prolonged exercise. Thus, the purpose of this study was to investigate the effects of milk-based drinks on exercise capacity.

Methods: Eight healthy males (age 24 ± 4 y, height 1.76 ± 0.04 m, mass 68.9 ± 9.5 kg, body fat 12.5 ± 2.4%, peak oxygen consumption 4.3 ± 0.6 L/min) exercised to volitional exhaustion at 70% peak oxygen consumption on four occasions. Subjects ingested 1.5 mL/kg body mass of plain water, a carbohydrate-electrolyte solution, low-fat (0.1%) milk, or low-fat (0.1%) milk with added glucose before and every 10 min during exercise. The effect of the drink on exercise capacity and the cardiovascular, metabolic, and thermoregulatory responses to prolonged exercise were examined.

Results: Exercise time to exhaustion was not significantly influenced by the drink ingested ($P = 0.19$), but there was a tendency for subjects to exercise longer when the carbohydrate-electrolyte (110.6, range 82.0–222.7 min), milk (103.3, range 85.7–228.5 min), or milk plus glucose (102.8, range 74.3–167.1 min) was ingested compared with water (93.3, range 82.4–192.3 min). The solution ingested did not influence the cardiovascular, metabolic, or thermoregulatory response to exercise.

Conclusion: The results of this study suggest that although the low-fat milk-based fluids did not enhance exercise capacity over that seen with the ingestion of plain water, the effect was comparable to that observed with a carbohydrate-electrolyte beverage.

Keywords: Carbohydrate; Protein; Lactose; Exercise

Introduction

The primary limitations to the capacity to perform prolonged exercise in temperate conditions are thought to be the availability of carbohydrate (CHO) and the progressive loss of body fluids [1]. The ingestion of exogenous CHO has been demonstrated to spare muscle [2,3] and liver [4] glycogen, maintain circulating blood glucose concentrations [2,5], and increase rates of CHO oxidation [2]. These factors appear to account for the increase in exercise capacity reported when CHO is ingested before and during prolonged exercise [2,5,6], although a direct or indirect effect on the central nervous system cannot be discounted. The ingestion of fluids also prolongs exercise time to exhaustion through the maintenance of circulating blood volume [7], thus reducing cardiovascular and thermoregulatory strain [8,9]. Fluid and CHO ingestions improve exercise performance independently, and their effects appear to be additive [10].

Commercially available sports drinks are formulated to include CHO, in concentrations of 2–10%, typically in the form of glucose, sucrose, fructose, and glucose polymers (maltodextrins). Sports drinks also include varying concentrations of electrolytes, primarily sodium, to replace those

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lost in sweat, promote the intestinal absorption of glucose and water, and enhance postexercise rehydration [11]. Milk is a nutrient-dense food, containing CHO at a concentration that is similar to many commercially available sports drinks, in addition to electrolytes and other micronutrients. It also contains protein, and the addition of this macronutrient may [12,13] or may not [14,15] influence exercise capacity. It could therefore be argued that low-fat milk, which has a low fat content (typically 1 g/L), has the potential to prolong exercise capacity. The presence of fat in whole milk, however, will slow gastric emptying, due to a higher total energy content, without contributing a useful energy source during exercise [16]. The presence of lactose as the source of CHO may also limit its efficacy when compared with alternative sources of CHO typically found in sports drinks, due to low rates of utilization and poor gastrointestinal tolerance when taken in large quantities [17].

At present there exists little or no information on the effects of milk-based drinks on the response to prolonged exercise. The aim of the present study was to investigate the effects of the ingestion of water (W), a CHO-electrolyte solution (CE), 0.1% fat milk (M), and 0.1% fat milk with added glucose (M+C) on exercise capacity and the physiologic and subjective responses to prolonged exercise to exhaustion in a temperate environment. The addition of the M+C trial was to match the amount of CHO present in a typical commercially available sports drink.

