

Post-exercise ingestion of lactose-free skim milk affects thirst but not subsequent performance and net fluid balance of collegiate badminton athletes

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ABSTRACT

Introduction: The hydration and nutritional needs of badminton athletes are of interest because of the unique demands of the sport on the player's physiology and skill. **Objective:** The current study investigated the acute effect of lactose-free skim milk (LFM) compared with a iso-volumic carbohydrate electrolyte sport drink (iCE) taken post exercise, on subsequent performance, net fluid balance (NFB) and other selected subjective variables (thirst, gastrointestinal comfort and palatability). **Methods:** Eleven collegiate badminton athletes (five male and six female, mean age=19.6±1.7 years, body mass=56.8±5.0 kg) volunteered to participate in this crossover study, with ≥7-day washout between trials. After a 2 h training session, the participants rested for 2 h, ingested the same volume of either LFM or iCE matched for carbohydrate content of 1.0 g carbohydrate/kg body mass. Performance tests were done post-ingestion. The body mass was taken, as well as visual analog scales administered throughout the protocol. **Results:** No significant difference between groups was found in terms of performance: aerobic capacity $t(10)=0.147$, $p=0.886$ and agility (sideways agility test: $t(10)=0.191$, $p=0.852$ and four-corner agility test: $t(10)=0.397$, $p=0.700$); and NFB $t(10)=0.434$, $p=0.670$. Thirst ratings between groups were significantly different at the end of the performance tests (LFM 6.71±2.09 and iCE 8.03±1.28, $t(10)=-2.35$, $p=0.041$). However, the subjective ratings for gastrointestinal comfort and palatability were similar. **Conclusion:** When matched for carbohydrate content, acute post-exercise ingestion of LFM offered a significant advantage over the sports drink in terms of thirst after subsequent performance.

Keywords: Lactose-free skim milk, collegiate badminton, net fluid balance, thirst

INTRODUCTION

The type of beverages being consumed by college level athletes is an aspect of hydration that has not been well studied. Of particular interest is the

hydration effect and possible ergogenic effects of beverages. Extensive research has been done comparing water and carbohydrate-electrolyte beverages (Casa *et al.*, 2000; Shirreffs, Armstrong

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& Chevront, 2004; Maughan & Shireffs, 2010; Peacock, Thompson & Stokes, 2012), and most have found the latter to be more effective in maintaining better performance especially after prolonged (>60 min) activity. Cow's milk ingestion in the context of sports has recently gained popularity, mainly due to its natural composition which is rich in high quality protein, electrolytes and calcium (Roy, 2008). Research has shown that the use of low fat milk for rehydration is as good as carbohydrate-electrolyte drinks in terms of effects on hydration and performance (Lee *et al.*, 2008; James, 2012). Milk-based drinks are recommended over traditional sport drinks for post-exercise rehydration because of its energy, protein, calcium content and sodium (Desbrow *et al.*, 2014). Milk has been found to have positive effects on protein synthesis (and therefore on muscle recovery) and has shown positive results in strength gains and muscle hypertrophy (Hartman *et al.*, 2007). However, full fat milk decreases gastric emptying and therefore absorption. Hence, recent research on the use of milk by athletes has seen the use of low fat milk (Shirreffs, Watson & Maughan, 2007). Other studies have also found milk-based drinks to cause more bloating and feelings of fullness when compared with sports drinks (Desbrow *et al.*, 2014). Its fat content has also given milk a reputation of being an unsuitable sports beverage. Recommendations for its use need to be prudent as well, since certain ethnic groups, and Asians in particular, are known to have a high incidence of lactose intolerance (Heyman, 2006; Purnell, 2013).

