The Different Effects of Fluid with and without Carbohydrate Ingestion on Subjective Responses of Untrained Men during Prolonged Exercise in a Hot Environment

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Summary This study examined the effects of maintaining euhydration by ingesting fluids with or without carbohydrate on subjective responses of untrained men during prolonged exercise in a hot environment. Six healthy untrained subjects completed 90 min of cycling exercises at 55% maximal oxygen consumption (VO2max) in a hot environment (temperature: 28°C, humidity: 50%) under three different experimental conditions. During the first trial, subjects did not ingest fluids during exercise (dehydration (DH) trial). In the second and third trials, subjects received mineral water (MW) and hypotonic fluid containing carbohydrate (HF), respectively, in amounts equaling their weight loss in the DH trial. At the end of exercise, the overall rating of perceived exertion (RPE-O) was lower in the MW and HF trials than in the DH trial (14.3±1.0 and 13.7±0.6 vs 17.7±1.0, p<0.05, respectively). RPE-cardiovascular and RPE-legs were lower at the end of exercise in the HF trial compared with the DH trial. VO2, heart rate (HR), and rectal temperature increased during exercise in the three trials. At the end of exercise, the drift in VO2 was lower in the MW and HF trials than in the DH trial (304±41 and 339±40 vs 458±33 mL, p<0.05, respectively). HR at the end of exercise in the HF trial was lower than in the DH trial (158±5 vs 173±7 bpm, p<0.05). These results suggest that maintaining euhydration during prolonged exercise in untrained men could attenuate RPE-O and that hypotonic electrolyte–carbohydrate solution could attenuate RPE-legs during exercise.

Key Words maintaining euhydration, perceived exertion, prolonged exercise, heat exposure

Dehydration, hyperthermia and muscle glycogen depletion are the major determinant factors that induce the reduction of performance during prolonged exercise. Fluid ingestion, especially in a hot environment, attenuates hyperthermia and cardiovascular drift (1–4), and carbohydrate ingestion reduces the rating of perceived exertion (RPE) during prolonged exercise in endurance-trained subjects (5–10). However, there is no available data about the physiological and subjective benefits of maintaining body water by ingesting fluid with or without carbohydrate supplementation during prolonged submaximal exercise in untrained healthy subjects.

Maintaining euhydration by fluid ingestion attenuates cardiovascular strain induced by both hyperthermia and dehydration during prolonged submaximal exercise in the heat (2–4). Gonzalez-Alonso et al. suggested that despite a marked cardiovascular drift at the 120 min of exercise, corresponding to ~60% maximal oxygen consumption (VO2max) in a dehydration trial, the increase in VO2 for exercising and nonexercising muscle of the whole body was similar to a euhydration trial (2). Additionally, it has been demonstrated that during prolonged exercise an increase in carbohydrate availability by carbohydrate supplementation attenuated RPE (8, 9, 11) while fluid ingestion did not attenuate the RPE (4, 12). However, these studies were performed on endurance-trained athletes and it was stated that there is no available data for untrained subjects. Although perceived exertion is usually expressed as the rating of perceived exertion (14-point RPE, Borg scale), perceived exertion has been also used by differentiated partially (RPE-overall, RPE-cardiovascular or chest, and RPE-legs). Differentiated ratings of perceived exertion may be used to assess the sensations of local and central fatigue. Peripheral fatigue in the legs has been reported to dominate the assessment of perceived exertion during cycling (13–16). In addition, it was observed that RPE-chest was lower than RPE-O and RPE-L (17, 18)
and it might be suggested that RPE-overall is the sum of RPE-cardiovascular and RPE-legs. It might detect the effect of fluid ingestion on subjective responses during prolonged submaximal exercise by using differentiated RPE.

Therefore, the present study aimed to investigate the effects of maintaining euhydration by ingesting fluids with or without carbohydrates on the physiological and subjective responses of untrained healthy men during moderately intense prolonged exercise in a hot environment.

**METHODS**

**Subjects.** Six healthy young men volunteered to take part in this study. They have not trained habitually. Since subjects participated at August to October (Summer in Japan), it was considered that they were heat acclimated. Mean (±SE) age, height, weight, \( V_{\text{O}2\text{max}} \), and peak power output (PPO) were 24.5±0.8 y, 171.5±2.4 cm, 64.1±3.4 kg, 54±3.8 mL/kg/min, and 234±21 W, respectively. As all subjects had experienced prolonged exercise tests before this study, they were familiarized with this type of exercise test. Each subject provided informed consent before the study. This study was approved by the local ethics committee of the Waseda University School of Sport Sciences, Japan.