Materials and methods

Eight healthy males (mean ± SD: age 24 ± 4 y, height 1.76 ± 0.04 m, mass 68.9 ± 9.5 kg, body fat 12.5 ± 2.4%, peak oxygen consumption [$V_{O_{2peak}}$] 4.3 ± 0.6 L/min) volunteered to participate in this study. At the time of the study all subjects were taking part in regular physical activity. Due to the nature of the investigation, those with known lactose intolerance or a history of metabolic disease were excluded. Before volunteering, all subjects received written details outlining the nature of the study. After any questions regarding the protocol, a written statement of consent was signed. The protocol received approval from the Loughborough University ethical advisory committee.

Each subject first completed a discontinuous, incremental cycle ergometer test to volitional exhaustion to determine $V_{O_{2peak}}$. These data were used to calculate the power outputs used during the investigation. Before the start of the experimental trials, two familiarization trials were undertaken that required the subject to exercise to exhaustion at 70% $V_{O_{2peak}}$. These were identical to the experimental trials, with the exception of the number of measurements taken, and served to ensure that subjects were familiar with the procedures used during the investigation and to minimize any potential learning or anxiety effects.

Each subject completed four experimental trials, randomized and administered in a crossover manner, separated by at least 7 d. The drinks ingested during the experimental trials were water (Aquapura, Basingstoke, United Kingdom), a commercially available CHO-electrolyte sports drink (Powerade, Coca Cola Ltd., Middlesex, UK), 0.1% fat milk (Tesco Ltd., Cheshunt, United Kingdom), and 0.1% fat milk with added glucose (glucose was added to increase the CHO content to 6%). Due to the nature of the solutions, neither the subjects nor investigators could be blinded to the treatment. All drinks were maintained at a temperature of 10°C before ingestion. The composition of the experimental drinks is presented in Table 1. To help ensure metabolic conditions were similar before the experimental trials, subjects were instructed to record dietary intake and physical activity during the 2 d before the first trial and to replicate their dietary and exercise patterns 2 d before the subsequent experimental trials. No alcohol consumption was permitted in the 24 h before each trial, and subjects were instructed to avoid strenuous exercise during this time. During the experimental trials, ambient temperature and relative humidity were maintained at 20.2 ± 0.4°C and 43 ± 8%, respectively.

Table 1
Composition and energy content of experimental drinks*

	W	CE	M	M+C
Carbohydrate (g/L)	0	60	50	60
Fat (g/L)	0	0	1	1
Protein (g/L)	0	0	33	33
Energy density (kJ/L)	0	1020	1450	1610
Sodium (mmol/L)	0 ± 0	28 ± 2	31 ± 2	32 ± 3
Potassium (mmol/L)	0 ± 0	1.6 ± 0.1	39.4 ± 1.4	39.1 ± 1.4
Osmolality (mosmol/kg)	1 ± 0	279 ± 2	281 ± 2	337 ± 3

CE, carbohydrate-electrolyte trial; M, milk trial; M+C, milk plus carbohydrate trial; W, water trial

* Macronutrients content and energy density obtained were from the manufacturers. Drink electrolyte content and osmolality were measured in the laboratory (mean ± SD).

All experimental trials commenced in the morning after an overnight fast, other than the ingestion of ~500 mL of water at least 90 min before the start of the trial. Upon arrival in the laboratory, postvoid body mass was measured, and the subject inserted a rectal thermistor 10 cm beyond the anal sphincter for the measurement of core temperature. Surface skin thermistor probes were attached to the skin surface at four locations (chest, triceps, thigh, calf) to determine weighted mean skin temperature [18] and a heart rate telemetry band was positioned.

Subjects were then seated for 10 min with one hand immersed in warm water (42°C) before a 21-gauge cannula was introduced into a superficial forearm vein to enable repeated collection of arterialized venous blood. The indwelling cannula was kept patent by flushing with a small volume of heparinized saline after sampling. A baseline blood sample (5 mL) was drawn, after which subjects mounted a cycle ergometer (Gould Corival 300, Groningen, Holland) and consumed 1.5 mL/kg of body mass of the

appropriate drink. After a second blood sample, subjects commenced exercise at a workload corresponding to 70% $V_{O_{2peak}}$. Exercise continued until volitional exhaustion, defined as an inability to maintain a pedal cadence of ≥60 revolutions/min despite verbal encouragement from the experimenter.