In a study by Baguley *et al.* (2016) on the *ad libitum* intake of a milk-based supplement compared with a carbohydrate-electrolyte (CE) sports drink taken post-exercise, no difference was found in terms of net fluid balance

(NFB) between the two drinks. CE sports drink however was preferred in terms of gastrointestinal tolerance and palatability. Another study found milk ingestion to be better at restoring NFB after exercise and thermal dehydration compared to CE and water (Seery & Jakeman, 2016). Similar findings were found in youth (grouped into 7-11 and 14-17 years), where skimmed milk was found to be more effective than water and CE in replacing fluid losses that occur during exercise in the heat (Volterman *et al.*, 2014). In another study, volunteers ingested either CE solution or skimmed milk after inducing a 2% body mass loss by intermittent exercise. These results suggest that milk is more effective for post-exercise rehydration because it caused a net positive fluid balance during the recovery period, even though exercise capacity 4 h afterwards was not different between both beverages (Watson *et al.*, 2008).

The intake of milk in sports has also been associated with recovery instead of having some benefit before or during activity. This may be due to preconceptions regarding its fat content and potential subsequent stomach discomfort. With the above-mentioned benefits, it would be sensible to recommend the ingestion of low fat or lactose-free milk due to the benefits from the natural components of milk without delaying absorption and stomach discomfort (Densupsoontorn *et al.*, 2004), especially in the sports setting. A study on the use of low-fat lactose-free milk showed positive effects in terms of hydration and subsequent performance of Thai endurance cyclists (Sudsard *et al.*, 2014). Another study by Desbrow *et al.* (2014) compared milk-based drinks with sport drinks post-intermittent exercise, however, subsequent performance was not measured. Hence, research still has to be done on lactose-

free milk and its effect on subsequent anaerobic exercise. Although several studies have been done on the effects of chocolate milk on post-exercise recovery in collegiate athletes (Spaccarotella & Andzel, 2011; Gilson *et al.*, 2010; Kitzke, Sittig & Schmidt, 2013), these were done on intermittent team sports such as soccer and basketball. No previous study was found pertaining to possible effects of drinking strategy nor ergogenic effects of milk or dairy products on performance in intermittent individual sports, specifically badminton.

Badminton offers a few key differences from other sports. The smaller size of the court area as compared to the playing areas of tennis, football, rugby, hockey and netball necessarily elicits a different movement style and specific fitness demands. Explosive movements (high intensity intermittent exercise) such as jumping, turning speed off the mark, lateral movements and agility therefore becomes extremely important (Barnard, 2008). Tests that are specific to badminton to measure the unique qualities of the sport have been developed by Chin *et al.* (1995).

Only one previous study by Abian-Vicen *et al.* (2012) analysed the influence of dehydration on strength after a competitive match of badminton players. However, no studies have been done on the possible effect of the ingestion of milk on performance variables in intermittent individual sports such as badminton. Therefore, the objective of this study was to investigate the effects of ingestion of lactose-free skim milk (LFM) against iso-volumic carbohydrate electrolyte sport drink (iCE) on badminton-specific performance and aerobic performance after intermittent sport activity. Its effect on NFB and the subjective parameters of thirst, gastrointestinal comfort and palatability were determined throughout the study.

MATERIALS AND METHODS

The collection of data was done using a randomised crossover study design, with ≥ 7 -day washout between experimental trials (Lee *et al.*, 2008; Sudsa-ard *et al.*, 2014). Consent was given by the participants during a briefing session that was held before the screening process. The study was reviewed and approved by the Mahidol University Central Institutional Review Board with the code COA No. MU-CIRB 2017/012.0102.

Eleven collegiate badminton athletes (five male and six female; age=19.6 \pm 1.7 years; body mass=56.8 \pm 5.0 kg; data expressed as mean \pm standard deviation) agreed to participate in this study. They were healthy, injury-free and had trained regularly (≥ 3 times per week) for the past six months. They had also previously participated in a badminton competition (at least once in the past year) at the level of university games or higher. Those with known allergies to milk or dairy products were not selected to participate in the study.