**Preliminary testing.** Graded incremental exercise was performed to obtain \( V_{\text{O}2\text{max}} \) on an electromagnetically braked cycle ergometer (Combi RS-232; Combi, Tokyo, Japan). Subjects cycled on the ergometer at an initial power output of 60 W, which was increased by 30 W every 3 min until exhaustion. Pedalling frequency was 70 rpm. To determine PPO, exercise was maintained until the subject could not maintain the given pedalling frequency. Flow volume and concentration of expired gases and heart rate (HR) were continuously measured in 30 s intervals using a respirometer (Minato AE300; Minato Medical Science, Osaka, Japan) and electrocardiograph (Cardiosuper 2.00E+32; Sanei-Sokki, Yamagata, Japan), respectively. At the end of each workload stage, subjects were asked to indicate the RPE using the Borg Scale (19). \( V_{\text{O}2\text{max}} \) was defined as the highest 60 s value (three data point average).

**Prolonged exercise in a hot environment.** Each subject performed 90 min of cycling exercise at 70 rpm, corresponding to a workload estimated to require 55% \( V_{\text{O}2\text{max}} \) in a hot environment (temperature, 28°C; humidity, 50%) under three experimental conditions. To ensure recovery, trials were separated by at least 1 wk. Each experiment was performed between 12 AM and 3 PM. As the weight of subjects before each experiment did not differ, it was considered that subjects were euhydrated before each experiment. Subjects were asked not to change their eating or drinking on the day before each experiment. Subjects ate a standardized regulation meal (500 kcal) more than 6 h before each experiment. After eating the regulation meal, subjects were not allowed to ingest any food or drink except for water. During the first trial, subjects did not ingest any fluid during the prolonged exercise period (dehydration trial, DH). In the second and third trials, each subject received mineral water (MW) and hypotonic fluid containing 3% carbohydrate (HF) every 15 min, respectively, in amounts that equaled their weight loss in the DH trial (−1.9±0.2 kg). The order of MW and HF trials was randomized. The researchers were blinded to the composition of the drinks. The composition of drinks is listed in Table 1. Before exercise, a rectal probe was inserted 10–15 cm beyond the anal sphincter. During exercise, flow volume, concentration of expired gas, and HR were measured every 15 min for 3 min. Rectal temperature (RT) was also measured every 15 min. Subjects were asked to indicate overall RPE (RPE-O), cardiovascular RPE (RPE-C), and the RPE for legs (RPE-L) at the end of warm-up and every 15 min during prolonged exercise.

**Blood samples.** Venous blood samples were obtained before and immediately after exercise for measurements of serum sodium (Na), serum potassium (K), hemoglobin (Hb), hematocrit (Hct), and plasma osmolarity (Osm). All blood parameters were analyzed by SRL Inc. (Tokyo, Japan). Relative change in plasma volume (ΔPV) from pre-exercise levels was calculated according to Dill and Costill (20).

**Statistics.** Values were expressed as mean ± SE. Two-way repeated measures analysis of variance (ANOVA) was used to determine statistical significance between groups and time courses. When a major difference was indicated, Fisher’s post hoc tests were applied.

**RESULTS**

**Perceived exertion**

RPE-O, RPE-C, and RPE-L were significantly increased during prolonged exercise in all trials (Fig. 1A, B, C). At the end of exercise, RPE-O was lower in the MW and HF trials compared with the DH trial (14.3±1.0 and 13.7±0.6 vs 17.7±1.0, \( p<0.05 \), respectively) (Fig. 1A). At the end of exercise, RPE-C and RPE-L were lower in the HF trial than in the DH trial (RPE-C: 13.2±0.8 vs 16.5±1.3, \( p<0.05 \); RPE-L: 14.7±0.9 vs 18.3±0.9, \( p<0.05 \)) (Fig. 1B, C).

**Cardiovascular and thermoregulatory responses**

During prolonged exercise, \( V_{\text{O}2} \) normalization, HR and RT were significantly increased in all trials (Fig. 2A, C, D). At the end of exercise, \( V_{\text{O}2} \), drift and ventilation (VE) were lower in the MW and HF trials than in the DH trial (\( V_{\text{O}2} \), drift: 304±41 and 339±40 vs 458±33 mL, \( p<0.05 \), respectively; VE: 54.0±2.9 and 52.3±3.3 vs...
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63.7 ± 4.2 L/min, p < 0.05, respectively) (Fig. 2A, B). HR at the end of exercise in the HF trial was significantly lower than in the DH trial (158 ± 5 vs 173 ± 7 bpm, p < 0.05) and HR in the MW trial tended to be lower than in the DH trial (Fig. 2C). RT at the end of exercise tended to be lower in the HF trial than in the DH trial (38.2 ± 0.2 vs 38.8 ± 0.1˚C, p = 0.089).