During exercise, heart rate (Polar Vantage, Kempele, Finland) and skin and rectal temperatures (Biopac Systems Inc., Goleta, CA, USA) were continuously logged. Expired gas samples were collected and analyzed at 15-min intervals using the Douglas bag method. These data were used to calculate O_2 uptake, CO_2 production, and respiratory exchange ratio and to estimate rates of substrate oxidation using the following equations: CHO = $(4.585 \times V_{CO_2}) - (3.226 \times V_{O_2})$, fat = $(1.695 \times V_{O_2}) - (1.701 \times V_{CO_2})$ [19], and energy expenditure. Subjective ratings of perceived exertion (RPE) [20] and thermal sensation (using a 21-point scale ranging from unbearable cold [−10] to unbearable heat [+10]) were assessed during the gas collection. In addition, 5.5-mL blood samples were drawn at 15-min intervals and at the point of exhaustion. Subjects ingested 1.5 mL/kg of body mass of the appropriate solution every 10 min during exercise. The subjective response to the drink taste and associated feelings relating to the drink were assessed using a series of 100-mm visual analog scales [21] immediately after the ingestion of each bolus. After the cessation of exercise all probes and the cannula were removed. Subjects were then asked to shower, towel dry, and were reweighed to allow the estimation of sweat losses occurring during exercise.

Blood handling and analysis

Blood samples collected throughout the experimental protocol were drawn into dry syringes with a 2.5-mL aliquot dispensed into tubes containing K_2 ethylene-diaminetetra-acetic acid with the remaining placed into plain tubes. Duplicate 100-μL aliquots of whole blood treated with ethylene-diaminetetra-acetic acid were rapidly deproteinized in 1 mL of ice-cold 2.5% perchloric acid. These were centrifuged, and the resulting supernatant was used for determination of glucose (God-PAP, Randox, Co., Antrim, United Kingdom) concentration. Hemoglobin (cyanmethemoglobin method) and hematocrit (microcentrifugation) values were used to estimate percentage changes in blood, plasma, and red cell volumes relative to the second resting sample [22]. The 2.5-mL aliquot added to a plain tube was kept on ice until the end of each trial before being centrifuged to yield serum. This was stored at 4°C for the measurement of sodium and potassium concentrations by flame photometry (Corning 410C, Corning, NY, USA), chloride by coulometric titration (Jenway PCLM 3, Essex, United Kingdom), and osmolality by freezing-point depression (Reobling, Camlab, Cambridge, United Kingdom).

Statistical analysis

Normality of data was first assessed using the Shapiro-Wilk test. Data are presented as mean ± standard deviation or median (range) in the text and as mean ± group SEM in figures (to improve clarity) unless otherwise stated. To identify differences in normally distributed results, two-way (time-by-trial) repeated measures analyses of variance were employed. Where a significant interaction was apparent, pairwise differences were evaluated using Tukey's post hoc procedure and paired t tests with Holm-Bonferroni adjustment for multiple comparisons. The exercise capacity data were found to be non-parametric. These are presented as median (range) and were analyzed using the Kruskal-Wallis non-parametric one-way analysis of variance, and pairwise differences were assessed using the Wilcoxon matched-pair signed-rank test. For the purpose of hypothesis testing, the 95% level of confidence was predetermined as the minimum criterion to denote a statistical difference ($P < 0.05$). All data analysis were undertaken using SPSS 12 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Hydration status

Pre-exercise serum (287 ± 3 mosmol/kg, $P = 0.99$) and urine osmolality (410 ± 284 mosmol/kg, $P = 0.83$) data suggested that all subjects were euhydrated before each trial [23].

