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Effect of Carbohydrate Drink Intake Patterns on Exercise in Heat

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Abstract: Carbohydrate drink can increase work capacity by maintaining power output or speed or prolonging the time to fatigue at a fixed workload. Literature is available on fluid intake content and exercise performance. No study has been undertaken till now on fluid intake patterns during high intensity exercise in heat. Therefore the present study is devised to fill this gap and to design an appropriate fluid volume intake pattern during high intensity exercise in hot environmental condition. 15 moderately trained men participated in the study. Each subject was given two different intake patterns of carbohydrate drink in two exercise sessions conducted on different days. A gap of seven days was kept between two exercise sessions. Total amount of fluid intake by the subjects in each session is 1000ml. During the experiment ambient temperature was kept constant at 35°C. Parameters evaluated were blood glucose concentration during and after the high intensity exercise, time to exhaustion and mental concentration. Findings of the present study revealed that when carbohydrate ingestion was done in large quantities before exercise, the rate of glucose disappearance was significantly ($t = 10.34$, $p < 0.05$) earlier as compared to carbohydrate ingestion intermittently during exercise in hot environmental condition. Time of exhaustion was significantly ($t = 13.73$, $p < 0.05$) higher in intermittent drink intake pattern. Performance in mental concentration was significantly ($t = 4.98$, $p < 0.05$) better in intermittent drink intake pattern.

Key words: Blood glucose, high intensity exercise, dehydration

Introduction

Dehydration resulting from physical exercise in the heat, followed by a brief period of rehydration and the continuation of activity or competition is a common scenario for athletes, labourers, military personnel and recreational exercises. Thirst sensation is an appropriate measure for rehydration. But thirst does not provide a good index of body water requirements; because thirst is probably not perceived until an individual has incurred a water deficit of approximately 2% of body weight.

The onset of fatigue during prolonged high intensity exercise is associated with reduction in blood glucose concentration and dehydration (Cheuvront *et al.*, 2001). Fortunately, there are a number of strategies that athletes can use to prevent and/or to reduce the dangers that are associated with exercise in heat such as muscle cramps, stomach upset, stomach cramps, nausea, flatulence, diarrhea, headaches, dizziness, unusual fatigue and delirium, coma and even death, can be blamed to extreme heat stress. Nutritional intervention seems to be the most effective to prevent athlete from heat stress and this also includes the optimization of hydration status by the use of fluid replacement beverages (Wendt *et al.*, 2007).

Ingestion of carbohydrate drink during high intensity exercise helps alleviate heat dissipation problems (Melin *et al.*, 1994). Carbohydrates, especially in the heat are able to supply quick energy.

Researches have been completed in the area of fluid intake content and exercise performance. But till now there is no study available on appropriate fluid intake patterns before and during high intensity exercise in the heat and its effect on mental concentration and performance.

In this regard Wright *et al.* (1991) had previously demonstrated that a combination of carbohydrate drink when given both before and during exercise has an additive effect on performance. They did not explain that what would be the effect of carbohydrate ingestion on performance when it is given either prior to exercise or during exercise separately, therefore the relative importance of each practice could not be elucidated. In addition glucose concentration was not determined in the study, so it was impossible to determine the underlying mechanism behind their observed performance enhancement.

In order to obtain glucose concentration during different fluid intake pattern Febbraio *et al.* (2000) had conducted a comprehensive study by obtaining glucose concentration throughout exercise. But this study was conducted in the thermo neutral environmental conditions. As much of the athletic event occur in hot environmental condition, this does not present practical scenario.

For long endurance and high intensity sports performed in hot environmental condition it is well known that ingestion of carbohydrate drink is essential to delay the

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Table 1: Comparison of blood glucose concentration values at different time duration during exercise between two different carbohydrate drink intake patterns.

