

นิพนธ์ต้นฉบับ (Original article)

โภชนาการการกีฬา (Sports Nutrition)

**EFFECT OF SPORTS DRINK ON REPEATED PERFORMANCE IN HEALTHY THAI MALES AFTER
GLYCOGEN DEPLETION**

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ABSTRACT

Background: Thus, for no research has differentiated the effect of carbohydrate with and without electrolyte drinks on endurance performance. The purpose of this study was, therefore, to examine the effects of acute sports drink on endurance performance, and on cardiorespiratory variables. **Method:** Fourteen healthy males age-ranged 18-25 years old participated in 3 trials with 1 week separated in each. Three consecutive sessions in each trial; glycogen depletion, recovery session and endurance exercise (cycling at 70% $VO_{2\text{peak}}$) were employed. Subjects were randomly assigned either sports drink 10% carbohydrate (CHO), 0.16% electrolytes (SD), placebo 10% CHO only (PL) or plain water (WT) during 2 h recovery. Cardiorespiratory variables (heart rate, stroke volume, cardiac output, end-diastolic volume, systemic vascular resistance, ejection fraction, respiratory rate, tidal volume and minute ventilation) were collected at pre- and post-endurance exercise, time to exhaustion (TTE) and work done (WD) were recorded during 70% $VO_{2\text{peak}}$. **Results:** The results showed longer time to exhaustion in SD group (52.93 ± 6.98 min) than PL group (45.05 ± 4.47 min) and WT group (37.95 ± 4.92 min), but significant difference was observed only between SD and WT ($p < 0.05$). Significantly higher work done under SD and PL compared with WT group, significantly higher ejection fraction (%EF) ($p < 0.05$) in SD than PL and WT. Moreover, significantly higher minute ventilation under SD than PL and WT ($p < 0.05$) was found. **Conclusion:** Carbohydrate with electrolyte (SD) did not affect to cardiorespiratory function. It probably provide a longer time to exhaustion than carbohydrate alone (PL) despite no difference. At least, one of cardiac function, ejection fraction, was enhanced by using sports drink.

Keywords: Sports drink / Endurance performance /Glycogen depletion / Carbohydrate / Electrolyte

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โภชนาการการกีฬา (Sports Nutrition)

ผลของเครื่องดื่มทางการกีฬาต่อสมรรถภาพทางกายในชายไทยสูขภาพดีภายหลังการพร่องไกลโคเจน

ศิริดา นันตะกุล, รุ่งชัย ชวนไชยະกุล*, เมตตา ปั่นทอง และ สายฝน กองคำ

วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล อ.พุทธมนษา จ.นครปฐม ประเทศไทย 73170