Exercise capacity

The time to volitional exhaustion under each experimental condition is displayed in Figure 1a. Exercise capacity was not influenced by trial order ($P = 0.49$). The solution ingested did not influence exercise capacity ($P = 0.19$), with median (range) exercise times of 93.3 min (82.4–192.3), 110.6 min (82.0–222.7), 103.3 min (85.7–228.5), and 102.8 min (74.3–167.1) observed in the W, CE, M, and M+C trials, respectively. When these data were expressed as a percentage change in exercise capacity using the W trial as a baseline (0%), exercise times were longer by 17.5 ± 13.6% (18.1 ± 13.2 min) in the CE trial and 10.4 ± 7.7% (12.0 ± 11.7 min) after milk ingestion (Fig. 1b). When the data were expressed in this way, exercise capacity with CE was significantly greater than that observed during the W trial ($P = 0.022$).

Metabolic data

Expired gas data are presented in Table 2. Oxygen uptake increased over time during exercise in each trial ($P = 0.015$); consequently, the subjects' relative exercise intensity increased from 69 ± 0% at 15 min to 75 ± 1% at the

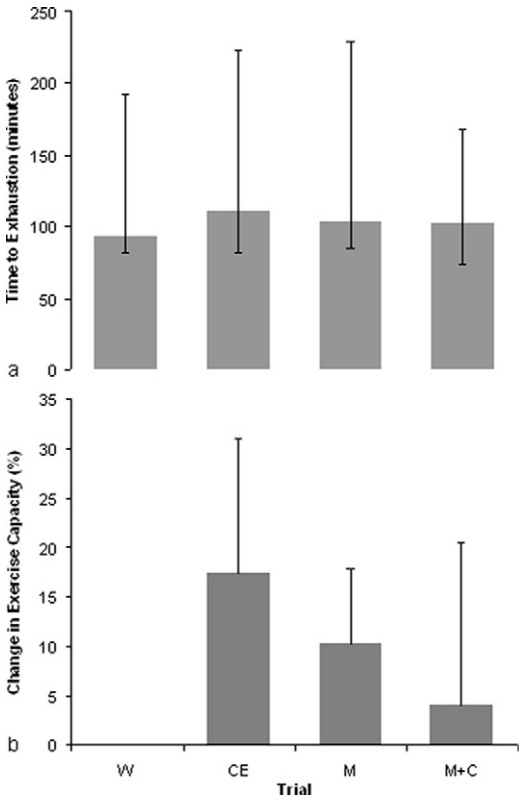

Fig. 1. (a) Exercise time to exhaustion at 70% peak oxygen consumption per unit time during the experimental trials (median ± range). (b) Percentage difference in exercise capacity compared with the W trial. CE, carbohydrate-electrolyte trial; M, milk trial; M+C, milk plus carbohydrate trial; W, water trial.

end of exercise, but ingestion of the experimental solutions did not alter this response ($P = 0.65$). Rates of CHO oxidation during exercise were not influenced by the drink ingested (W 3.27 ± 0.71, CE 3.29 ± 0.54, M 3.27 ± 0.75, M+C 3.19 ± 0.69 g/min; $P = 0.63$). Similarly, fat oxidation rate was not altered by the treatment ($P = 0.55$). There was no difference in blood glucose concentrations between trials while at rest or during exercise. Circulating blood glucose concentrations were similar at the point of exhaustion, with values of 5.2 ± 0.8, 6.1 ± 0.9, 5.7 ± 0.6, and 5.8 ± 0.8 mmol/L observed in the W, CE, M, and M+C trials, respectively ($P = 0.34$).

Thermoregulatory responses

There was no difference in rectal temperature between trials before exercise (Fig. 2). Although the drink ingested did not influence rectal temperature ($P = 0.83$), there was a progressive increase during exercise in all trials ($P < 0.001$), reaching 39.0 ± 0.7°C in the W trial, 39.2 ± 0.7°C in the CE trial, 39.1 ± 0.6°C in the M trial, and 39.1 ± 0.7°C in the M+C trial. Skin temperature was elevated above resting levels during exercise in all trials ($P < 0.001$).