Time duration	Bolus pattern			Intermittent pattern			t
	Mean	SD	SE	Mean	SD	SE	
30 min before exercise	86.370	4.35	1.09	84.94	2.84	0.71	1.61 ^{NS}
At the onset of exercise	102.200	5.59	1.39	86.37	3.11	0.78	12.65**
At 30 min during exercise	70.060	5.48	1.37	96.25	4.59	1.15	13.83**
At 1 hour during exercise	88.370	4.31	1.08	108.69	6.85	1.71	10.25**
At time to exhaustion	75.630	4.81	1.21	91.64	4.33	1.08	10.34**

NS-Non Significant *p<0.05 - Significant **p<0.01 - Highly Significant

onset of fatigue. But the exact pattern of carbohydrate drink ingestion in hot environmental condition remains controversial. Hargreaves *et al.* (1996) suggested that during exercise in the heat there is an increase in liver glucose output without any change in the whole body glucose utilization. Due to this fact coaches and sports physician normally prescribe ingestion of large amount of glucose prior to exercise. This raises a question is this pattern appropriate to delay fatigue and enhance mental concentration during the late stage of game by maintaining blood glucose at euglycemic level. Therefore the aim of the present study is to design an appropriate fluid intake pattern so the athletes had a better maintenance of blood glucose concentration during the late stage of exercise in hot environmental condition.

Materials and Methods

Subjects: Sixteen recreational athletes (age 23±1.13 years, weight 67±3.02kgs, maximal oxygen uptake 52.08±3.44 ml/kg/min) were recruited as subjects for this study. Informed written consent was obtained from each participant prior to the data collection and each participant was debriefed about the procedure. All subjects had a competitive athletic background but none were currently training for endurance or sporting activities. The study was approved by the Institutional ethics committee of the Guru Nanak Dev University, Amritsar.

Preliminary Testing: Subjects attended pre-participation screening phase 2 days prior to the actual experiment in which they were asked to fill the screening questionnaire. VO₂ max was determined by Queen's College step test. Subjects with VO₂ max 45-55 ml/kg/min had participated in the study.

Experimental Trials: Subjects reported to the laboratory on two occasions after an overnight fast, having abstained from alcohol, caffeine, tobacco and strenuous exercise for the previous 24 hours. To minimize differences in resting muscle and liver glycogen concentration, subjects were provided with prepared food packages for 24 hours before each trial. Such a dietary exercise regimen has previously been shown to

minimize differences in pre-experimental metabolism and substrate availability (Angus *et al.*, 2000). Each experiment was separated by a period of 7 days.

A complete cross over design was used. During each trial subject continued cycling till exhaustion at an intensity 60-70 % age predicted maximum heart rate derived from Karvonen's (1957) equation in a climatic chamber at 35°C till exhaustion.

Subjects exercised after ingesting 1000ml of an isotonic carbohydrate drink, 30 min before exercise in single bolus drink intake pattern. In the second exercise session, 1000 ml of fluid was divided into 4 equal parts and given at the start of exercise, 15 minutes, 30 minutes and 45 minutes. Drink temperature was maintained at 10°C.

On arrival in the laboratory, the subjects voided and blood sample was collected for the analysis of baseline blood glucose concentration with the help of glucometer (Elegance CT X - 10). Subjects were asked to complete mental concentration test - Stroop test (Ridley and Mulcahy, 1930). This test is a psychological test of mental (attentional) vitality and flexibility. The test takes advantages of ability to read words more quickly and automatically than naming colours. The word is printed or displayed in a colour different from the colour it actually represents. After a basal blood glucose concentration was derived, subjects undergoing cycle ergometry were made to wear the polar short-range telemetry strap on the chest and monitoring watch on their wrists. Leger and Thierge (1988) suggested that portable light weight telemetric heart rate monitors were valid and accurate tools for measuring heart rate.

Further fingertip blood samples were obtained at 30 minutes, 1 hour and at the time of exhaustion. Post experimental reading of mental concentration test was also recorded.

