THE EFFECT OF PERSONALIZED FLUID REPLACEMENT ON PHYSIOLOGICAL RECOVERY AFTER HALF-MARATHON RUNNING

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Abstract

Long-distance running generates heat accumulation and physiological stress, especially in cardiovascular and thermoregulatory systems. Proper fluid and electrolyte replacements have been reported to prevent adverse effects during exercise. Nevertheless, whether the benefit of personalized fluid replacement continues to the recovery period after half-marathon running remains unclear. Therefore, this study aimed to compare the effect of fluid replacement protocols on physiological recovery after half-marathon running. Eight healthy male runners (age 34.50 ± 4.8 yr., BMI 23.60 ± 1.8 kg/m^2, body fat 18.82 ± 4.6%) performed two sessions of 21.1 km running with self-paced speed. The subjects received either Personalized drinking (PD; 70% of water and 100% of sodium loss matching individual sweat) or Ad libitum (AD; drinking water as much as desired) in a random order. Body weight, sodium loss, and plasma osmolality were measured before and after running, while heart rate (HR) and mean body temperature were monitored at 0-minute, 5-minute and 10-minute time points after completion of running. The running pace and volume of fluid replacement between AD and PD trials were not significantly different. The percentage of water intake, when compared to bodyweight loss, was significantly higher in the PD than AD trials (76.6% vs. 39.4%). Consequently, bodyweight loss in the AD trial was 80% higher than the PD trial. At 0-minute, HR of the subjects in the PD trial was lower than AD ($p < 0.05$). In addition, mean body temperature at 5-minute and 10-minute after finishing half marathon in the PD trial was lower than that of the AD trial ($p < 0.05$). These findings suggested that personalized fluid replacement during half-marathon running would be beneficial to physiological recovery, possibly due to maintaining thermoregulation and plasma volume.

Keywords: Fluid replacement, Half-marathon, Dehydration, Sweating

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Introduction

Long-distance running such as marathon and half-marathon have become one of the most popular sport worldwide including in Thailand. Running that lasts more for longer than an hour typically causes physiological challenges in thermoregulation. Under hot and humid conditions, runners tend to have a lower capacity in heat dissipation leading to the development of heat-related illnesses.

One simple and effective intervention is maintaining fluid and electrolytes losses from the body to prevent a reduction of plasma volume and lower cardiovascular strain. In recent years, there has been a considerable debate in programmed drinking aiming to maintain body mass loss < 2% and self-manage of fluid intake called ad libitum drinking, which causes dehydration in athletes (Goulet & Hoffman, 2019, pp. 221-232). Moreover, previous studies try to investigate drinking protocols in terms of different rates (Dugas, Oosthuizen, Tucker, & Noakes, 2008, p. 69), volume (Hosseinlou, Khamnei, & Zamanlu, 2014, pp. 3757-3762), and sodium concentrations of fluid intake to promote performance and prevent adverse effects. However, there have been some challenges due to the fact that sweat rate and its composition vary among individuals depending on several internal factors such as regional local sweat rate, structural differences in sweat glands, rate of ductal $Na+$ reabsorption, and central and peripheral control of the sweating response, etc. (Baker, 2017, pp. 111-128). Currently, it still lacks specific recommendations for sodium replacement during and post-exercise on endurance activities. Therefore, a personalized hydration protocol approach may be beneficial for individuals.

Most previous studies about fluid replacement protocols focused on performance and unexpected events during exercise, but the post-exercise period has not been investigated clearly. Post-running responses are considerably crucial among runners. It was reported that the core temperature rises to 38.5-39.0 °C in the post-exercise period (Costill, Kammer, & Fisher, 1970, pp. 520-525; Montain & Coyle, 1992, pp. 1340-1350). Therefore, accelerating recovery following intense exercise is necessary to reduce the risks of fainting and dizziness. Besides, if the heart rate can return to more swiftly, followed by the quicker cooling of the core’s temperature, skin temperature, and muscle temperature can cause less cardiovascular strain, promote a redistribution of blood to the central area, which could increase the ability of the body to eliminate waste products (Bongers, Hopman, & Eijsvogels, 2017, pp. 60-78). In addition, it still lacks specific recommendations for sodium replacement during and post-half-marathon running. A personalized hydration protocol approach may be effective and appropriate for long-distance runners.