Fluid balance and cardiovascular responses

Mean body mass loss during exercise was 0.80 ± 0.37 kg, with no differences apparent between trials ($P = 0.95$). This equates to a loss of 1.2 ± 0.5% of pre-exercise body mass. The mean volumes of ingested drink were 1.14 ± 0.36, 1.33 ± 0.46, 1.22 ± 0.47, and 1.09 ± 0.27 L for trials W, CE, M, and M+C, respectively ($P = 0.65$). Plasma volume decreased 6–8% during the first 15 min of exercise in all trials, with no further change apparent. This response was not influenced by the drink ingested ($P = 0.474$). Similarly, no differences were identified in mean serum Na^+ (143 ± 5 mmol/L, $P = 0.214$), Cl^- (102 ± 3 mmol/L, $P = 0.817$), and K^+ (5.8 ± 0.4 mmol/L, $P = 0.38$) concentrations.

Baseline heart rate was not different between trials ($P = 0.96$), with a mean value of 62 ± 10 beats/min recorded during the 20-min rest period. There was a clear elevation in heart rate throughout exercise, reaching 171 ± 8 beats/min at the point of exhaustion ($P < 0.001$), but the drink ingested did not alter this response ($P = 0.44$).

Subjective feelings

The subjects' RPE and perceived thermal sensation during exercise are presented in Fig. 3. Perceived exertion ($P = 0.63$) and thermal sensation ($P = 0.40$) were not influenced by the drink ingested, but a significant increase over time was apparent in all trials (RPE, $P < 0.001$; thermal sensation, $P = 0.021$). There were clear differences between trials in the perceived sweetness ($P = 0.006$) and pleasantness ($P = 0.012$) of the drinks reported, with the CE drink scoring markedly higher than the other solutions. No differences were reported in the subjective feelings of hunger ($P = 0.22$) or head soreness ($P = 0.54$) between trials, but there was a tendency for feelings of thirst ($P = 0.08$) and bloatedness ($P = 0.09$) to differ. Subjects did report greater feelings of stomach fullness with the ingestion of M and M+C compared with CE and W ($P = 0.014$; Fig. 4).

Discussion

The effects of CHO and fluid ingestion on exercise capacity have been reported to be independent and additive [10], leading to the widespread use of sports drinks before and during training and competition. The essential elements of a sports drink are water, CHO, and sodium. Milk contains all these nutrients, but to date little or no work has examined the effect of milk ingestion on the cardiovascular, metabolic, and thermoregulatory responses to prolonged exercise. The aim of the present study was to investigate the effects of the ingestion of water, a CHO-electrolyte solution, 0.1% fat milk, and 0.1% fat milk with added glucose on the response to prolonged exercise to exhaustion in a temperate environment.

Table 2
Expired gas data during exercise*

	15 min	30 min	45 min	60 min	Final min
Oxygen uptake (L/min)					
W	2.97 ± 0.55	3.02 ± 0.57	3.04 ± 0.57	3.05 ± 0.53	3.18 ± 0.59
CE	2.99 ± 0.59	3.05 ± 0.58	3.06 ± 0.55	3.13 ± 0.53	3.27 ± 0.58
M	2.98 ± 0.55	3.03 ± 0.59	3.05 ± 0.58	3.05 ± 0.53	3.23 ± 0.64
M+C	3.02 ± 0.64	3.03 ± 0.65	3.08 ± 0.61	3.07 ± 0.61	3.16 ± 0.60
Respiratory exchange ratio (no units)					
W	0.98 ± 0.01	0.99 ± 0.02	0.98 ± 0.03	0.99 ± 0.04	1.00 ± 0.07
CE	0.97 ± 0.02	0.97 ± 0.02	0.97 ± 0.03	0.96 ± 0.03	1.00 ± 0.05
M	0.99 ± 0.02	0.98 ± 0.02	0.97 ± 0.03	0.97 ± 0.03	0.98 ± 0.05
M+C	0.99 ± 0.03	0.96 ± 0.02	0.96 ± 0.03	0.94 ± 0.01	1.03 ± 0.05
CHO oxidation (g/min)					
W	3.79 ± 0.65	3.93 ± 0.91	3.82 ± 0.89	4.01 ± 0.86	4.40 ± 1.53
CE	3.69 ± 0.71	3.69 ± 0.64	3.69 ± 0.61	3.61 ± 0.55	4.37 ± 0.98
M	3.84 ± 0.77	3.89 ± 1.01	3.81 ± 1.10	3.68 ± 0.84	4.21 ± 1.32
M+C	3.91 ± 0.98	3.53 ± 1.03	3.55 ± 0.89	3.38 ± 0.79	3.88 ± 2.09
Fat oxidation (g/min)					
W	0.08 ± 0.06	0.07 ± 0.09	0.12 ± 0.12	0.10 ± 0.11	0.14 ± 0.16
CE	0.12 ± 0.11	0.15 ± 0.14	0.15 ± 0.17	0.23 ± 0.14	0.12 ± 0.18
M	0.08 ± 0.05	0.09 ± 0.09	0.12 ± 0.12	0.16 ± 0.11	0.14 ± 0.13
M+C	0.09 ± 0.13	0.20 ± 0.11	0.21 ± 0.13	0.27 ± 0.08	0.04 ± 0.08

