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Supplementary effect of carbohydrate-electrolyte drink on sports performance, lactate removal & cardiovascular response of athletes

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***Background & objectives*: Carbohydrate-electrolyte drink has a significant role on energy balance during exercise. The present study was designed to investigate the effect of oral carbohydrate-electrolyte supplementation on sports performance and cardiovascular status of the national level male athletes during exercise and recovery.**

***Methods*: A total of 10 male athletes (age range: 20-25 yr) were selected. The experiment was performed in laboratory (25°C and 60% relative humidity) in two phases; phase 1 - no supplementation, and phase 2 - a 5 g per cent carbohydrate-electrolyte drink was given orally during exercise and a 12.5 g per cent carbohydrate-electrolyte drink during recovery. Subjects performed an exercise test at 70 per cent of VO_2max. Performance time, heart rate during exercise and recovery were noted, blood samples were collected during exercise and recovery for the analysis of glucose and lactate levels in both the phases.**

***Results*: Significant improvements were noted in total endurance time, heart rate responses and blood lactate during exercise at 70 per cent VO_2max after the supplementation of 5 g per cent carbohydrate-electrolyte drink. However, no significant changes were noted in blood glucose and peak lactate level irrespective of supplementation of carbohydrate-electrolyte drink. Significant improvement in cardiovascular responses, blood glucose and lactate removal were noted during recovery following a 12.5 g per cent carbohydrate-electrolyte drink.**

***Interpretation & conclusion*: Carbohydrate-electrolyte drink can increase endurance performance as well as enhance lactate removal and thereby delaying the onset of fatigue.**

Key words Carbohydrate - electrolyte - exercise - glucose - heart rate - lactate

Loss of fluid electrolyte and reduction of the body's carbohydrate stores are the major causes of fatigue in prolonged exhaustive exercise[1-3]. Dehydration resulting from sweat loss, and increase in core temperature may be primary cause of fatigue even in moderate climatic conditions[4,5]. Though sweat loss in high intensity, short duration exercise is small, exercise capacity is impaired if there is a pre-exercise fluid

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deficit. Fluid ingestion during exercise has the twin benefits of providing a source of carbohydrate fluid to supplement the body's limited store, and of supplying water to replace losses caused by sweating[6,7]. Several studies have indicated that carbohydrate supplementation during prolonged exercise improves endurance performance by maintaining blood glucose level[8,9]. Electrolyte content of the fluid maintains the electrolyte balance and reduces the onset of fatigue[10-13].

Though many studies has been performed worldwide in this area, studies from India are limited. We carried out this study to find out the effect of carbohydrate-electrolyte drink on endurance performance and cardiovascular status during exercise and recovery in male Indian athletes playing at national level.

Material & Methods

Subjects and supplementation: The study was conducted at Bangalore in the month of October 2001 in the Sports Authority of India. A total of 16 male endurance athletes (age range 20-25 yr) participated at National level were selected after thorough medical examination. Four athletes left the study in between and two got injured during practice session. Study could be completed with ten subjects only. The subjects were given a detailed description of the procedure and potential complications. The physical and physiological characteristics of the athletes were recorded (Table I). Participants were advised not to engage in strenuous activities two days before an exercise test and not to exercise on the day of the test. They were requested to maintain their normal diet and to refrain from alcohol and caffeinated beverage in the week preceding the experiment and throughout the experiment.

The experiment was performed in two phases: in the first phase no supplementation was given, whereas, in the second phase a 100 ml of 5 g per cent carbohydrate-electrolyte drink (carbohydrate 5 g, sodium 9.2 mg, potassium 13.6 mg) was supplied during exercise at an interval of 15 min till exhaustion, and another 100 ml of 12.5 g per cent carbohydrate-electrolyte drink (carbohydrate 12.4 g, sodium 24.5 mg, potassium 34.1 mg) was given after 5 min of recovery and thereafter at an interval of 5 min up to 20 min. Heart rate and performance time were recorded. Blood samples were collected during exercise and recovery for analysis of blood glucose and lactate. Each test was scheduled at a similar time of day (±1 h) with a room temperature of 25±2°C, 60 per cent relative humidity in order to minimize the effect of diurnal fluctuation. All the parameters were measured before and after the supplementation. The Sports Authority of India approved the study and the procedures followed were in accord with the ethical standards on human experimentation (as per the guidelines laid down by the Central Ethical Committee of the Indian Council of Medical Research)[14].