The LFM and CE that were ingested had content that was in accordance with recommendations for post-exercise carbohydrate replacement of 1.0 g carbohydrate/kg body weight (Karp *et al.*, 2006; Thomas, Morris & Stevenson, 2009; Sudsa-ard *et al.*, 2014; Spaccarotella & Andzel, 2011). The CE served as a control beverage as this was the beverage typically consumed by athletes during recovery (Spaccarotella & Andzel 2011). A water-only control was not used in this study because recommendations for post-exercise recovery requires rehydration with beverages containing fluid, electrolytes and carbohydrate. In addition the athletes were exercising in the heat where dehydration and depleted energy stores may occur (Spaccarotella & Andzel, 2011). The experimental days

started and ended at approximately the same time with temperature and relative humidity in the indoor badminton facility ranging from 30.8–32.5°C (mean T°C 31.8±1.55, $p=0.279$) and 50–54% (mean RH% 51.8±4.97, $p=0.395$), respectively.

Preliminary day testing protocol

The participants were asked to arrive at the lab at 0700 hours, well rested and well hydrated. They were requested to empty their bladders, and a urine sample was collected for the measurement of urine specific gravity using a urine refractometer (Atago 300CL/URC-NM, Japan). Subsequently, body mass was determined using a Tanita RD-901 IRONMAN body composition monitor (Tanita, Japan) to establish euhydrated weight. Other baseline data, such as height (standard stadiometer), resting heart rate and blood pressure (Omron SEM-1, Kyoto Japan) were also measured. A physical activity readiness questionnaire (PAR-Q) was administered, and a brief interview was carried out for medical history and medications taken recently and at the time of data collection (Armstrong *et al.*, 2014). The participants were also asked to recall their diet and physical activity over the past 24 h and asked to replicate this the day before experimental days to ensure similar metabolic conditions (Lee *et al.*, 2008; Shirreffs *et al.*, 2007; Dion *et al.*, 2013). They were requested to avoid unusually strenuous exercise and alcohol intake 48 h and 24 h respectively, before the trials. The recommendation on fluid intake on the day before the trials was ~2.2 L/day for adult females (~58 kg) and 2.5 L/day for adult males (~70 kg) under average conditions (Howard & Bartram, 2003). A briefing on the test protocol was given to the participants on both the familiarization and experimental days, as well as the instructions they had to follow for the preliminary tests. The use of the 100 mm visual analogue scales

to rate subjective perceptions of thirst, gastrointestinal comfort and palatability were explained. For thirst, the rating was from not at all thirsty (0) to very, very thirsty (10); for gastrointestinal discomfort, it was no discomfort (0) to extreme discomfort (10); and for palatability rating, it ranged from dislike very much (0) to like very much (10). The participants then did a five minute warm-up and one familiarisation trial for the performance tests (movement agility tests and shuttle run test).

Badminton-specific on-court movement agility tests

The badminton-specific on-court movement agility test that was used in this study was developed by Ooi *et al.* (2009) and was modified from the general movement and badminton-specific speed tests, as described by Hughes and Bopf (2005). These tests were used to measure the badminton-specific anaerobic performance variable in this study. Each test was done twice with a five-minute recovery that was allowed between trials and tests. The best performance time was recorded.

The players started in the ready position at central base without racket in hand. They were instructed to use badminton-specific footwork and movements during the test. The participants were required to perform the badminton-specific movement agility test that consisted of two movements, namely, the sideways-agility test and the four-corner agility test.

Five up-turned shuttlecocks were placed on each side on the line marking the outside of the single's court for the sideways-agility test. The sideways-agility test required the participants to run laterally across the width of the court for ten repetitions (five shuttles on each side), where they needed to strike the up-turned shuttlecocks with their dominant hand. The timing started

when the participant began to move from the central base and stopped when the participant's feet had returned to the same base.

For the four-corner agility test, a total of 16 up-turned shuttlecocks were placed on four corners of the court, with four shuttlecocks each corner marked A, B, C and D. The participants had to strike the shuttles in order (i.e. A, B, C and then D) with their dominant hand. The timing started when the participant began to move from the central base and stopped when the participant's feet had returned to the central base.

Shuttle run

After resting 30 minutes, the participants did a 20-minute shuttle run to fatigue based on the multi-stage fitness test (Mackenzie, 2005). This test is usually used to estimate maximal oxygen uptake ($VO_2\max$) and for testing aerobic fitness. The shuttle run involved running between two lines separated by 20 m. Computer generated beeps determined running speed and increased in frequency each minute. The onset of fatigue was determined by the failure to reach the second line for two consecutive ends. This time was recorded as time to reach fatigue and was used to compute the estimated $VO_2\max$, as follows: $VO_2\max = 18.043461 + (0.3689295 \times TS) + (-0.000349 \times TS \times TS)$, where TS is the total number of shuttles completed.