CE, carbohydrate-electrolyte trial; CHO, carbohydrate; M, milk trial; M+C, milk plus carbohydrate trial; W, water trial
* Values are means ± SDs. Where present, statistical differences are described in the text.

The results of the present study failed to observe a clear difference in time to exhaustion between the ingestion of CHO, in the form of a CE solution, skimmed milk, or skimmed milk with added CHO over a plain water placebo. Given the large body of evidence supporting a marked increase in exercise capacity after the ingestion of CHO before and during exercise [2,5,6], this outcome was unexpected. Further analysis of the data reveals that although no improvement in time to exhaustion was identified, seven of the eight subjects did exercise for longer when ingesting CE and M. Additionally, when these data are expressed as a change in time to exhaustion as a percentage difference from the W trial, a significant effect of CE on exercise capacity was apparent (Fig. 1b; $P = 0.022$). Due to the nature of the treatments administered in the present study, it is important to recognize that the taste and appearance of the drinks were not blinded from the subjects. Although it is possible that knowledge of the treatment may have introduced some subjective bias, the subjects were not informed of the experimental hypothesis and received encouragement to produce a maximal effort during each trial.

The maintenance of circulating blood glucose concentrations, sparing of muscle and liver glycogen, and an increase in the rate of CHO utilization are widely reported after exogenous CHO ingestion during prolonged exercise [1]. No differences were observed between trials in blood glucose concentrations or in the estimated rates of CHO and fat oxidation, but other investigators have also reported that blood glucose concentrations are not affected by CHO ingestion during exercise [5,24]. The difference between studies may be explained by the amounts of CHO administered, and the absence of response may be related to the relatively small amount of CHO ingested in the present study. Studies reporting a marked effect of CHO ingestion on rates of CHO and fat oxidation have typically administered 45–75 g of CHO per hour [25], whereas subjects ingested around 30 g of CHO per hour during the CE, M, and M+C trials in the present study (subjects ingested ~100 mL every 10 min). Additionally, the nature of the CHO found in milk may have limited its efficacy. Before it is absorbed in the small intestine, lactose is hydrolyzed by lactase into its constituent monosaccharides, glucose and galactose. Although maximum rates of exogenous glucose oxidation during exercise are typically reported as 1.0–1.1 g/min, galactose utilization appears to be limited to around 0.41 g/min [17].

In addition to CHO, milk contains around 3.6% protein, primarily in the form of casein. Although the effect of CHO-protein mixtures on postexercise recovery of muscle glycogen has received a great deal of attention [26–28], the effect of these solutions on exercise capacity has only recently been investigated. Two laboratory-based studies have reported a marked increase in exercise time to exhaustion after the ingestion of CHO-protein solutions when compared with a CHO-only control [12,13]. The results of the present study, however, fail to support the suggestion that the co-ingestion of protein and CHO will enhance exercise capacity. Similar findings have been reported in a number of recent studies [14,15,29], and perhaps the apparent discrepancy between these data may be explained by the type of CHO and/or protein ingested and/or differences in the total energy content of the drinks.