Table I. Physical and physiological characteristics of the athletes (n=10)

Parameters	Values (mean ± SD)
Age (yr)	25.8 ± 2.4
Height (cm)	167.2 ± 7.0
Weight (kg)	58.7 ± 8.5
VO_2 max (l/min)	3.2 ± 0.6
Relative VO_2 max (ml/kg/min)	54.4 ± 4.4
70% of VO_2 max (ml/kg/min)	38.1 ± 3.1
Maximum heart rate (bpm)	193.2 ± 6.6
Heart rate at 70% of VO_2 max (bpm)	159.3 ± 4.7
Oxygen pulse (ml/beat)	18.1 ± 2.3
Ventilatory equivalent (l/l of O_2)	35.1 ± 2.7

VO_2 max, maximum oxygen capacity
bpm, beats per minute

Exercise test: One week prior to experimental testing, each subject's maximum oxygen capacity (VO_2 max) was determined following standard methodology[15]. The subject was asked to run on the treadmill (Jaeger LE 6000, Germany) at a speed of 6 km/h for 2 min thereafter, the workload was increased by 2 km/h for every 2 min until volitional exhaustion. Expired gas was collected and measured from a mixing chamber using Oxycon Champion (Jaeger, Germany). Evaluation of endurance performance and cardiovascular status were performed at 70 per cent of their maximum aerobic capacity using treadmill during two phases of experiment. Heart rate was monitored during exercise and recovery using sports testers (PE-3000, Finland). The maximum running time till voluntary exhaustion was taken with a stopwatch (Sports Testers PE-3000, Finland). All the above parameters were measured during first and second phases of experiment with a gap of one week.

Estimation of blood glucose and lactate: Blood samples were collected at an interval of 10 min during exercise and recovery from fingertips for estimation of blood glucose[16] by spectrophotometric method (Hitachi U-2000 Spectrophotometer, Japan) using Boehringer Manneheim kit, and lactate[17] by lactate analyzer (Analox P-LM55, UK) using Analox lactate kit supplied by Analox (UK) during exercise and recovery.

Statistical analysis: Wilcoxon signed rank test was applied for finding the significant difference between paired observations of single group. Two way repeated measure ANOVA was applied to find the effect of carbohydrate-electrolyte supplementation on endurance performance and recovery[18]. All the statistical analysis were performed using SPSS for Windows 10.0 (SPSS Inc., USA).

Results & Discussion

Effect of carbohydrate-electrolyte drink on endurance time and cardiovascular response during exercise and recovery: Total time of endurance at 70 per cent VO_2 max was found to increase significantly ($P<0.01$) following a 5 g per cent carbohydrate-electrolyte drink supplement. The increase of total endurance time was noted about 51 per cent when supplied with carbohydrate-electrolyte drink. The endurance time recorded with and without carbohydrate-electrolyte drink supplement was 94.1±17.7 and 62.3±10.4 min respectively. Significant improvements in cardiovascular responses were noted during moderate intensity exercise (at 70% VO_2 max) following a 5 g per cent carbohydrate-electrolyte drink (Fig.). Cardiovascular responses during recovery were also improved significantly after the supplementation of 12.5 g per cent carbohydrate-electrolyte drink (Table II).

Effect of carbohydrate-electrolyte drink on blood glucose levels during exercise and recovery: Blood glucose values were noted at rest and then at an interval of 10 min each during exercise and recovery. No significant changes were noted in blood glucose level throughout the exercise period at 70 per cent VO_2 max when suplied with 5 g per cent carbohydrate-electrolyte drink. No significant change in blood glucose level was noted during receovery after 10 min (without supplementation 100.8±9.2 mg/dl; with supplementation 108.4±25.6 mg/dl), however, a significantly ($P<0.01$) higher blood glucose level was noted during recovery after 20 min (without supplementation 100.3±9.9 mg/dl; with supplementation 119.2±10.3 mg/dl) with a 12.5 g per cent carbohydrate-electrolyte drink.