Experimental day protocol

One of the pre-weighed drinks, LFM or an iCE drink was randomly given to each participant at the start of the day. The drinks during the trials were maintained at 10°C (Lee *et al.*, 2008). Data was collected during the regular training schedule of the participants. They were requested to empty their bladders on arrival, and a urine sample was collected for measurement of urine specific gravity. Body mass was determined

to check if they were at euhydrated weight (similar body mass and urine specific gravity during preliminary day). Clothing was limited to spandex shorts for the males and shorts and sports bra for the females during measurement of body mass. Baseline measurements for resting heart rate and blood pressure were also recorded. The FT1 Polar heart rate monitor was then worn by the participants. They were interviewed to ascertain compliance to the instructions that were given on diet, physical activity and hydration, and were also reminded of the specific instructions for the exercise protocol and the use of the analogue scales. NFB was calculated as follows: $NFB = \text{body mass at end} - \text{body mass start protocol}$ (pre-exercise body mass as reference point 0, adjusted for drink volume, urine output and sweat rate (Perez-Idarraga & Aragon-Vargas, 2014).

2-h training session

Each participant was requested to perform similar 2 h badminton-specific training in terms of duration and intensity of training and resting period in all experimental sessions. The heart rate was monitored to ensure similarity between trials. Plain water was given during the training at 0.4 or 0.8 L/h *ad libitum*, with the former volume provided to the slower, lighter persons and the latter given to faster, heavier individuals (Sawka & Noakes, 2007). After 1 h of training, the body mass was measured to ensure that proper hydration levels of participants (<1% body mass loss) was met. *Ad libitum* water intake was maintained until the end of the 2 h training since the participants were properly hydrated.

Beverage ingestion

After the training session, the participants rested for ten minutes and their post-exercise body mass measured. The participants then ingested the

predetermined amount of LFM or iCE beverage (1 g carbohydrate per kg body mass) that was computed according to the reference values found in Table 1. Although the volume of drink was the same (1158 ml), the mean drink weights were different since LFM (which weighed 1173±104 g) was heavier than iCE (1158±103 g). Fifty percent of the amount was first ingested at 0 minutes (after measurement of post-exercise body mass), then the next 25% at 30 minutes and last 25% was ingested at 45 minutes. The bottles were opaque in an attempt to blind the participants as to their type of drink for the day. The

participants were supposed to take the same volume of drink after the 2 h rest period, but due to certain limitations (time and venue), the performance tests (movement agility tests and 20 m shuttle run) were immediately done after the 2 h rest period. Urine output was collected throughout the protocol (Table 2).

The subjective measures were taken immediately before and after training, and, before and after the performance tests. Participants were instructed to freely mark their subjective ratings of thirst, gastrointestinal comfort and palatability along the line. Heart rate was measured at 10 min

Table 1. Nutrient content per 250 ml serving of LFM and CE sports drink (Gatorade brand), as indicated on the package labels

<i>Content</i>	<i>LFM[†]</i>	<i>Gatorade sports drink[‡]</i>
Energy (kcal)	89	67
Protein (g)	9.0	0.0
Fat, total (g)	0.3	0.0
Carbohydrate (g)	12.5	16.9
Sugars (g)	11.5	13.5
Sodium (mg)	88.0	100.4
Calcium (mg)	275.0	2.5

[†]Harvey Fresh Lactose Free Skim Milk brand (Australia)

[‡]Gatorade also contains potassium (36.6 mg) and phosphorus (24.4 mg) per 8 fluid ounce

Table 2. Body mass and NFB at different time points (N=11, *p*<0.05)