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาผลของเครื่องดื่มทางการกีฬาต่อสมรรถภาพทางกายแบบทันทันว่ำกับการเปลี่ยนแปลงตัวแปรของระบบหัวใจและหัวใจในชายไทยสุขภาพดี โดยได้คัดเลือกผู้เข้าร่วมวัยรุ่นวัยเพาะกาย ช่วงอายุ 18-25 ปี จำนวน 14 คนเพื่อเข้าร่วมการศึกษาทั้งหมด 3 ครั้ง และมีระยะเวลาห่างกันอย่างน้อย 1 สัปดาห์ โดยแต่ละครั้งจะประกอบด้วยการทดสอบ 3 ช่วงดังนี้ ช่วงของการทำให้สารไกลโคลเจนในร่างกายลดลงอย่างมาก ช่วงพักฟื้นร่างกาย และช่วงการออกกำลังกายแบบทันทีที่ระดับความหนัก 70% ของอัตราการใช้ออกซิเจนสูงสุดของร่างกาย จากนั้น ในช่วงพักฟื้น 2 ชั่วโมง ผู้เข้าร่วมวิจัยจะได้รับการสูบให้เครื่องดื่ม 3 ชนิด ได้แก่ เครื่องดื่มที่ประกอบด้วยคาร์บอโนไดออกไซด์ 10%, อิเล็กโกราઇล์ 0.16%, เครื่องดื่มหลอก (คาร์บอโนไดออกไซด์ 10%) หรือน้ำเปล่า ตัวแปรที่ถูกวัดช่วงก่อนและหลังการออกกำลังกายได้แก่ ตัวแปรเกี่ยวกับระบบหัวใจและหัวใจรวมไปถึงระยะเวลาการออกกำลังกายจนล้า (TTE) และงานที่ทำได้ (work done, WD) ถูกวัดในระหว่างการออกกำลังกายที่ความหนัก 70% $VO_{2\text{peak}}$ ผลการศึกษาพบว่า ระยะเวลาการออกกำลังกายในผู้ที่ได้รับเครื่องดื่มนักกีฬา เครื่องดื่มหลอก และน้ำเปล่าคือ 52.93 ± 6.98 นาที, 45.05 ± 4.47 นาที และ 37.95 ± 4.92 นาที ตามลำดับ อย่างไรก็ตาม มีเพียงเครื่องดื่มนักกีฬาและน้ำเปล่าที่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) นอกจากนี้ยังพบว่างานที่ทำได้ในเครื่องดื่มนักกีฬาและเครื่องดื่มหลอกมีค่าสูงกว่างานที่ทำได้เมื่อได้รับน้ำเปล่าอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) ยิ่งไปกว่านั้นพบว่าค่าความสามารถของหัวใจในการบีบเลือดออกจากหัวใจ (%EF) ของกลุ่มเครื่องดื่มนักกีฬามากกว่ากลุ่มที่ได้รับเครื่องดื่มหลอกและกลุ่มน้ำเปล่า ($p<0.05$) สรุปผลการศึกษา เมื่ัวจะไม่พบความแตกต่างทางสถิติของระยะเวลาในการออกกำลังกายจนล้าระหว่างเครื่องดื่มนักกีฬาและเครื่องดื่มหลอก กลุ่มเครื่องดื่มนักกีฬามีแนวโน้มในการออกกำลังกายได้นานกว่าเครื่องดื่มหลอก อีกทั้งในกลุ่มเครื่องดื่มนักกีฬา ปริมาณเลือดที่ถูกบีบออกจากหัวใจได้ดีกว่า นั้น อาจช่วยส่งเสริมการทำงานของร่างกายในขณะออกกำลังกาย

คำสำคัญ: เครื่องดื่มน้ำกีฬา / สมรรถภาพทางกายแบบทันทนา / การพร่องไกลโคลเจน / คาร์บอไฮเดรต / อิเล็กโทรไลต์

INTRODUCTION

Many recovery strategies are seriously considered in order to gain speedy recovery. Sports drink is one of those strategies which can mainly replace fluid and electrolytes lost during exercise. It is well known that carbohydrate is an essential energy substance for vigorous and prolonged exercises. Some previous studies reported that athletes who consumed 24% of carbohydrate can gain better glycogen re-synthesis storages in muscle and liver within 2 hours after exercise at 70% $VO_{2\max}$ ¹. Moreover, recent study found an improvement of time trial performance, increased blood glucose after ingested sports drink contained 6% carbohydrate². Some sports require short recovery period within a day, for instance, swimming, badminton and taekwondo. Thus, glycogen re-synthesis may be critical before the second bout³. Some previous studies found that carbohydrate combined with electrolytes can further extend time to exhaustion than placebo^{4,5}.

Evidence has been elucidated that electrolytes, mainly as sodium and potassium, play an important role to stimulate rehydration and fluid absorption⁶, as well as cardiac function⁷. Therefore, it might be such an important factor to sustain longer exercise duration than beverage contained carbohydrate alone. A study conducted by Sun JM (2008)⁸ who investigated the effect of sports drink on hydration status, and reported that $0.72 \pm 0.38\%$ fluid loss in Gatorade sports drink group while $1.10 \pm 0.52\%$ fluid loss in water group. However, there are controversial results in cardiovascular function, some studies showed lower heart rate^{9,10}, but some did not change^{5,11}. Thus, for no report on the effect carbohydrate-electrolyte and carbohydrate drink alone. Hence, in this study examine the effect of acute sports drink on endurance performance, in concomitant with cardiorespiratory variables (heart rate, stroke volume, cardiac output, end-diastolic volume, systemic vascular resistance, ejection fraction, respiratory rate, tidal volume and minute ventilation), and to compare the acute effects of sports drink, water and placebo on endurance performance, in concomitant with cardiorespiratory variables. It is hypothesized that acute intake of sports drink during recovery period could affect on subsequent long term exercise, as well as on cardiorespiratory function.

