CARPATHIAN JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

journal homepage: http://chimie-biologie.ubm.ro/carpathian_journal/index.html

EFFECTS OF SOLID EXERCISE DRINKS ON BODY FLUID EQUILIBRIUM OF SPORTSMEN ENGAGING IN ENDURANCE EVENTS

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Article history:
Received:
18 January 2016
Accepted:
23 August 2016

Keywords:
Sports drinks;
Endurance events;
Body fluid equilibrium;
Metabolic balance;
Biochemical indexes.

ABSTRACT

This study aimed at investigating the effects of solid exercise drinks with different components on the body fluid equilibrium of sportsmen engaging in endurance events and providing a more accurate, high-efficient and economic reference basis for the selection of exercise drinks in competition. Twenty male sportsmen engaging in endurance events were selected as research subjects. The effects of solid exercise drinks which contained low molecular sugar (L-CHO), high molecular sugar (H-CHO) and sugar + protein (CHO-Pro) and placebo (blank control) on sportsmen were investigated. Research results demonstrated that, the weight of sportsmen in different groups significantly decreased after physical activities ($p < 0.05$); plasma osmotic pressure and total protein were much higher after exercise compared to before exercise ($p < 0.05$), and the difference between sportsmen taking different fluids had no statistical significance; urine osmotic pressure had no obvious change after exercise, but the urine osmotic pressure of H-CHO group was much higher than that of the placebo blank group ($p < 0.05$); plasma sodium and chlorine showed no remarkable changes after exercise, and the differences between sportsmen taking different fluids had no statistical significance; serum potassium in all groups demonstrated an obvious increase after exercise compared to during exercise ($p < 0.05$), and there was no obvious difference between groups; urine sodium and chlorine showed no significant differences after exercise compared to before exercise, and urine chlorine of the H-CHO group was much lower than that of the placebo blank group ($p < 0.05$); urine potassium after exercise was much lower than that before exercise ($p < 0.05$), and the difference between different groups had no statistical significance; the level of lactic acid after exercise was significantly higher than that in static state ($p < 0.05$), and the difference between different groups had no statistical significance; pH value had no remarkable change; the duration of exercise in groups had no remarkable difference. Thus it can be concluded that, low molecular sugar drinks can effectively maintain the metabolic balance of water and electrolyte and sports drinks containing low molecular sugar, high molecular sugar and sugar + protein have similar performance in regulating acid-base balance and promoting exercise performance.

1. Introduction

Energy consumption, water loss and the increase of core temperature during exercise all can result in the decline of exercise capacity (Lafata et al., 2014). Sports drink as a kind of sports supplement can rapidly and efficiently help human body maintain or recover to an ideal state and supplement the energy consumed during exercise (Buxton et al., 2012). Due to the different energy supply methods and body fluid metabolism characteristics (Zhou et al., 2013), components of different sports drinks differ greatly. A large number of studies in this aspect have been carried out to comprehensively and systematically compare and analyze the effects of different concentrations of electrolyte, different kinds of sugar and special components on the physicochemical level of human body (Attarzadeh et al., 2013).

Alexander et al. (Kratz et al., 2005) found that, among 140 marathon runners who did exhaustive exercise, 25% of the runners showed hypernatremia, 12% of them showed increased plasma osmotic pressure, 9% of them developed hyponatremia, and 16% of them had decreased osmotic pressure. Gonzalez-Alonso (1998) pointed out that, the ability for sportsmen to fulfill skilled movement decreased by 7 ~ 8% in dehydration but non-heat exhaustion state. Some researchers (Tam and Noakes, 2013; Seo et al., 2014] proposed that, exercise capacity was inversely proportional to temperature in dehydration state. Another study (Firsov et al., 2012) suggested that, there was a significant loss of water and electrolyte, but no obvious change of osmotic pressure, after normal people did one-hour exercise with strength of 60% maximum oxygen uptake; a loss of water which was 5% of the weight of body could result in a decrease of 20% ~ 30% of skeletal muscle function; a loss of 1 L of water could result in 8 times more heart rate every one minute, a decrease of 1 L of cardiac output and an increase of 0.3 °C of core temperature. The increase of core body temperature can further increase heart rate and pulmonary ventilation volume (Hayashi et al., 2011). Further loss of water can induce symptoms such as fatigue and heat exhaustion (Moreno et al., 2013). Perspiration rate is in direct proportion to exercise strength (Kounalakis et al., 2010).