Statistical analysis: A statistical computer software program [SPSS 14.0] was used for statistical analysis. The metabolic data from the two trials was compared with related t-test.

Results

The purpose of this investigation was to determine that which of the two intake patterns of carbohydrate drink

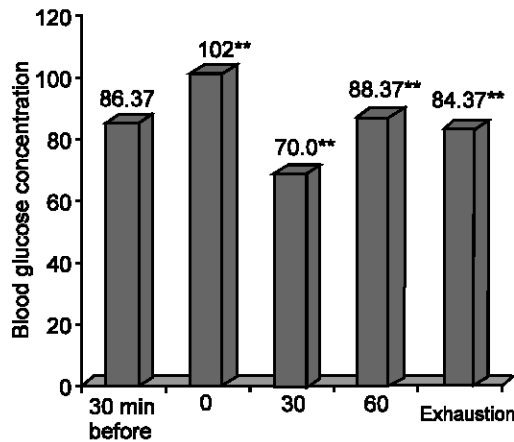


Fig. 1: Comparison of Blood Glucose Concentration at Different Time Duration in Single Bolus Drink Intake Pattern.

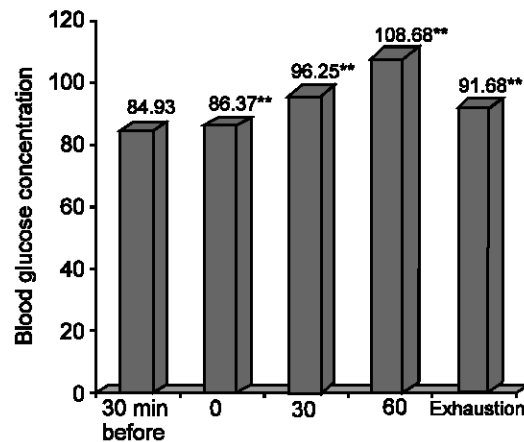


Fig. 2: Comparison of Blood Glucose Concentration at Different Time Duration in Intermittent Drink Intake Pattern.

Table 2: Comparison of time of exhaustion (in minutes) in two different drink intake pattern

	Time of exhaustion			
	Mean	SD	SE	t
Bolus pattern	77.06	4.09	1.02	-13.73**
Intermittent pattern	90.56	5.85	1.46	-

NS-Non Significant * $p < 0.05$ - Significant ** $p < 0.01$ - Highly Significant.

Table 3: Comparison of pre value and post values of mental concentration test in two different carbohydrate drink intake pattern.

	Bolus Pattern			Intermittent Pattern			
	Mean	SD	SE	Mean	SD	SE	t
Pre exercise	13.31	1.30	0.33	12.81	1.11	0.28	1.73 ^{NS}
Post exercise	16.68	2.41	0.66	14.56	1.93	0.48	4.98**

NS-Non Significant * $p < 0.05$ - Significant ** $p < 0.01$ - Highly Significant

i.e. bolus or intermittent is more effective to maintain blood glucose concentration at euglycemic level and enhance mental performance.

Comparison of blood glucose concentration values were made with related t test between two different drink intake pattern, there was significant difference ($p < 0.05$) at all time durations except the basal values ($t = 1.61$) ($p > 0.05$), (Table 1). At the time of exhaustion blood glucose concentration was significantly ($t = 10.34$) ($p < 0.05$) higher in intermittent drink intake pattern.