<i>Time point</i>	<i>LFM group (kg) Mean±SD</i>	<i>iCE group (kg) Mean±SD</i>	<i>LFM NFB (kg)[†] Mean±SD</i>	<i>iCE NFB (kg)[†] Mean±SD</i>	<i>Significance level[‡]</i>
Body mass					
Start protocol	56.37±4.98	56.30±5.14			
+1-hr training	56.73±4.88	56.66±5.01			
+2-hr training	56.66±4.92	56.52±5.04			
Pre-agility test	57.39±5.15	57.18±5.15			
End of protocol	56.66±5.01	56.43±5.13			
Net fluid balance					
+2-hr training			-0.69±0.82	-0.77±1.14	0.71
Pre-agility test			0.41±0.62	0.24±1.19	0.45
End of protocol			-1.54±1.23	-1.66±1.92	0.67

[†]NFB = body mass at end – body mass start protocol [pre exercise body mass as reference point 0, adjusted for drink volume, urine output and sweat rate (Perez-Idarraga & Aragon-Vargas, 2014)]

[‡]*p*-value shown for the body mass changes only after 2-hr training and NFB only

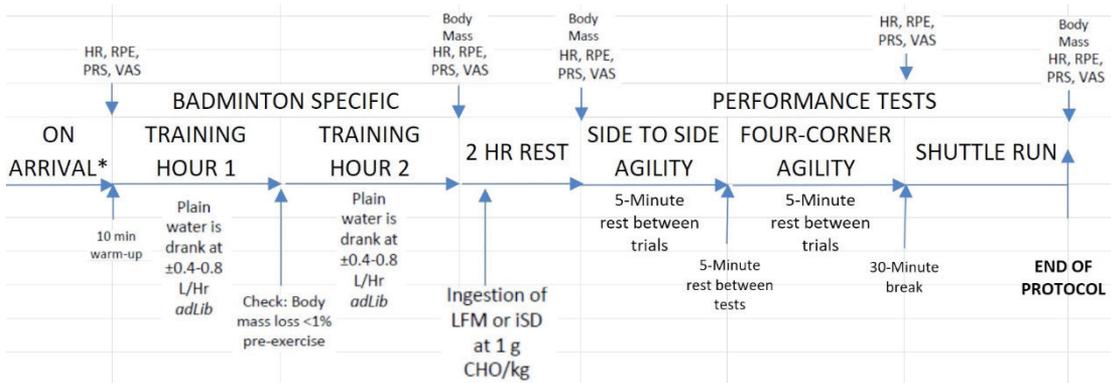


Figure 1. Experimental day protocol

intervals throughout the training and performance. The experimental day procedure is summarized in Figure 1.

Statistical analysis

Results were reported as mean \pm SD and significance level was set at $p < 0.05$. Normality was assessed using Shapiro Wilk test and analysis of results done using paired t -test or Wilcoxon signed rank test, using SPSS IBM Statistical package v.20, when appropriate. Two-way repeated measures analysis of variance (ANOVA) was also used to look into the interaction of the drink and performance heart rate over time.

RESULTS

Net fluid balance

No significant difference between the LFM and iCE groups was found in terms

of body mass (kg) and NFB, despite a significant difference in the mean weight of the drinks ingested [LFM:1173 \pm 104 g and iCE:1158 \pm 103 g; $t(10)=37.4$, $p=0.000$] (Table 2).

Sodium intake and drink weights for the groups were found to be significantly different ($p=0.000$), although drink volume was the same (iso-volumic conditions) (Table 3).

Subsequent performance

After the 2 h training session, the test beverages were ingested and after another hour of rest, performance tests were done as previously described. The training heart rate was similar for the LFM and iCE groups at the end of the 2 h training session $t(10)=1.98$, $p=0.076$. The performance heart rate (PHR) was measured to determine if the intensity

Table 3. Sodium content of beverages and sodium intake of participants (N=11)

	LFM Mean \pm SD	iCE [†] Mean \pm SD	CE [‡]	<i>p</i> -value
Sodium content (mg/ml)	0.352	0.297	0.402	-
Drink volume (ml)	1135.5 \pm 100.8	1135.5 \pm 100.8	-	-
Drink weight (g)	1173 \pm 104	1158 \pm 103	-	0.000***
Sodium intake (mg)	399.7 \pm 35.5	337.3 \pm 29.9	0.0	0.000***