All in all, sports drinks can supplement nutritional substances lost during exercise (Millar et al., 2014) and it is consistent with the physical characteristics of sportsmen and manual labor population and the targeted nutritional demand (Sibthorpe et al., 2011). This study first explored the composition proportion, ionic concentration and osmotic pressure of solid sports drinks, then performed exercise tests on 20 male sportsmen who engaged in endurance events and took solid sports drinks in different composition proportion, and finally detected various blood and urine indexes of the sportsmen.

2. Test materials and subjects

2.1. Preparation before test

Twenty male sportsmen who engaged in endurance events were selected as research subjects and all of them had normal index values. Three different kinds of solid sports drinks were selected from the list of centralized purchasing nourishment for national teams; besides, placebo was taken as a negative control. The three kinds of solid sports drinks contained low molecular sugar, high molecular sugar and sugar + protein respectively. The placebo was made from multiple kinds of sweetening agents dominated by aspartame. The sugar content of the placebo depended on the sugar content of sports drinks. The taste and flavor of the placebo and sports drinks should be kept consistent as far as possible. The drinks and placebo were mixed with pure water to prepare water solution with sugar content of 8%, following the principle of equal sugar content. The three kinds of sports drinks and sweetening agent were all in apple flavor. The main components of the drink water solution systems are shown in Table 1.

Table 1. Main components of different sports drinks

Drink	L-CHO	H-CHO	CHO-Pro	Placebo
Types of sugar and protein	Low molecular sugar	High molecular sugar	Sugar + whey protein	/
Molecular weight of sugar	<1500	500000~750000	<1500	/
Sugar content (%)	8	8	8	8

Protein content (%)	0	0	2.68	0
Other	Na^+, K^+, VitC, nicotinic acid, inositol, etc.	Na^+, K^+, Ca^{2+}, Mg^{2+}, etc.	Na^+, K^+, Ca^{2+}, Mg^{2+}, VitC, VitE, etc.	Aspartame, etc.

The ion concentrations of the three kinds of sports drinks containing different components and placebo were detected using a fully automatic biochemical analyser; the osmotic pressure was detected using a freezing point osmotic pressure detector. The components are shown in Table 2.

Table 1. Components of the placebo and drinks

Different components and ions	Na^+ (mmol/L)	K^+ (mmol/L)	Cl^- (mmol/L)	Osmotic pressure (mOsm/L)
L-CHO	21.6	2.25	14.5	98.32
H-CHO	13.60	2.35	6.6	52.34
CHO-Pro	4.66	10.76	15.1	420.35
Placebo	9.1	0.75	2.6	17.68

The 20 subjects aged from 19 to 27 years old. All of them did not take drugs that can affect sugar and lipid metabolism such as β receptor blocker, drugs that can affect liver and hepatic functions such as diuretic and antitubercular agent, β-lactam antibiotics and quinolones three months before test. One day before test, the subjects were asked to relieve the bowels after waking up in the morning and then their weight and body composition were detected. The whole test was performed in the conditions of constant temperature, humidity and pressure (average 25.06 ± 0.65 °C, 56.95 ± 5.30 % and 1004.13 ± 5.15 mbar). During test, the oxygen intake and diet were assigned to each sportsman uniformly. The exercise scheme designed by Nybo et al. (2009) was improved by combining cycle ergometer with progressively increased load to test the maximum oxygen intake (de et al., 2009).

2.2. Formal exercise test

This study adopted Cortex Metalyzer II-R for gas metabolism analysis (Hillman et al., 2012). The curve equation of oxygen intake and exercise load as well as the load corresponding to 70% of the maximum oxygen intake was determined through trend line. The subjects were tested by means of riding cycle ergometer under the condition of the maximum oxygen intake. According to crossover design, the test process was divided into four stages to reduce individual variation. Every stage was composed of exercise test (one day) and washout period (seven days). Fluids given to each sportsman every day were the same. The diet and exercise of sportsmen were monitored and recorded; besides, the sportsmen took standard diet every day to expel the influence of other variables except drinks. Two days before the first stage of exercise test, factors that can affect test indexes should be avoided. The last three stages of test should be kept the same with the first stage.