METHOD

Subjects

15 healthy Thai males, ages ranged between 18-25 years old, completed questionnaire about their health condition¹² and physical activity¹³. Subjects who have average to high level of peak oxygen consumption were recruited. The exclusion criteria were cardiopulmonary diseases, musculoskeletal disorders or metabolic diseases, taking any drugs which may affect cardiorespiratory, metabolic system and level of consciousness. One subjects dropped out due to his unable to participate all testing. Therefore, there were totally 14 subjects in this study. This experimental procedure received ethical approval from Mahidol University Institutional Review Board. All subjects were instructed about experimental protocol before signed inform consent.

Experimental protocol

Double blind cross-over design was employed. Subjects completed four visits included peak oxygen consumption testing in the first visit and the other three remained visits were randomly provided three different drinks. In each trial, there were 3 consecutive occasions; subjects completed glycogen depletion followed by two hours recovery period and the endurance exercise until exhaustion. In each trial, cardiorespiratory variables, i.e., heart rate, stroke volume, cardiac output, end-diastolic volume, systemic vascular resistance, ejection fraction, respiratory rate, tidal volume and minute ventilation (Physioflow, France and Jaeger Oxycon Mobile, Germany) were collected before and after testing, heart rate and blood pressure were monitored during the test, urine specific gravity (Refractometer, ATAGO manual, Japan) was collected before testing to ensure hydration status. Subjects were collected about their food taken within 3 days before test day to eliminate unequal calories intake. Prior to trial, they were asked to assess their body composition; weight, height, body fat, muscle mass and body mass index (BMI) by using bioimpedance machine (Omron, HBF362, Japan).

Glycogen depletion session

Subjects rode on cycling ergometer (Monark 828E, Sweden) at workloads between 60-90% P_{max} with 50% P_{max} intersperse (2-min interval). After 2-min warm up at 0.5kp, pedal cadence of 60 rpm, intensities are initially adjusted at 90% P_{max} for 2-min, with 50% P_{max} (80 rpm, 2-min interval). If their cadence is experienced to be below than 70 rpm more than 30 sec, the power output is considerably reduced to 80% P_{max} , 70% P_{max} and 60% P_{max} respectively. They were then terminated either when cadence was below 70 rpm for more than 30 sec at 60% P_{max} or they requested to stop the test themselves.

Recovery session

During 2 hours recovery session, subjects were randomly provided 250 ml of the beverage, either sports drink (7% sucrose, 4% dextrose, 0.13% NaCl, 0.03% KCl, 153 m.Osm/L) or placebo (7% sucrose, 4% dextrose, 150 m.Osm/L) or water. Amount of energy consumed from the drink was calculated at 1 gram of carbohydrate (CHO)/kgBW¹⁴. For example, subject who weighed 70 kg would consume 603.45 ml (calculated from (70 kg BW * 1 gm CHO/kg BW * 250 ml/ 29 g of CHO). The amount of drink given was divided into 3 portions: first at 50% at immediately after finished glycogen depletion, then 25% at 30 minutes and another 25% at 60 minutes respectively.

Endurance exercise session

Subjects performed endurance exercise on cycle ergometer. This test composed of 5-min stretching, followed by 2-min warm up on cycle ergometer at 0.5 kp at 60 rpm¹² and cycling at steady workload of

70% $\text{VO}_{2\text{peak}}$ at 60 rpm until volitional exhaustion⁽¹⁵⁾. Exercise termination was considered if their revolutions either less than 60 rpm more than 30 second or voluntarily stop the test themselves.

Statistical analysis

Shapiro wilk test was used to test normal distribution. The differences of SV, RR, V°_E , TTE and WD among three groups were compared using one-way repeated measures ANOVA. Friedman test was used to detect significant difference of HR, CO, EDV, SVR, EF and V°_T . Post hoc analysis using paired *t*-test for SV, RR, V°_E , TTE and WD, and Wilcoxon sign-ranked test for HR, CO, EDV, SVR, %EF and V°_T . The difference between end values and corresponding resting values of SV, RR and V°_E was compared using paired *t*-test, whereas other variables using Wilcoxon sign-ranked test. All statistical analyses were compared using SPSS software 17.0 version, differences were considered at $p<0.05$.

RESULTS

Fourteen Thai males successfully completed health screenings and physical activity questionnaires to meet inclusion criteria previously determined. All characteristics were shown in Table 1.

Table1: General characteristics of 14 Thai male subjects.