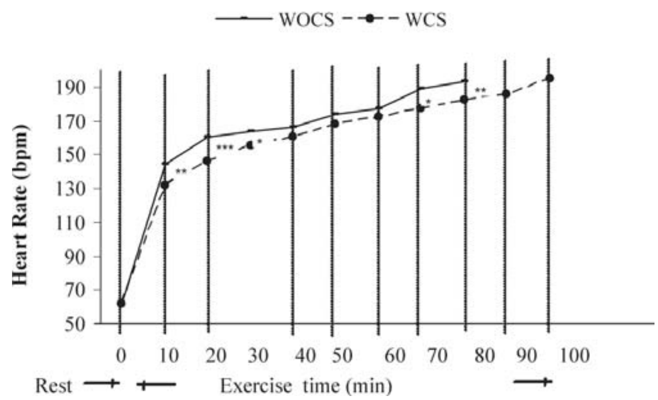

Fig. Heart rate responses during exercise with and without supplementation of carbohydrate-electrolyte drink (n=10). WOCS, without carbohydrate supplementation; WCS, with carbohydrate supplementation. P*<0.05; **<0.01; ***<0.001 compared to WOCS.

Table II. Effects of supplementation of 12.5 g% carbohydrate-electrolyte drink on recovery heart rate

Groups	WOCS	WCS
Rec HR1 (bpm)	154 ± 6.1	148 ± 6.4*
Rec HR2 (bpm)	138 ± 6.6	127 ± 4.9**
Rec HR3 (bpm)	118 ± 5.2	109 ± 5.8**

Rec HR1, recovery heart rate after 1st min; Rec HR2, recovery heart rate after 2nd min; Rec HR3, recovery heart rate after 3rd min; WOCS, without carbohydrate supplementation; WCS, with carbohydrate supplementation

*$P<0.05$, **$P<0.01$ compared to WOCS

Effect of carbohydrate-electrolyte drink on blood lactate levels during exercise and recovery: Blood lactate values were noted at rest and then at an interval of 10 min each during exercise and recovery. It was noted that supplementation of 5 g per cent carbohydrate-electrolyte drink keeps the blood lactate at lower levels. Although most of the values were not significant, but significantly lower (P<0.01) value was noted after 70 min of exercise (without supplementation 3.4±0.6 mmol/l compared to 2.1±0.4 mmol/l with supplementation). However, no significant alteration was noted in peak lactate level (without supplementation 3.7±1.2 mmol/l with supplementation 3.2±1.0 mmol/l). Removal of blood lactate was significantly (P<0.05) faster after 10 min (without supplementation 3.1±1.0 mmol/l; with supplementation 2.1±0.8 mmol/l) and 20 min (without supplementation 2.5 ± 0.9 mmol/l; with supplementation 1.5±0.4 mmol/l) with 12.5 g per cent carbohydrate-electrolyte drink.

Hypohydration impairs the body's ability to regulate heat resulting in increased body temperature and an elevated heart rate, causing the athlete to feel more fatigued than usual at a given work rate with reduced mental function, followed by slow gastric emptying which results in stomach discomfort. All these effects lead to impairment in exercise performance. There is substantial evidence that consumption of an isotonic sports drink during exercise can improve performance during prolonged sub-maximal, intermittent, high intensity, and shuttle running test[19]. The consumption of isotonic sports drinks either throughout or late in exercise has been shown to delay the onset of tiredness and thus improve performance[20]. It may be either due to carbohydrate ingestion preventing a decline in blood glucose and maintaining carbohydrate oxidation at a high rate late in exercise, or due to muscle glycogen sparing early in exercise[21,22]. The amount of pre-exercise muscle glycogen stores is an important factor in determining endurance capacity. Prolonged exercise causes dehydration and reduces the body's carbohydrate energy stores. These are the major contributors to the onset of fatigue.