2.3. Blood and urine test indexes

2.3.1. The preparation of blood samples

Firstly, 2 ml of venous blood was taken and transferred into an Ethylene Diamine Tetraacetic Acid (EDTA) anticoagulation tube. Blood glucose and blood lactic acid were detected after standing. Then 4 ml of whole blood was taken and put into a vacuum aseptic tube containing blood clotting catalyst. After 30-min standing, it was centrifuged at 3000 r/min for 15 min. Plasma and serum were obtained after centrifugation and they were stored at – 20 °C for the detection of various indexes.

2.3.2. The preparation of urine samples

Containers from the same batch were used to collect urine before and after exercise for the detection of the osmotic pressure of urine. The rest were stored in – 20 °C for the content detection of Na^+, K^+ and C^-.

2.3.3. Blood and urine test indexes

Osmotic pressure: the osmotic pressure of the plasma and urine were tested using a freezing point osmotic pressure meter and the sample was added using a micropipettor. The average value of measured results was taken as the final result.

Blood lactic acid: 20 μl of the prepared venous whole blood was mixed with 40 μl of membrane rupture diluents. It was shaken constantly till the membranes completely ruptured. Then the content of lactic acid in the whole blood was detected using YSI1500 lactid acid detector and lactate dehydrogenase method.

Total protein: 1 mL of the prepared plasma was taken and the total protein content of the plasma was detected using a fully automatic biochemical analyser and colorimetric method.

Na+, K+ and Cl-: The ion concentrations of Na+, K+ and Cl- in the blood and urine samples were detected and the average values were regarded as the final results.

2.4. Statistical method

Data were statistically analyzed using SPSS ver. 17.0 and expressed as mean ± standard error (SE). Difference between groups was analyzed using group F test. Difference was considered as statistically significant if $p < 0.05$.

3. Results and discussions

3.1. Changes of water balance

3.1.1. Changes of weights of the sportsmen after the supplement of drinks

The changes of weights of the sportsmen are shown in the Figure 1.

Figures 1 and 2 demonstrate that, the weights of the sportsmen significantly decreased after exercise; the sports drinks containing different components had no obvious influence on their weights ($p < 0.05$); the weight difference between the L-CHO group and the H-CHO group had no statistical significance ($p < 0.05$), so did the CHO-Pro group and the placebo group. It indicated that, the components of the three kinds of sports drinks produced no effect on perspiration rate compared to the placebo and moreover the weight loss percentage of sportsmen taking solid sports drink containing low molecular sugar was the smallest.

3.1.2. Changes of osmotic pressure after the supplement of drinks

Before the supplement of drinks, the plasma osmotic pressure between groups had no statistically significant difference ($p > 0.05$). The changes of plasma osmotic in pressure are shown in Figure 3. Figure 3 demonstrates that, the plasma osmotic pressure at the three time points had no remarkable difference; compared to the static state, the plasma osmotic pressure during exercise had an obvious increasing tendency ($p < 0.05$); the plasma osmotic pressure of the four groups had no obvious difference ($p > 0.05$).

Before the supplement of drinks, the osmotic pressure of urine had no significant difference. The change of urine osmotic pressure is shown in Figure 4. Figure 4 demonstrates that, urine osmotic pressure had no significant change after exercise compared to before exercise; urine osmotic pressure of the four groups had no obvious difference; but urine osmotic pressure of the H-CHO group and placebo group had remarkable difference ($p < 0.05$, suggesting that urine ion concentration of the H-CHO group was much higher than that of the L-CHO group, which might be correlated to the weight change difference between L-CHO group and H-CHO group. There might be a correlation between weight, urine osmotic pressure and perspiration rate.