[†]iCE – iso-volumic sport drink that was diluted to match carbohydrate content of LFM

[‡]CE sport drink – undiluted

*** $p < 0.001$

Table 4: Table of subsequent performance results (N=11)

Performance variable	LFM Mean±SD	iCE [†] Mean±SD
VO ₂ max- shuttle run (ml O ₂ min ⁻¹ kg ⁻¹ body mass)	38.73±8.26	38.53±4.96
Sideways agility test (sec.)	18.68±1.49	18.61±1.33
Four corner agility test (sec.)	34.77±3.48	34.36±3.49

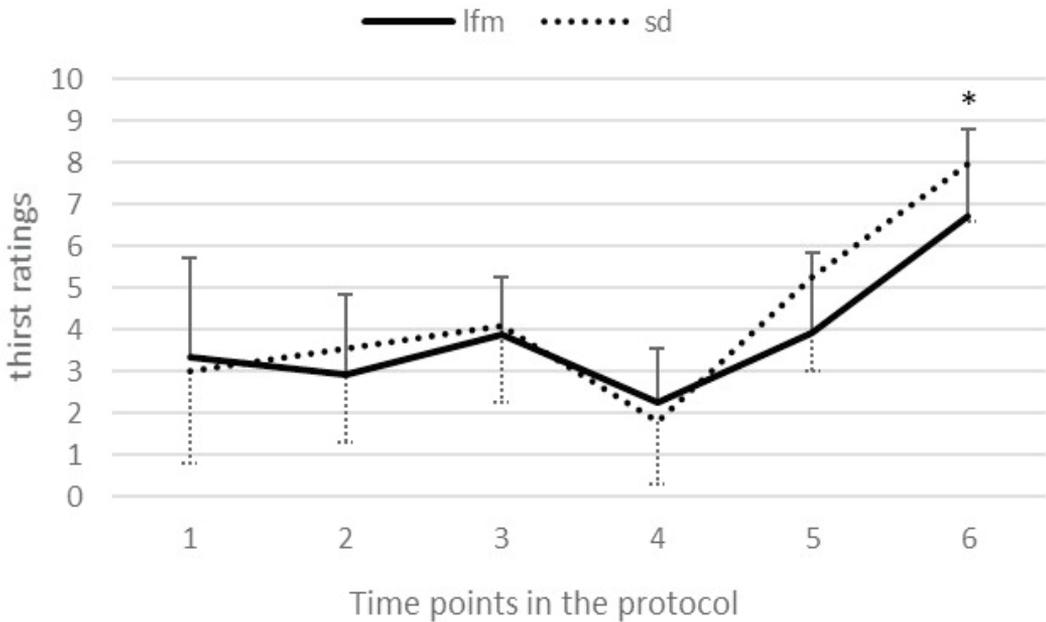
[†]iCE – iso-volumic sport drink that was diluted to match carbohydrate content of LFM

of activity was similar while doing the performance tests, and to check the effect of drink on performance over time. The two way repeated measures ANOVA revealed that type of drink had no effect on PHR $F(1,10)=2.856, p>0.05$, and there was no interaction found between drink and PHR at the different time points $F(3.513, 35.127)=0.415, p>0.05$. No significant difference between groups was found in terms of aerobic capacity $t(10)=0.147, p=0.886$ and agility [sideways agility test: $t(10)=0.191,$

$p=0.852$ and four-corner agility test: $t(10)=0.397, p=0.700$] (Table 4).

Subjective measures

One of the main findings in this study was a significant difference in thirst ratings between groups. Thirst ratings between groups were significantly different after the shuttle run/post-performance test [$t(10)=-2.35, p=0.041$] as seen in Figure 2. However, the ratings were similar for gastrointestinal discomfort and palatability.