Different mechanisms have been proposed to show that the ergogenic effect of carbohydrate does not affect muscle glycogen at a critical point in endurance exercise when liver and muscle glycogen levels are low and uptake of glycogen by skeletal muscle is increased[23,24]. The carbohydrate content of drinks taken should be determined by relative needs to supply fuel and water. This depends on the intensity and duration of the exercise, the ambient temperature and humidity, and on the physiological and biochemical characteristics of the individual athlete[20-24]. Electrolytes of sodium, magnesium, calcium and potassium help the cells to function normally and provide the key to muscle function, mental focus and body cooling. Electrolytes are easily lost in sweat and urine during physical activity, so replenshing these minerals is important[25-27]. More severe water loss at high temperatures along with electrolytes puts a person at risk of heat cramps or sometimes heat stroke. Low level of potassium or magnesium enhances muscles cramp[25-28].

Optimal post-exercise rehydration requires both higher fluid volume replacement and sodium content compared with rehydration during exercise[29]. Ingestion of plain water delays rehydration because it decreases plasma osmolality, reduces thirst and increases free-water clearance[29]. Replacement of sodium lost in sweat is important in maximizing the retention of ingested fluids[29]. Sodium is particularly important for fluid restoration after exercise. The optimum means of replacing fluid and salts lost during exercise is to provide a combination of water, carbohydrate and mineral salts. Water reduces dehydration and helps to maintain blood volume, which improves performance because it lowers the heart rate and body temperature, and mineral salts help to restore electrolyte balance by boosting the process of water absorption[25-30].

In summary, it may be concluded that carbohydrate replacement during exercise may enhance performance of sports and activities, which typically deplete body carbohydrate stores, by providing an additional fuel source for the muscle. Carbohydrate and electrolyte balance keeps low heart rate as well as low blood lactate level during exercise.

References

1. Andrews JL, Sedlock DA, Flynn MG, Navalta JW, Ji H. Carbohydrate loading and supplementation in endurance-trained women runners. *J Appl Physiol* 2003; *95* : 584-90.

2. Applegate E. Effective nutritional ergogenic aids. *Int J Sport Nutr* 1999; *9* : 229-39.

3. Arkinstall MJ, Bruce CR, Nikolopoulos V, Garnham AP, Hawley JA. Effect of carbohydrate ingestion on metabolism during running and cycling. *J Appl Physiol* 2001; *91* : 2125-34.

4. Bilzon JL, Allsopp AJ, Williams C. Short-term recovery from prolonged constant pace running in a warm environment: the effectiveness of a carbohydrate-electrolyte solution. *Eur J Appl Physiol* 2000; *82* : 305-12.

5. Bilzon JL, Murphy JL, Allsopp AJ, Wootton SA, Williams C. Influence of glucose ingestion by humans during recovery from exercise on substrate utilisation during subsequent exercise in a warm environment. *Eur J Appl Physiol* 2002; *87* : 318-26.

6. Daries HN, Noakes TD, Dennis SC. Effect of fluid intake volume on 2-h running performances in a 25 degrees C environment. *Med Sci Sports Exerc* 2000; *32* : 1783-9.

7. Morris JG, Nevill ME, Thompson D, Collie J, Williams C. The influence of a 6.5% carbohydrate-electrolyte solution on performance of prolonged intermittent high-intensity running at 30 degrees C. *J Sports Sci* 2003; *21* : 371-81.

8. Haff GG, Lehmkuhl MJ, McCoy LB, Stone MH. Carbohydrate supplementation and resistance training. *J Strength Cond Res* 2003; *17* : 187-96.

9. Brouns F, Rehrer NJ, Saris WH, Beckers E, Menheere P, ten Hoor F. Effect of carbohydrate intake during warming-up on the regulation of blood glucose during exercise. *Int J Sports Med* 1989; *10* (Suppl 1) : S68-75.

10. Chryssanthopoulos C, Williams C, Nowitz A. Influence of a carbohydrate-electrolyte solution ingested during running on muscle glycogen utilisation in fed humans. *Int J Sports Med* 2002; *23* : 279-84.