Blood glucose concentration after ingestion of carbohydrate drink 30 minutes before exercise in single bolus drink intake pattern, was significantly ($t = 33.64$, $p < 0.05$) raised at the start of exercise. After 30 minutes of exercise it declined significantly ($t = 18.63$, $p < 0.05$) below the level of fasting blood glucose. At 1 hour of exercise blood glucose concentration was raised significantly ($t = 11.25$, $p < 0.05$). At the time of exhaustion it declined to a greater extent ($t = 9.62$, $p < 0.05$) (Fig. 1). Blood glucose concentration after ingestion of carbohydrate drink intermittently during exercise, was significantly ($t = 5.96$, $p < 0.05$) raised at the start of exercise and it significantly raised at all time durations during exercise i.e., at 30 minutes ($t = 11.47$, $p < 0.05$) and at 1 hour ($t = 14.44$, $p < 0.05$) of exercise. After 1 hour, at the time of exhaustion it was significantly ($t = 17.67$, $p < 0.05$) declined (Fig. 2).

Time to exhaustion was compared with related t test between the two different drink patterns, it was

significantly ($t = 13.73$) ($p < 0.05$) higher in intermittent pattern in comparison to single bolus drink intake pattern (Table 2).

The time taken for the completion of mental concentration test was significantly ($t = 4.98$) ($p < 0.05$) towards lower side in intermittent drink intake pattern (Table 3).

Discussion

The purpose of the study was to design an appropriate fluid intake pattern for athletes participating in high intensity sports in hot environmental condition and to enhance mental concentration during the late stage of a game. Specific parameters included were blood glucose concentration at regular intervals, time to exhaustion and mental concentration test.

Blood glucose concentration: In the present study it was observed that there was a decline in blood glucose concentration in both the groups post experiment but the extent of decrease in blood glucose concentration was more in the single bolus pattern ($p < 0.05$). This indicates that ingestion of carbohydrate drink intermittently during exercise in heat would help to maintain blood glucose concentration at normoglycemic level after 1 hour of strenuous exercise. It was previously suggested that fall in blood sugar leads to several performance related problems including lack of energy, headache, dizziness and the treated 'bonking' or 'hitting the wall' (McArdle *et*

al., 2001). Hargreaves (1996) had suggested that in heat there is an increase in liver glucose output which results in hyperglycemia. To blunt this increase in liver glucose output, Marmy *et al.* (1996) had revealed that pre exercise glucose ingestion results in rapid fall in plasma glucose due to higher muscle glucose uptake with the onset of exercise. They also suggested that with pre exercise glucose ingestion liver glucose output can be reduced up to 62%.

The decrease in blood glucose concentration when fluid was ingested in a single bolus pattern was observed from the start of exercise. Previous studies suggest that when pre exercise glucose ingestion was done in large amounts 30 minutes before exercise it causes blood glucose to rise rapidly which may trigger insulin release in large quantity (Brand-Miller and Factor, 1996). This will lead to rebound hypoglycemia, which can be observed after 30 minutes of strenuous exercise (McArdle *et al.*, 2001). The results of the present study observed that blood glucose concentration rapidly fell after 30 minutes of exercise. This decrease in blood glucose concentration after 30 minutes of exercise was not observed in the intermittent drink intake pattern, this could be due to the fact that the amount of pre exercise carbohydrate glucose ingestion did not match with the single bolus pattern session. Thus, pre exercise glucose ingestion had completely suppressed endogenous glucose production (Jeukendrup *et al.*, 1999) in single bolus drink intake pattern.

Significant fall in blood glucose concentration in single bolus pattern can also be observed due to decrease in liver glucose output with large amount of pre exercise glucose ingestion (Fontvieille, 1992). The amount of intermittent drink intake pattern was not sufficient to blunt the increase in liver glucose output. Furthermore, it partially blunted the rise in blood glucose concentration. After 1 hour of strenuous exercise, blood glucose concentration in single bolus pattern, returned to the basal values due to increase in the endogenous glucose production i.e. liver glucose output. But this increase did not match with the blood glucose concentration attained with intermittent drink intake pattern after 1 hour of exercise. This difference in blood glucose concentration was found to be statistically significant. After 1 hour of exercise blood glucose concentration was significantly higher in intermittent drink intake pattern. This could be due to the fact that a supply of exogenous glucose was there in latter pattern. In single bolus pattern the rise in blood glucose concentration after rebound hypoglycemic values could be due to the release of stress hormones such as glucocagon (McArdle *et al.*, 2001).