*significant at $p<0.05$

Figure 2. Thirst ratings at different time points

DISCUSSION

NFB was not significantly different for the LFM and iCE groups as shown in Table 2. This finding was also similar to the study on a milk-based liquid meal supplement and CE sports drink done by Baguley *et al.* (2016). However, another study that compared rehydration with milk and with CE-sports drink (150% body mass loss) after exercise and thermal dehydration found milk to produce higher overall NFB (Seery & Jakeman, 2016). The nutrient composition of milk was highlighted as one of the reasons for this result. In this study, body mass for LFM group was consistently higher than iCE group although the difference was not significant. Pre-exercise body mass was used as the reference point for NFB calculations and was set as the zero (0) point. Table 2 shows us that the NFB values for both groups decreased post-training and then increased after ingestion of the beverages. This steep decrease in NFB for the post-performance test/final NFB was possibly because of the adjustment to include the sweat rate of the participants and was expected, given the hot and humid conditions during the collection of data.

Our findings on subsequent performance showed that acute post-exercise ingestion of LFM compared with carbohydrate electrolyte sport drinks had similar effects on the LFM and iCE groups. The intermittent exercise or the 2 h badminton training in this study was the protocol used for glycogen depletion. The ingestion of either LFM or iCE was done during a 2 h rest period after the 2 h training and the performance tests done after. This study protocol is similar to Sudsa-ard *et al.*, (2014) where 1 g carbohydrate/kg body mass was also ingested once before performance tests were done. Although milk has been recommended as a post-exercise recovery drink

(Desbrow *et al.*, 2014; Watson, 2008; Sudsa-ard *et al.*, 2014), the results of its effectiveness on subsequent exercise are varied. Differences in the experimental procedures as well as the beverage amount ingested may have influenced the results as well. Sudsa-ard *et al.* (2014) reported that lactose-free milk ingestion increased endurance capacity in cycling compared to water and CE drink. In one study where the effects of carbohydrate versus carbohydrate-protein beverages were ingested during recovery from exhaustive aerobic exercise, the time-to-exhaustion subsequent exercise was not different between groups (Algahannam *et al.*, 2016). Even though the results did not reveal any advantage of drinking LFM over iCE, possible “day after” effects (e.g. the next 24-48 h) could have yielded positive results but it was not measured in this study. LFM is better known as a recovery drink, and its intake after training may provide an anabolic environment to help protein synthesis. Milk has the added benefit of providing additional nutrients, vitamins and minerals that are not present in commercial sports drinks. As such, it may help to correct some mineral deficiencies due to sweat loss and inadequate nutrition.

The drinks administered during experimental days were iso-volumic and matched for carbohydrate content. Since the sports drink contained more carbohydrate (Table 1), distilled water was added to it to match the carbohydrate content of the LFM. As can be seen in the table, LFM contains more nutrients and fat with a higher osmolality compared to sport drink. This explains the consistent and significant difference for drink weight for the participants despite having the same volume (of drinks).

Participants of this study rated palatability or “liking the taste” of the beverages similarly. Gastrointestinal comfort was also similar for the two

beverages possibly because of the use of LFM which covers discomfort that may arise from lactose-intolerance, as well as fullness that may arise from fat in milk. LFM may also be taken in boluses, since milk is associated with poor gastrointestinal tolerance in individuals when taken in large quantities.

Some studies that measured thirst found it to be similar for milk and CE drink, but ratings for bloating and fullness were higher for milk (Desbrow *et al.* 2014). Another study found participants to prefer CE sports drink over the milk-based liquid supplement in terms of gastrointestinal tolerance and palatability (Baguley *et al.* 2016). It should be noted that LFM was not utilised, and subsequent exercise was not a variable in these studies mentioned.