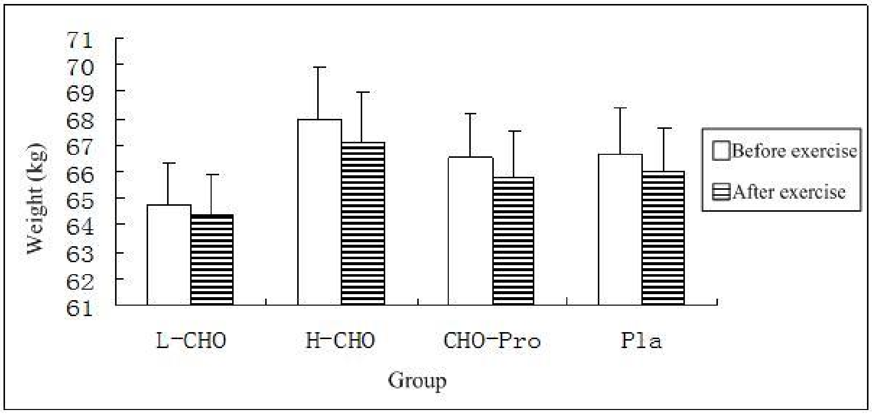

Figure 1. Effects of sports drinks containing different components on weight

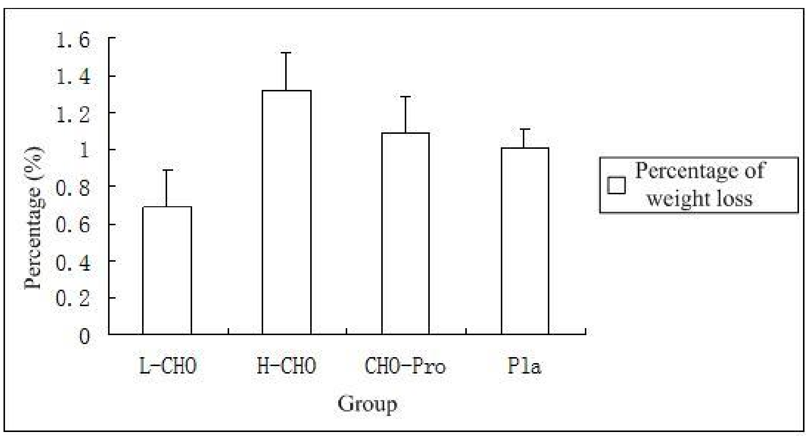

Figure 2. Weight loss percentages of sportsmen after exercise

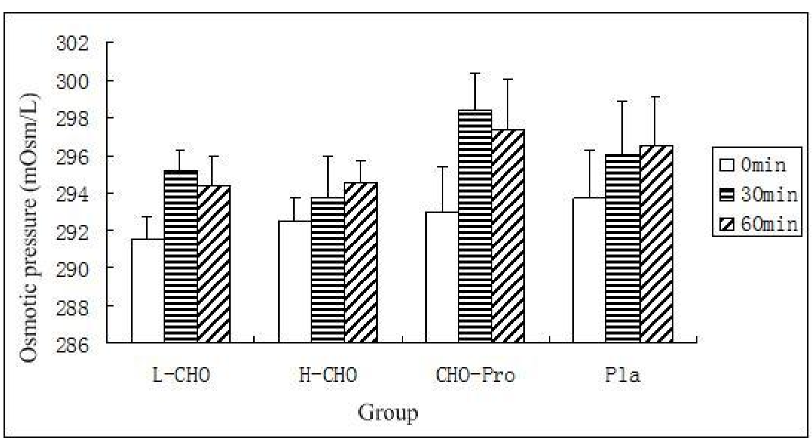

Figure 3. Effects of sports drinks containing different components on plasma osmotic pressure

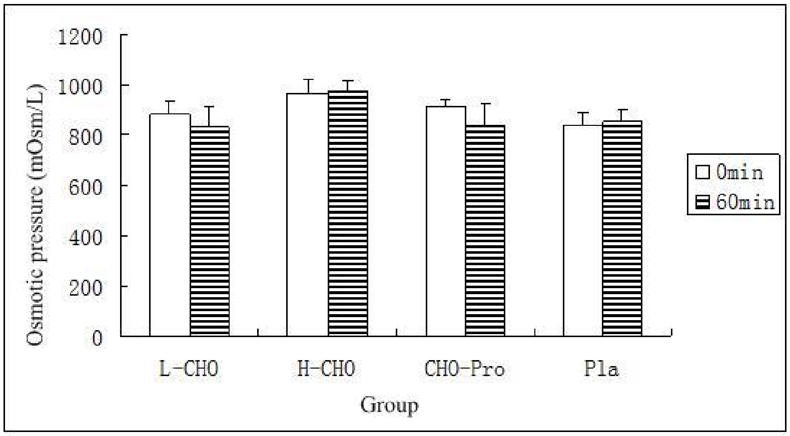

Figure 4. Effects of sports drinks containing different components on urine osmotic pressure