Parameters	Mean \pm SD
Age (yr)	21.50 \pm 1.65
SBP (mmHg)	116.14 \pm 7.32
DBP (mmHg)	67.21 \pm 3.76
Height (cm)	174.00 \pm 5.30
Weight (kg)	68.37 \pm 6.74
Body fat (%)	14.09 \pm 3.61
Muscle (%)	37.05 \pm 1.36
Body mass index (kg.m^{-2})	22.54 \pm 1.96
$\text{VO}_{2\text{peak}}$ ($\text{ml}.\text{kg}^{-1}.\text{min}^{-1}$)	40.71 \pm 2.72

SBP: systolic blood pressure; DBP: diastolic blood pressure; $\text{VO}_{2\text{peak}}$: peak oxygen consumption.

At baseline of glycogen depletion(GD), all cardiorespiratory variables were in normal ranges (Table 2), and there were no differences among three groups ($p > 0.05$). However, all cardiorespiratory variables were significantly higher when compared to the corresponding resting values ($p < 0.05$). After 2 hours recovery periods, there were no differences of all cardiorespiratory variables among three groups ($p > 0.05$) (Table 3). At

the end of endurance exercise, only EF and V^o_E under SD group were significantly higher than PL and WT groups ($p < 0.05$). Moreover, longer exercise duration in SD and PL groups compared with WT group were 40% and 20% respectively (Figure 1). However, statistics only showed that exercise duration in SD group was significantly longer than WT group ($p = 0.002$). Work done in SD and PL groups was significantly higher than WT group ($p < 0.01$) (Figure 2), but difference between SD and PL groups was not observed ($p > 0.05$).

Table 2: Cardiorespiratory variables at pre- and post-glycogen depletion (GD) exercise under the conditions of sports drink (SD), placebo (PL) and water (WT) groups.

	WT		PL		SD	
	Pre-GD	Post-GD	Pre-GD	Post-GD	Pre-GD	Post-GD
HR (bpm)	73.5±2.2	170.5±3.3 [*]	75.5±2.3	173.5±3.2 [*]	74.0±2.3	174.0±2.4 [*]
SV (ml)	82.8±4.1	98.0±6.6 [*]	88.1±3.9	97.0±6.6 [*]	85.9±3.8	103.6±6.5 [*]
CO (L/min)	5.8±0.4	15.6±1.1 [*]	6.7±0.4	16.3±1.1 [*]	6.0±0.4	17.2±1.1 [*]
EDV (ml)	147.7±4.1	148.0±6.9 [*]	139.7±4.7	148.8±5.9 [*]	141.9±4.9	156.1±6.9 [*]
SVR (dyne./s/cm ³)	1092.5±70.0	397.8±40.8 [*]	1013.5±50.0	372.1±26.5 [*]	1108.0±60.7	380.5±29.7 [*]
EF (%)	59.5±3.2	65.9±2.7 [*]	65.6±3.9	63.1±4.0 [*]	59.9±2.7	62.5±3.4 [*]
RR (times/min)	18.9±0.7	48.7±2.5 [*]	20.1±0.7	50.5±2.6 [*]	18.7±0.7	50.2±2.4 [*]
V^o_T (L/times)	0.7±0.0	1.8±0.1 [*]	0.7±0.0	1.7±0.1 [*]	0.8±0.0	1.7±0.0 [*]
V^o_E (L/min)	15.4±0.8	85.9±5.6 [*]	15.0±0.5	89.4±4.1 [*]	15.8±0.6	90.2±5.4 [*]

HR: heart rate; SV: stroke volume; CO: cardiac output; EDV: end-diastolic volume; SVR: systemic vascular resistance; EF: ejection fraction; RR: respiratory rate; V^o_T : tidal volume; V^o_E : minute ventilation. * $p < 0.05$ versus pre-GD

Table3: Cardiorespiratory variables at pre- and post-endurance exercise (EX) under the conditions of sports drink (SD), placebo (PL) and water (WT) groups.