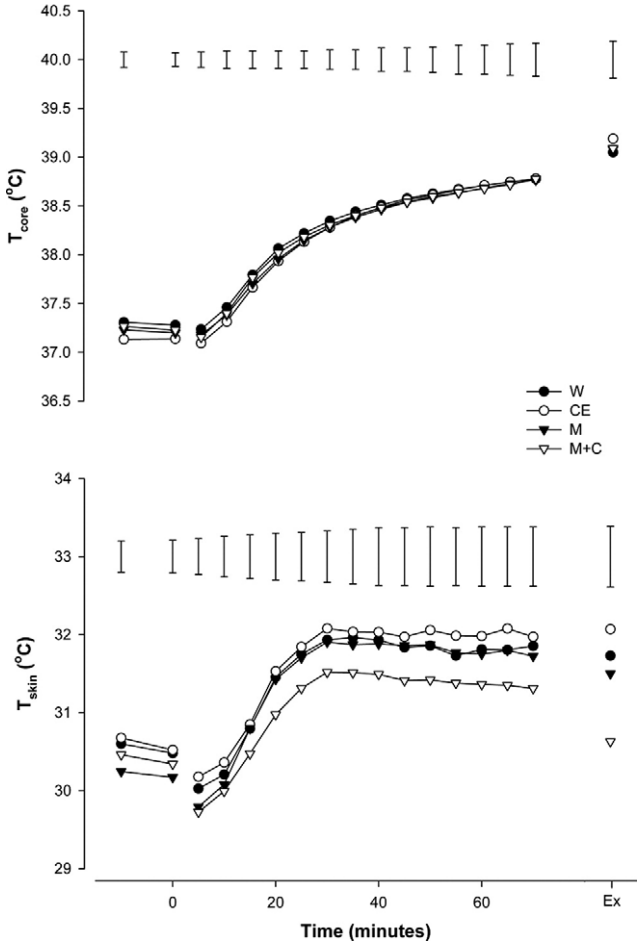

Fig. 2. T_{core} (top) and T_{skin} (bottom) at rest and during exercise (mean ± group SEM). Significant differences are described in the text where present. CE, carbohydrate-electrolyte trial; M, milk trial; M+C, milk plus carbohydrate trial; T_{core}, rectal temperature; T_{skin}, weighted mean skin temperature; W, water trial.

There was no effect of the treatment on the subjects' thermoregulatory response to the exercise, with no significant differences between trials apparent in rectal and weighted mean skin temperatures or in perceived thermal sensation. Similar responses have been reported by Maughan et al. [30] and Galloway and Maughan [31] after the ingestion of CHO solutions during exercise in temperate and warm environments, respectively. Mean rectal temperature at the point of fatigue was 39.1 ± 0.6°C. This is considerably lower than the "critical" core temperature of 40.0°C proposed as limiting during prolonged exercise in a warm environment [32], but it is worth noting that 75% of individuals tend to fatigue when attaining a rectal temperature of 39.2°C [33]. The results of the present investigation suggest that M appears to be as effective as W and CE at maintaining fluid balance, denoted by similar changes in body mass, plasma volume and serum osmolality.

Data collected from the subjective feeling questionnaires, completed immediately after the ingestion of each bolus, suggest that all the experimental solutions were well tolerated. There was an increase in feelings of stomach fullness and bloatedness as exercise continued in all trials, suggesting that the rate of fluid intake may have been greater than the rate of gastric emptying, resulting in a progressively increasing residual volume of fluid in the stomach. Because the rate of gastric emptying of liquids is inversely proportional to the energy density of the solution in the stomach [16], M would have emptied at a slower rate compared with W or CE. This delay in gastric emptying may have attenuated the influx of fluid into the circulation, despite a potentially greater volume of fluid present in the stomach. Ratings of stomach fullness by subjects in the present study were higher during the later stages of exercise when ingesting M and M+C than reported during the CE and W trials. Any discomfort associated with stomach fullness may accelerate the cessation to exercise, but there was no suggestion that the ingestion of M during exercise caused any significant gastrointestinal discomfort.