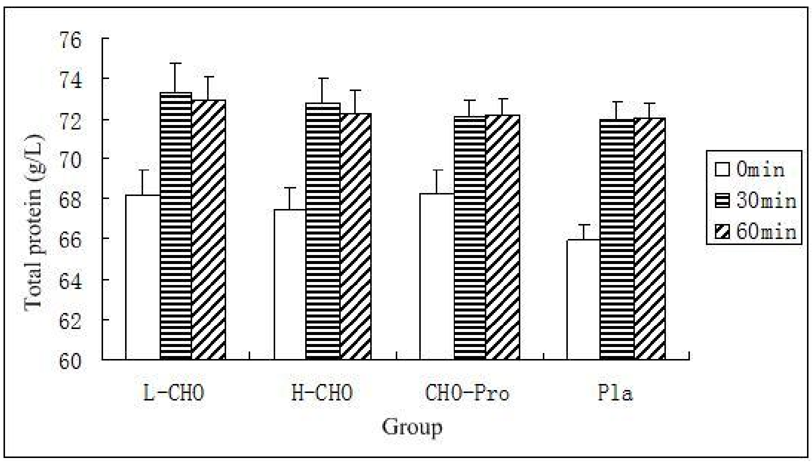

Figure 5. Effects of sports drinks containing different components on total protein in plasma

3.1.3. Change of total protein after the supplement of drinks

The total protein in plasma of sportsmen had no statistically significant difference before the supplement of drinks. The change of total protein in plasma is shown in Figure 5. Figure 5 demonstrates that, the duration of exercise had an obvious effect on total protein in plasma ($p < 0.05$); compared to before exercise, total protein in plasma had an obvious increase after exercise ($p < 0.05$); the effects on total protein in different groups had no significant difference.

3.2. Change of electrolyte balance

3.2.1. Change of sodion in body fluid after the supplement of drinks

The content of sodium in serum of sportsmen had no statistically significant difference before the supplement of drinks. The change of sodium content is shown in Figure 6.

It could be known from figure 6 that, the content of serum sodium of sportsmen had no obvious change after exercise; the content of serum sodium of the four groups had no obvious difference.

Before the supplement of drinks, the content of sodium in urine had no statistically significant difference. The change of urine sodium is shown in Figure 7. Figure 7 demonstrated that, the content of urine sodium of sportsmen had no obvious change after exercise; the content of urine sodium of the four groups had no remarkable difference. It indicated that, the content of sodium in three kinds of drinks had certain effect on the concentration of serum sodium. The control group also contained sodium and moreover the concentration was higher than that of the CHO-Pro group; but the low osmotic pressure of the drink in the control group might dilute serum sodium, thereby resulting in the decrease of serum sodium concentration.

3.2.2. Change of potassium ion in body fluid after the supplement of drinks

There was no statistically significant difference in the content of serum potassium before the supplement of drinks. The change of blood potassium is shown in Figure 8. Figure 8 demonstrates that, the content of blood potassium of sportsmen increased significantly after exercise ($p < 0.05$); the content of blood potassium in the late stage of exercise significantly increased compared to the middle stage of exercise ($p < 0.05$); the content of blood potassium of the four groups had no statistically significant difference.

The content of urine potassium had no statistically significant difference before the supplement of drinks. The change of urine potassium is shown in Figure 9.

Figure 9 demonstrates that, the content of urine potassium significantly increased after exercise ($p < 0.05$); the content of urine potassium in the four groups had no statistically significant difference. It indicated that, different fluid supplement schemes had no obvious influence on the concentration of serum and urine potassium.

3.2.3. Change of chlorine ion in body fluid

The content of serum chlorine in the four groups had no statistically significant difference before the supplement of drinks. The change of serum chlorine is shown in Figure 10. Figure 10 demonstrated that, the serum chlorine had no significant change after exercise compared to before exercise; serum chlorine of the four groups had no remarkable difference. The content of urine chlorine had no statistically significant difference before the supplement of drinks. The change of urine chlorine is shown in Figure 11. Figure 11 demonstrated that, the blood chlorine had no obvious change after exercise, and the difference of blood chlorine between four groups had no significant difference; the urine chlorine of the H-CHO group was much lower than that of the placebo group ($p < 0.05$). It indicated that, the addition of a certain concentration of chlorine ion was beneficial to the stability of chlorine ion in body fluid.