Thirst ratings were found to be significantly different for the two groups. As seen in Figure 2, thirst was slightly elevated at the start of the day, which is considered normal even for euhydrated individuals (Obika *et al.*, 2009; Perez-Idarraga & Aragon-Vargas, 2014). Thirst slightly increased after training despite the *ad libitum* water intake and dropped considerably after beverage intake. The thirst sensation increased dramatically and peaked after post performance tests, with the iCE group feeling significantly more thirsty than LFM group (Figure 2). There are many factors that may influence the sensation of thirst (Greenleaf, 1992), some of which are physiological as an indicator of hypohydration (Armstrong *et al.*, 2014) and some psychological (Johnson, 2007). In a study on thirst sensations and mouth dryness after high-intensity intermittent exercise (HIIE) (compared with continuous exercise), values were higher in HIIE, albeit these were found not significant (Mears & Shirreffs, 2013). HIIE which results in increased blood lactate concentrations, serum osmolality and sweat loss was found to be the reason

for greater voluntary water intake (thirst and *ad libitum* drinking) in participants. The thirst sensation increased after high-intensity intermittent exercise and remained so until participants were able to drink water despite decreasing levels of serum osmolality during recovery (Mears, Watson & Shirreffs, 2016). It was highly likely that the high-intensity intermittent exercise nature of the subsequent performance tests (badminton-specific agility tests and shuttle run) in this study could have triggered the thirst sensations to heighten for both groups.

Thirst perception increases in dehydrated persons and it was suggested that drinking decreases plasma osmolality and diminishes thirst sensation (Obika *et al.*, 2009). Milk compared to CE and water W ingestion increased plasma osmolality (Seery & Jakeman, 2016); however, they could not explain the higher NFB found for milk in that study. In our study, NFB was found to be similar for both groups, but plasma osmolality was not measured. Since the HIIE was done under hot and humid conditions and resulted in a decrease in NFB, the participants were hypohydrated, and therefore feelings of thirst increased. Thirst increased significantly and more so for the iCE group. Considering the components of LFM and CE drinks, LFM is superior in terms of energy, protein, fat and calcium compared to CE which has higher carbohydrate content (Table 1). Upon dilution of the CE to match the drinks for carbohydrate content, the resulting iso-volumic carbohydrate electrolyte sports drink iCE had a sodium content that was less than that of the LFM. This resulted in a significantly different sodium intake for the two groups [$t(10)=37.4$, $p=0.000$], where LFM group consumed more sodium compared to the iCE group (Table 3). Given the significant difference in the amount of sodium ingested for the LFM

and iCE groups and a possible increase in lactate levels post-performance test, serum osmolality could have possibly increased. This is a primary stimulus for the sensation of thirst (Mears *et al.*, 2016). The post-performance thirst sensations that were found to be significantly greater for iCE group in this study may therefore be related to amount of sodium ingested which affected serum osmolality. Under extreme conditions, one may be dehydrated even before feeling thirsty (Johnson, 2007), so proper hydration throughout exercise in the heat is very important. One may use thirst sensation as a marker of hydration status since the threshold for thirst onset is hypohydration at ~2% body mass (Armstrong *et al.*, 2014).

Neither plasma osmolality nor any other markers such as serum sodium content and lactate levels were measured in this study. Due to dilution of the CE to match the drinks for carbohydrate content, its sodium content decreased significantly and affected thirst sensations. Similar to the results of a study by Watson *et al.* (2008), the performance variables that were measured post-ingestion were not different in this study. Differences in results will ultimately depend on the type of milk ingested and other manipulations done to the drinks being tested.

CONCLUSION

The findings of this research are beneficial for lactose tolerant or lactose intolerant collegiate badminton athletes and those participating in different types of intermittent sports. Fluid balance was similar for the two groups; however, post-exercise ingestion of LFM offered a significant advantage over carbohydrate-matched iso-volumic carbohydrate electrolyte sports drink in quenching thirst at the end of the performance tests. Collegiate athletes

engaged in intermittent sports may be advised to ingest LFM and milk-based drinks (if tolerated) in place of traditional CE drinks for post-exercise rehydration mainly because its nutrient content can attenuate thirst which may positively affect subsequent intermittent sport performance.

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Authors' contributions

MMFT, principal investigator, conceptualised and designed the study, led the data collection, data analysis and interpretation, prepared the draft of the manuscript; NA, conceptualised and designed the study, interpretation of data, prepared the draft of the manuscript and reviewed the manuscript; PM, conceptualised and designed the study, advised on the data analysis and interpretation and reviewed the manuscript; KS and CR reviewed the manuscript.

Conflict of interest

The authors have no conflicts of interest to report.

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