Objective

To investigate the effect of personalized fluid drinking (PD) to match sweat loss compared with *ad libitum* drinking (AD) on physiological responses after half-marathon running in healthy men runners.

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Methods

Measurements and Tools

1. Anthropometric assessment

1.1) Body weight was measured by a scale, body mass index (BMI) was calculated from Weight and height and body composition by bioelectrical impedance analysis; Tanita MC-780 P MA

1.2) Standing height measured by height scale

1.3) Subcutaneous fat assessment by skinfold (Lange Skinfold Caliper) in four regions (Durnin & Womersley, 1974, pp. 77-97).

4-Site Skinfold Equation

% Body Fat = (0.29669 x sum of skinfolds) – (0.00043 x square of the sum of skinfolds) + (0.02963 x age) + 1.4072, where the skinfold sites (measured in mm) are abdominal, triceps, thigh, and suprailiac location.

1.4) VO_2max test by The Bruce protocol (Bruce & Lovejoy, 1949, pp. 1431-1438; Bruce & Pearson, 1949)

2. Thermoregulatory measurement

2.1) Gastrointestinal temperature (T_{GI}) using thermoregulatory pills

2.2) Skin temperature (thermocouple/thermistors)

Mean $T_{sk} = 0.3\,(T_{chest} + T_{forearm}) + 0.2\,(T_{thigh} + T_{calf})$ (Bardis, Kavouras, Adams, Geladas, Panagiotakos, & Sidossis, 2017, pp. 1244-1251)

2.3) Mean body temperature: $Tb = 0.1(Tsk) + 0.9\,(T_{GI})$

3. Cardiovascular parameters

3.1) Heart rate (HR) was recorded by wireless HR monitor (Polar watch)

3.2) Blood pressure was measured twice before and immediately after by blood pressure monitor

4. Sweat analysis (Lindsay B. Baker, 2017, pp. 1-6)

4.1) Total whole-body sweat loss (WBSL/(L)) = (Pre-exercise body mass - Post-exercise body mass) + Fluid intake – Urine output

4.2) Predicted WB sweat $[Na^+]$ (mmol/L) = 0.57 (forearm sweat Na^+) + 11.05

4.3) WB Sweat Na^+ Loss (mmol) = WB Sweat Loss * WB Sweat $[Na^+]$

5. Performance variables

5.1) Pace speed (minute/km) is measured by Polar watch

5.2) Total running time

Experiment Procedure

Participants

Eight male runners signed informed consent forms to participate in the study, which was approved by the Center of Ethical Reinforcement for Human Research, Mahidol University. All subjects had no history of metabolic, cardiovascular, and renal disorders as well as musculoskeletal injury and heat stroke history. They had to be trained runners and experienced half marathon events at least 2 times. The participants experienced in running around 2.3 ± 1.4 years and joined half-marathon races about 6.3 ± 4.3 times. The average age and BMI of runners were 34.5 ± 4.8 and 23.60 ± 1.8 kg/m^2, respectively. Maximum oxygen uptake (VO_{2max}) was excellent. All subjects had no history of metabolic, cardiovascular, and renal disorders as well as musculoskeletal injury and heat stroke history. The overall design of this study is shown in Figure 1.