Blood variables

Na, K, Hb, Hct, and Osm during the DH trial were significantly increased after prolonged exercise, whereas the concentrations of Na and Osm during the MW and HF trials were significantly decreased after prolonged exercise (Table 2). Na and Osm during the MW and HF trials were lower than in the DH trial after prolonged exercise. Hb and Hct during the HF trial were lower than in the DH trial after prolonged exercise.

Plasma volume (PV) was significantly decreased after prolonged exercise during the DH and MW trials (Table 2). ΔPV in response to prolonged exercise in the MW and HF trials was lower than in the DH trial. ΔPV in the HF trial after prolonged exercise tended to be lower than in the MW trial (p = 0.061).

DISCUSSION

The main findings of this study were (1) that RPE-O was attenuated in the MW and HF trials compared with the DH trial, and the differentiated RPEs, especially RPE-L, were attenuated in the HF trial compared with the DH trial; (2) that the elevation in VE, HR, and $V_{O_2}$ drift were suppressed by maintaining euhydration during prolonged submaximal exercise in a hot environment (MW and HF trials) compared with the DH trial; and (3) that the decrease of PV in the DH trial after prolonged exercise was greater than in the MW and HF trials, and ΔPV in the HF trial tended to be smaller than in the MW trial.

These results suggest that in untrained men, maintaining euhydration by fluid ingestion during prolonged exercise regardless of carbohydrate supplementation attenuates RPE-O. Additionally, ingestion of hypotonic carbohydrate–electrolyte solution during prolonged exercise attenuates RPE-L and RPE-C by suppressing hemoconcentration better than mineral water alone.
It has been well demonstrated that the cardiovascular drift induced during prolonged exercise is suppressed by fluid ingestion (1–4). However, Gonzalez-Alonso et al. suggested that despite cardiovascular drift being markedly incurred at the 120th minute of exercise, corresponding to ~60% VO2max in a dehydration trial, the increase in VO2 for exercising and nonexercising muscles of the whole body was similar to the euhydration trial (2). Additionally, Vallier et al. observed that VO2 was not different in trials with or without fluid ingestion; however, VO2 significantly increased without fluid ingestion in a trial involving 3 h of cycling at 60% VO2max in a hot environment (4).

The discrepancy between this study and previous studies might also be attributed to the training status of the subjects. Most previous studies in this area recruited endurance-trained athletes (3, 4, 8, 9, 11, 12). On the other hand, we recruited healthy untrained subjects to examine the potential impact of maintaining euhydration by fluid ingestion. The results of this study suggest that maintaining euhydration by fluid ingestion with or without carbohydrate supplementation suppresses cardiovascular responses such as VO2 drift in untrained men. In untrained men, fluid ingestion during prolonged exercise in a hot environment may provide many more physiological benefits than in well-trained endurance athletes. We propose that these benefits were accompanied by a difference in RPE-C among the three trials (DH: 16.5 ± 1.3; MW: 13.8 ± 1.0; HF: 13.2 ± 0.8).

**Hemoconcentration**

Another unique finding of this study was that the ΔPV in the HF trial tended to be smaller than in the MW trial. Furthermore, Hb and Hct after prolonged exercise were significantly lower only in the HF trial compared with the DH trial. Because mineral water is markedly hypotonic, with 25 mosmol/L in this study; it would be expected to be the most efficient form of water absorption. However, Sladen reported that water absorption was faster from isotonic carbohydrate–electrolyte solutions than from plain water (23). Leiper et al. also reported that net water absorption was about twice fast from moderately hypotonic solutions than from isotonic solutions (24). The main reason for the relatively poor rates of water absorption from water is thought to be because of the efflux of electrolytes down...
CONCLUSION

The results of this study demonstrate that in untrained men, maintaining euhydration by fluid ingestion with or without carbohydrate during prolonged exercise attenuates RPE-O. In addition, hypotonic carbohydrate–electrolyte solution attenuated RPE-L per-exercise attenuates RPE-O. In addition, hypotonic carbohydrate–electrolyte solution may be recommended as a better option than mineral water for maintaining euhydration when the benefits in blood profile and subjective responses are taken into account.

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