	WT		PL		SD	
	Pre-EX	Post-EX	Pre-EX	Post-EX	Pre-EX	Post-EX
HR (bpm)	77.5±2.8	154.5±2.4 [*]	75.0±3.0	159.5±3.3 [*]	80.5±2.3	159.0±2.3 [*]
SV (ml)	81.7±3.1	90.8±5.3 [*]	82.1±2.2	92.0±5.1 [*]	79.9±4.0	95.0±5.0 [*]
CO (L/min)	6.5±0.1	14.3±0.8 [*]	6.6±0.5	14.5±0.9 [*]	6.3±0.3	14.9±0.8 [*]
EDV (ml)	136.7±5.3	142.3±5.1 [*]	135.6±7.4	138.8±5.9 [*]	135.1±5.8	137.7±8.3 [*]
SVR	1025.0±40.0	431.8±31.1 [*]	1092.5±62.9	418.8±27.0 [*]	1061.5±73.0	425.0±31.7 [*]
(dyne/s/cm ³)						
EF (%)	60.5±3.0	64.7±3.3 [*]	64.0±3.0	64.7±3.3 [*]	62.4±2.9	70.7±3.0 ^{*,b,c}
RR (times/min)	20.8±0.8	41.6±2.1 [*]	18.8±0.9	40.0±1.1 [*]	19.2±0.8	39.2±1.6 [*]
V [°] _T (L/times)	0.7±0.0	1.3±0.0 [*]	0.7±0.0	1.4±0.1 [*]	0.7±0.0	1.2±0.0 [*]
V [°] _E (L/min)	15.5±2.9	60.0±2.9 [*]	14.5±0.8	57.9±2.2 [*]	14.9±0.6	52.5±2.3 ^{*,b,c}

HR: heart rate; SV: stroke volume; CO: cardiac output; EDV: end-diastolic volume; SVR: systemic vascular resistance; EF: ejection fraction; RR: respiratory rate; V[°]_T: tidal volume; V[°]_E: minute ventilation. ^{*} p<0.05 versus pre-EX; ^b: p<0.05 versus post-EX in WT; ^c: p<0.05 versus post-EX in PL.

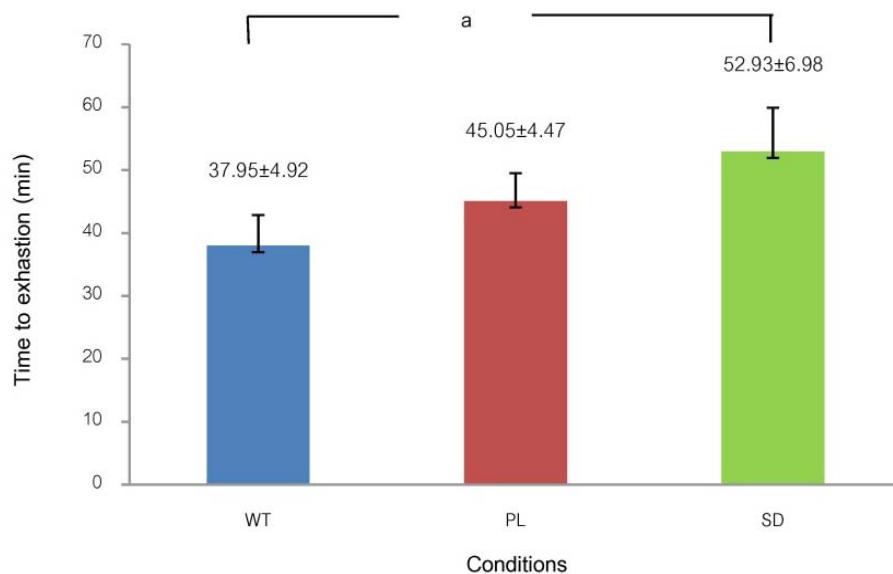


Figure 1 Comparisons of time to exhaustion during endurance exercise in Water (WT, blue), Placebo (PL, red) and Sports drink (SD, green)(n=14). Values are means and SEMs. ^a: significant difference between WT-SD. Significant values at p < 0.05.

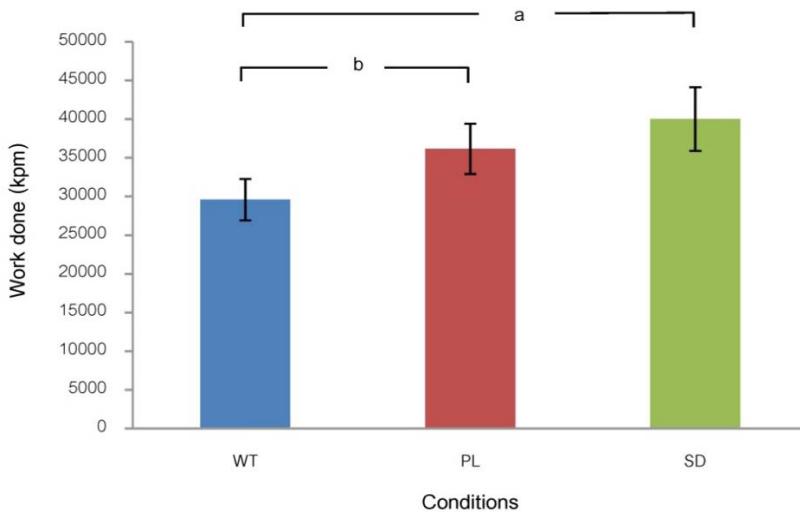


Figure 2 Comparisons of total work done during endurance exercise in Water (Blue), Placebo (Red) and Sports drink (Green) groups (n=14). All values are means and SEMs. ^a: significant difference between WT-SD; ^b: significant difference between WT-PL; Significant values at $p < 0.05$.