3.3 Change of acid-base balance

The content of lactic acid in venous blood had no statistically significant difference before the supplement of sports drinks. The change of blood lactic acid is shown in Figure 12. Figure 12 demonstrates that, the content of blood lactic acid had no obvious change after exercise compared to that before exercise; in pairwise comparison, the content after exercise was much higher than that before exercise ($p < 0.05$). It indicated that, lactic acid produced during exercise and the production of lactic acid had little influence on endurance performance.

The pH value had no statistically significant difference before the supplement of sports drinks. The change of pH value is shown in Figure 13. Figure 13 suggests that, pH value had no obvious change after exercise compared to before exercise; the effects on pH value in four groups had no obvious difference, suggesting the effects of different sports drinks on pH value were basically consistent.

3.4. Change of exercise capacity

Exhaustive time of exercise capacity of sportsmen taking sports drinks containing different components had no statistically significant difference ($p > 0.05$), as shown in Table 3.

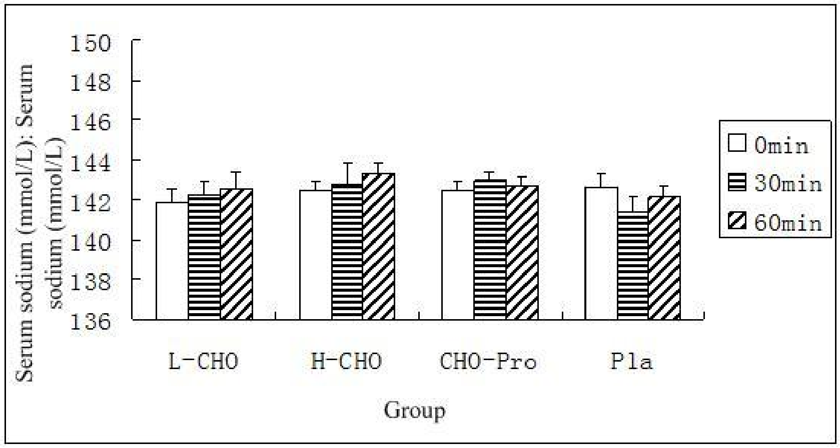

Figure 6. Effects of sports drinks containing different components on serum sodium

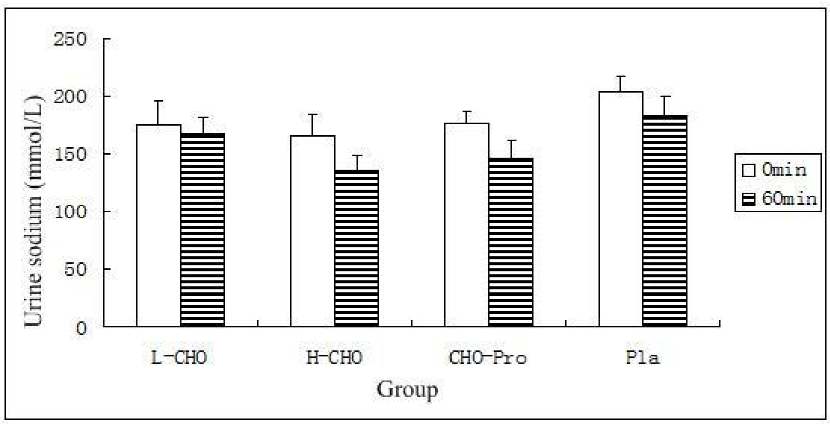

Figure 7. Effects of sports drinks containing different components on urine sodium

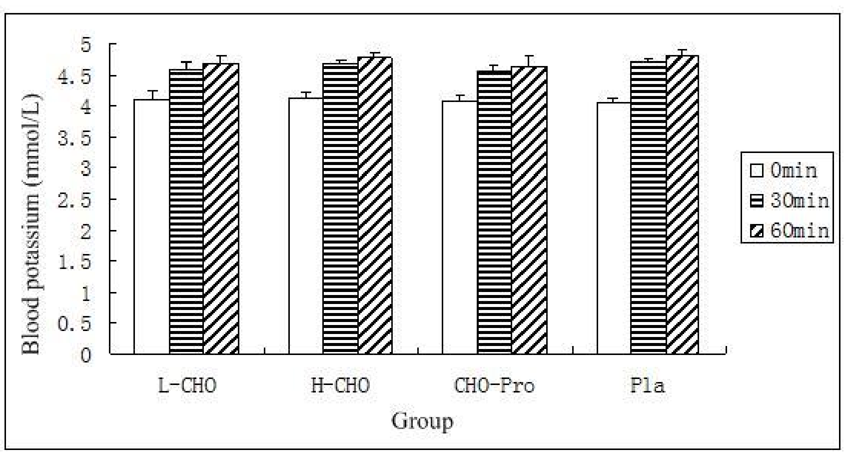

Figure 8. Effects of sports drinks containing different components on blood potassium