11. Clapp AJ, Bishop PA, Smith JF, Mansfield ER. Effects of carbohydrate-electrolyte content of beverages on voluntary hydration in a simulated industrial environment. *Am Indus Hyg Assoc J* 2000; *61* : 692-9.

12. Rehrer NJ. Fluid and electrolyte balance in ultra-endurance sport. *Sports Med* 2001; *31* : 701-15.

13. Sanders B, Noakes TD, Dennis SC. Sodium replacement and fluid shifts during prolonged exercise in humans. *Eur J Appl Physiol* 2001; *84* : 419-25.

14. Ethical guidelines for biomedical research on human subjects. New Delhi: Indian Council of Medical Research; 2000.

15. Astrand PO, Rodahl K, editors. *Text book of work physiology.* New York: McGraw-Hill; 1970.

16. Wibler RL, Moffatt RJ. Influence of carbohydrate ingestion on blood glucose and performance in runners. *Int J Sport Nutr* 1992; *2* : 317-27.

17. Powers SK, Howley ET, editors. Exercise Physiology. Madison, WI: Brown & Benchmark Publishers; 1997.

18. Das D, Das A. Analysis of variance. In: Das D, editor. *Statistics in biology and psychology*. Calcutta: Academic Press; 1998 p. 250-82.

19. Nicholas CW, Williams C, Lakomy HKA, Phillips G, Nowitz A. Influence of ingesting a carbohydrate-electrolyte solution on endurance capacity during intermittent high-intensity shuttle running. *J Sports Sci* 1995; *13* : 283-90.

20. Tsintzas OK, Williams C, Wilson W, Burrin J. Influence of carbohydrate supplementation early in exercise on endurance running capacity. *Med Sci Sports Exerc* 1996; *28* : 1373-9.

21. Tsintzas OK, Williams C, Boobis L, Greenhaff P. Carbohydrate ingestion and single muscle fiber glycogen metabolism during prolonged running in men. *J Appl Physiol* 1996; *81* : 801-9.

22. Fallowfield JL, Williams C, Singh R. The influence of ingesting a carbohydrate-electrolyte beverage during 4 hours of recovery on subsequent endurance capacity. *Int J Sports Nutr* 1995; *5* : 285-99.

23. O'Brien MJ, Viguie CA, Mazzeo RS, Brooks GA. Carbohydrate dependence during marathon running. *Med Sci Sports Exerc* 1993; *25* : 1009-17.

24. Fahey TD, Larsen JD, Brooks GA, Colvin W, Henderson S, Lary D. The effects of ingesting polylactate or glucose polymer drinks during prolonged exercise. *Int J Sport Nutr* 1991; *1* : 249-56.

25. Bilzon JL, Allsopp AJ, Williams C. Short-term recovery from prolonged constant pace running in a warm environment: the effectiveness of a carbohydrate-electrolyte solution. *Eur J Appl Physiol* 2000; *82* : 305-12.

26. Gisolfi CV. Water and electrolyte metabolism during exercise. In: Fox EL, editor. *Nutrient utilization during exercise*. Columbus: Ross Laboratories; 1983 p. 21-5.

27. Gisolfi CV, Lambert GP, Summers RW. Intestinal fluid absorption during exercise: role of sport drink osmolality and [Na+]. *Med Sci Sports Exerc* 2001; *33* : 907-15.

28. Koulmann N, Melin B, Jimenez C, Charpenet A, Savourey G, Bittel J. Effects of different carbohydrate-electrolyte beverages on the appearance of ingested deuterium in body fluids during moderate exercise by humans in the heat. *Eur J Appl Physiol Occup Physiol* 1997; *75* : 525-31.

29. Burke LM. Rehydration strategies before and after exercise. *Aust J Nutr Dietet* 1996; *53* (Suppl 1) : S22-6.

30. Costill DL, Hargreaves M. Carbohydrate nutrition and fatigue. *Sports Med* 1992; *13* : 86-92.

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