DISCUSSIONS

The main finding of this study was that SD group could extend subsequent exercise duration than WT group. In addition, more blood supply as shown by higher EF and lower V^o_E during SD than other groups at the end of endurance exercise. All cardiorespiratory parameters, including heart rate, stroke volume, cardiac output, end-diastolic volume, ejection fraction, respiratory rate, tidal volume and minute ventilation were increased except systemic vascular resistance. These changes were in the similar fashion no matter which kind of fluids were being intervened. These responses are solely dependent upon exercise stimuli ¹⁶⁻¹⁸. In this study, sports drink contained 10%carbohydrate and 0.16%electrolytes did not affect cardiovascular function. Similarly, previous studies with 6% carbohydrate and electrolyte solution did not change cardiovascular function ^{5, 11}. In contrast, some recent researches ^{9,10} elucidated that heart rate was more elevated in low carbohydrate sports drink. It was conducted that, during exercise, cardiac responses mainly rely on carbohydrate energy substrate rather than electrolytes ⁹. Indeed, myocardial contraction depends on Na^+ , K^+ and Ca^{2+} ions where Na^+ and K^+ are related to firing rate and Ca^{2+} is related to contraction ¹⁹. Sports drink which contained only Na^+ and K^+ , but not Ca^{2+} , was in the hypotonic solution form. Therefore, sports drink less likely causes physiologic changes of cardiac function.

It is well known that carbohydrate ingestion is essential for exercise performance. One study reported that muscle glycogen concentration was nearly empty in the first half time during soccer game ²⁰. They found 3 folds depleted muscle glycogen concentration by using muscle biopsy technique. It was indicated that

endogenous carbohydrate was declined after prolonged exercise and/or vigorous exercise. Thus, resynthesized muscle glycogen is important, especially in subsequent exercise²¹.

The current finding supported previous study which was also demonstrated longer time to exhaustion after 13 recreational subjects consumed sports drink contained 6% CHO and underwent prolonged exercise thereafter⁵. They suggested that exogenous carbohydrate utilization played an important role to spare and resynthesize muscle glycogen during recovery period, therefore, it led to perform greater duration during subsequent endurance exercise. Similarly, recent research reported greater performance times under commercial sports drink²² and carbohydrate drinks²³. Although carbohydrate with (SD) and without electrolytes(PL) drinks did not show any statistical difference, but SD could extend longer exercise duration, as well as higher total work done than PL. Besides carbohydrate substance, electrolyte, especially Na^+ is possibly played role to support longer endurance exercise duration under SD. In part of muscle function, electrolytes, mainly as Na^+ and K^+ , promote neurotransmitter function, as well as adequate actin-myosin function; consequently, greater performance was occurred. In addition, K^+ is contributed in CHO metabolism; it can support changes of glucose to glycogen and store in the liver for future fuel²⁴. The mechanism⁶ has been described that Na^+ can stimulate more fluid absorption from stomach into small intestine. Na^+ gradient causes sodium dependent glucose transporter (SGLT1) generating, as well as GLUT2 generated by glucose concentration²⁵⁻²⁶; therefore, the combination of SGLT1 and GLUT2 in small intestine enhances carbohydrate availability.

Longer and intense exercise can influence to sodium depletion. In this study, it was not examined amount of sodium lost via sweat rate during exercise; therefore, it cannot be ensured whether replaced electrolyte would affect to physiological need or not. Further study should consider this factor to assess the amount of sodium via sweat loss.

CONCLUSIONS

Despite EF and V_E° changes after consumed sports drink, other cardiorespiratory parameters were not. It can be conducted that sports drink did not affect the cardiorespiratory function. Sports drink could only extend endurance exercise durations. Moreover, sports drink and placebo demonstrated higher work done than water. It was likely that glycogen supplement drink is needed following exhaustive exercise and should be provided during 2-hour recovery period. At least, one of cardiac function, ejection fraction, was enhanced by using sports drink.

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