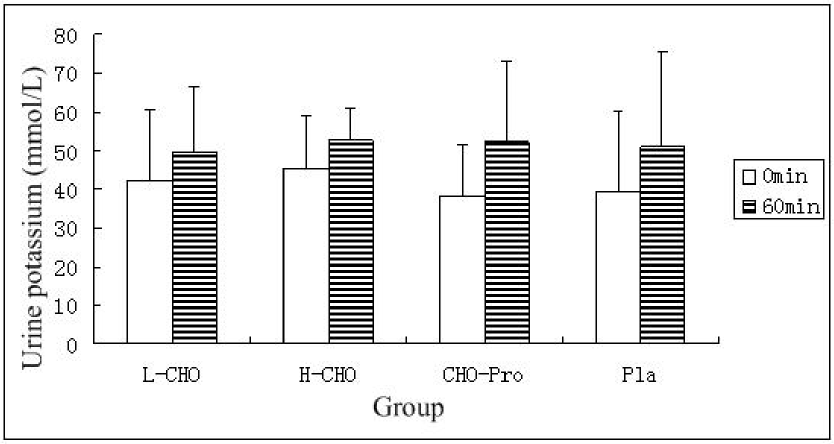

Figure 9. Effects of sports drinks containing different components on urine potassium

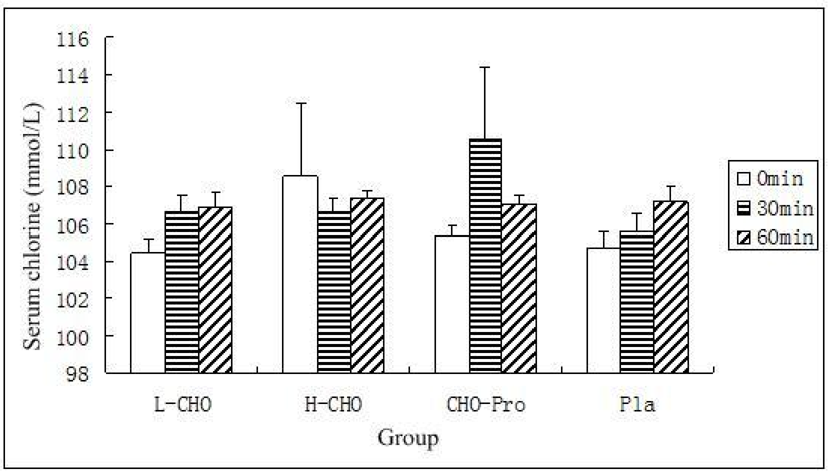

Figure 10. Effects of sports drinks containing different components on serum chlorine

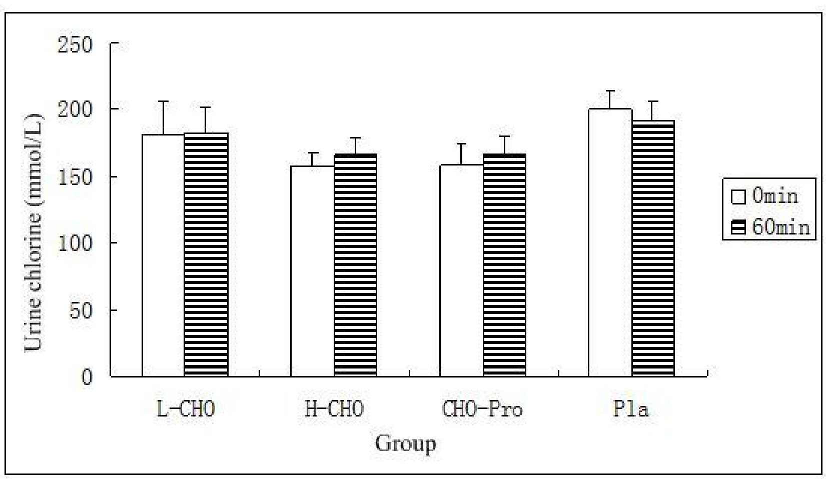

Figure 11. Effects of sports drinks containing different components on urine chlorine