In summary, milk is a nutrient-dense food, containing CHO at a concentration that is similar to many commercially available sports drinks in addition to electrolytes and

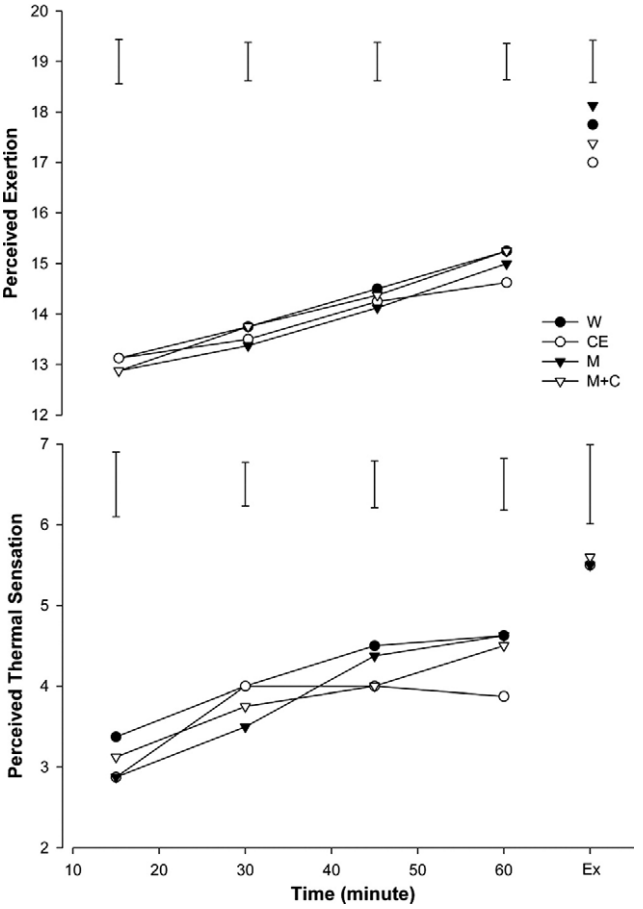

Fig. 3. Rating of perceived exertion (top) and perceived thermal sensation (bottom) during exercise (mean ± group SEM). Where present, significant differences are described in the text. CE, carbohydrate-electrolyte trial; M, milk trial; M+C, milk plus carbohydrate trial; W, water trial.

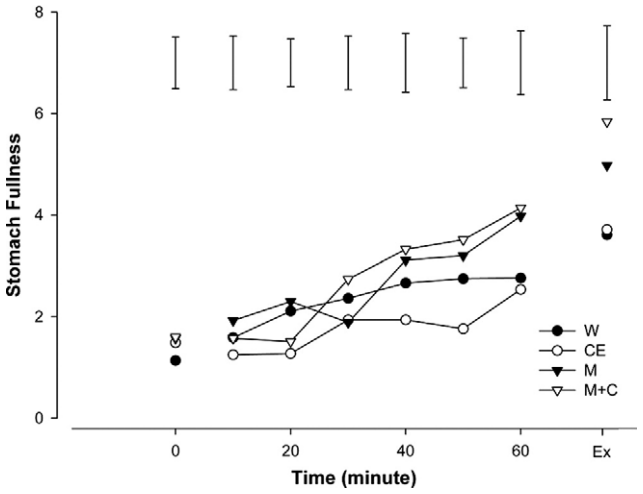

Fig. 4. Subjective feelings of stomach fullness at rest and during exercise (mean ± group SEM). A score of 0 refers to "not at all full," whereas a score of 10 refers to "very full." Where present, significant differences are described in the text. CE, carbohydrate-electrolyte trial; M, milk trial; M+C, milk plus carbohydrate trial; W, water trial.

other micronutrients that may be beneficial to the sports performer. The results of the present study suggest that milk did not influence exercise capacity when compared with the ingestion of plain water or a CE solution. The treatments did not influence the metabolic, cardiovascular, or thermoregulatory response to the exercise. Although subjective feelings of stomach fullness were significantly greater late in exercise during both milk trials when compared with the ingestion of CE or W, this was not associated with any significant feelings of gastrointestinal discomfort that may have negatively influenced exercise capacity.

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