After the completion of exercise blood glucose concentrations declined in both the patterns from the blood glucose concentration values at 1 hour of exercise. The result also suggest that the decrease relatively more with single bolus pattern. Even though

the time taken in completion for exercise was towards higher side in intermittent pattern, blood glucose was maintained at euglycemic levels. The results thus suggest that intermittent drink intake pattern can partially suppress the endogenous glucose production by liver, which allows the athlete to continue exercise for a longer period of time in comparison to single bolus pattern. This stored endogenous glucose will then allow the athlete to utilize this stored glucose during later stage of exercise without reaching glycogen depletion state. This could also be related to the fall in blood glucose concentration but this factor alone could not be responsible for fatigue in high intensity exercise.

In the present study, percentage of glucose rate of appearance came from exogenous glucose was not determined. Nonetheless, even if hepatic glucose production was completely suppressed as is possible when large amounts of glucose are ingested during exercise (Wagenmakers *et al.*, 1999), we cannot account for all the ingested glucose appearing in the blood and/or being taken up by the tissue. Therefore our data is in agreement with the previous suggestion that the rate of exogenous glucose oxidation may be limited by digestion, absorption and glucose rate of appearance into the blood stream.

It must be noted that, in the present study, it was assumed that glucose rate of disappearance matched with the glucose oxidation as it was not directly measured using primed continuous infusion (6, 6-2H). However, this assumption of blood glucose measurement is valid because it has been previously demonstrated that 98% of glucose rate of disappearance is oxidized during exercise (Jeukendrup *et al.*, 1997).

Time of exhaustion: There was significant difference in time to exhaustion between two different carbohydrate drink intake patterns. Time to exhaustion was considerably towards higher side in intermittent drink intake pattern in comparison to bolus drink intake pattern (Table 2).

Previous findings of Coyle *et al.* (1986) suggested that when carbohydrate drink ingestion was done during exercise it postpones fatigue by 15-30 minutes. They had compared carbohydrate drink with a placebo drink. In the present study, although carbohydrate drink was ingested in both the sessions but the pattern of intake was different. From the findings of the present study it can be suggested that carbohydrate drink can postpone fatigue if consumed intermittently throughout exercise.

Mental concentration: The present study revealed that there was a significant decrease in mental concentration ability in single bolus drink intake pattern in comparison to intermittent drink intake pattern ($P < 0.05$) after the completion of high intensity exercise in heat (Table 3).

Gopinathan *et al.* (1988) had suggested that even 2% of body mass loss impair mental functioning. Mental functioning is important during the late stage of many athletic events or team games. As the game reaches towards the end there is a need to have a good mental concentration ability to succeed in achieving the task with tactical skills. Reilly (1996) had suggested that reduction in work rate, mental fatigue, technical errors and deterioration in skills were observed as the game reaches towards the end.

Blood glucose is the main substrate for energy metabolism within the central nervous system. It is not surprising; therefore, that hypoglycemia has been suggested as a possible reason for deterioration in performance observed in sports, which require both tactical thought and co-operative intervention between players.

In the present study differences were found in blood glucose concentration in two different drink intake patterns. Blood glucose concentration was significantly higher in the intermittent drink intake pattern in comparison to the single bolus drink intake pattern. Therefore the decrease in the blood glucose concentration in the single bolus intake pattern might be the cause for decrement in mental concentration ability in comparison to intermittent drink intake pattern.

Conclusion: From the results it is concluded that even when carbohydrate is ingested in large quantities before exercise the glucose rate of disappearance is earlier, as compared to ingestion of carbohydrate drink intermittently during exercise in hot environmental conditions. The time of exhaustion might be linked to this decrease in blood glucose concentration. Mental concentration will be better when carbohydrate drink was ingested intermittently during exercise.

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