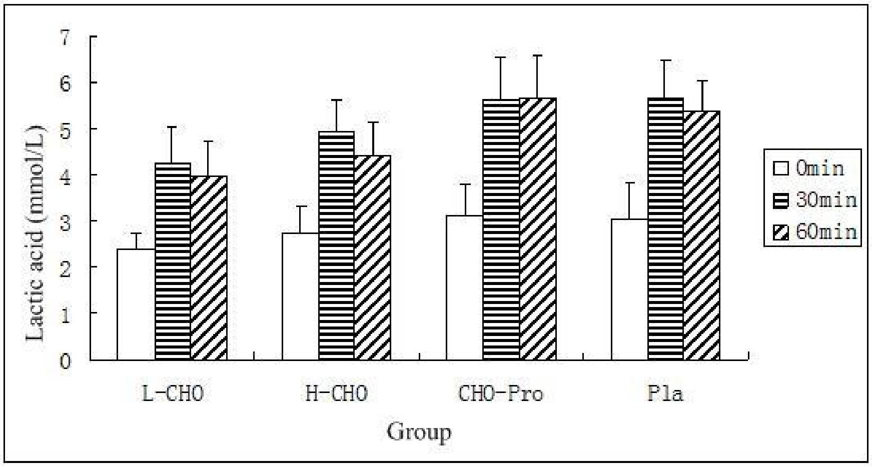

Figure 12. Effects of sports drinks containing different components on blood lactic acid

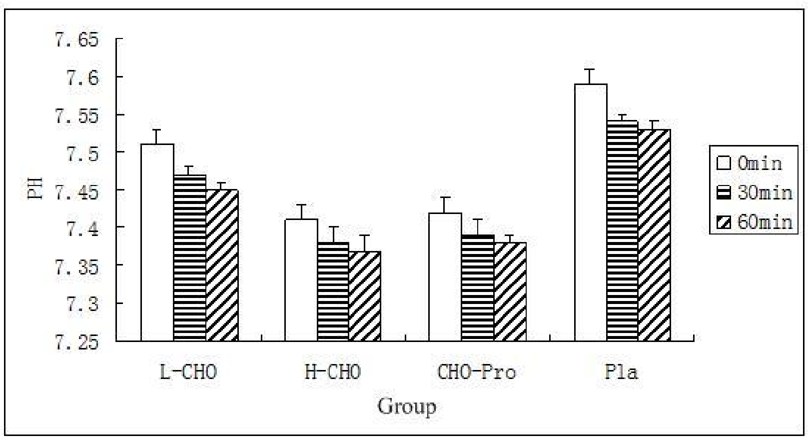

Figure 13. Effects of sports drinks containing different components on pH value

Table 3. Comparison of exhaustive time of sportsmen taking sports drinks containing different components

Group	L-CHO	H-CHO	CHO-Pro	Placebo
Exhaustive time (s)	3505.38±210.55	3317.68±273.21	3164.35±233.02	3237.34±179.78

It could be known from Table 3 that, the exhaustive time of sportsmen taking sports drinks containing different components had no statistically significant difference, suggesting the effects of different sports drinks on exercise capacity nearly had no difference.

4. Conclusions

To explore the effects of sports drinks containing different components on the body fluid balance of sportsmen engaging in endurance events, 20 sportsmen engaging in endurance events were given solid sports drinks containing different sugar components in this study. Research results suggested that, the supplement of L-CHO was more beneficial to the balance of water and electrolyte compared to other components; sports drinks containing three different components performed the same in regulating acid-base balance; sports drinks containing three different components had the same promotion effect on exercise capacity; the three kinds of sports drinks has no effects on evacuation and absorption speed in gastrointestinal tract and subjective feeling during exercise.

The sports drinks analyzed in this study are of positive significance to the maintenance of acid-base balance and the prevention of hyperglycemia induced by long-term extensive exercise.

5. Acknowledgement

This study was supported by Planning Project of 2015 College Scientific Research of Yan'an University, YDK2015-36.

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