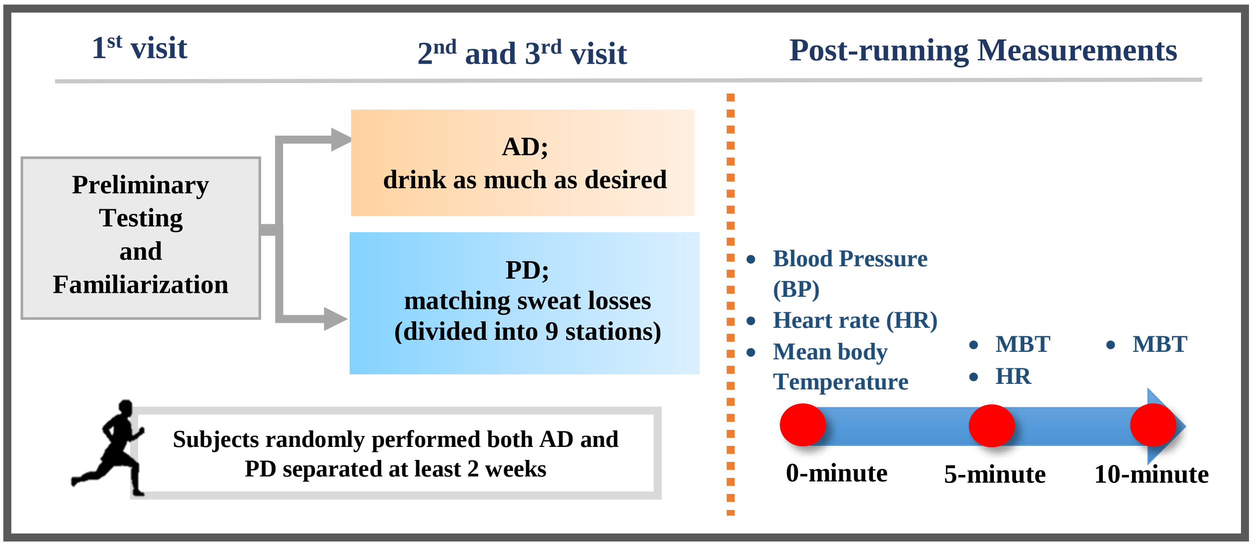

Figure 1. Randomized, cross - over study design and parameter measurements in post-running period

Experimental protocol

Each subject attended 3 visited, including 1) preliminary testing and familiarization phase for sweat analysis by mimicking the real assessments from experimental trials with 10-km running, 2) Ad libitum drinking protocol (AD), and 3) Personalized drinking protocol (PD). All subjects needed to perform both in AD and PD, so the subjects were randomly assigned by a random number method (sample random sampling) of hydration protocol for the order of either ad libitum drinking (AD) or Personalized drinking (PD) separated at least 2 weeks (14 days) for providing a full recovery. Each hydration protocol was finished in one time beginning at 5.00 am in both AD and PD sessions. During experimental trials, participants were asked to run 21.1 km. Then, all parameters were analyzed afterward.

Preliminary testing

Anthropometric characteristics of each subject were recorded during the first visit in the laboratory, including body weight, standing height, body composition, subcutaneous fat, body surface area (AD), and VO_2max.

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Familiarization session

Each subject completed a familiarization session after preliminary testing to get accustomed to the experimental protocol, all assessments, and the running track. Subjects ran 10-km. Body mass was measured before and after the running to estimate individual's sweat rates. A sweat patch was placed on a forearm to determine sweat Na^+ and K^+ concentration losses. Subjects were asked to drink as much as desired, and fluid intake was recorded. The volume of water intake during PD in the experimental trial was estimated based on the familiarization session by 70% of fluid loss replacement, and a matching amount of Na^+ loss individually.

Experimental trials

The experimental trials consist of two 21.1-km separated by at least two weeks. Each subject commenced half-marathon running by finishing in one time by starting at 5.00 am. Subjects were randomly assigned in a counterbalanced manner to either *ad libitum* drinking (AD) or personalized drinking (PD). Subjects were asked to run at self-paced effort in the two conditions based on the hydration protocol. During AD, subjects were provided with a glass of water (300 ml) and asked to drink as much as they want. During PD, subjects were given an individualized amount of water and sodium assessed from the familiarization phase to drink throughout 9 water stations every 2 km, and they were instructed to drink the full amount of fluid given. Subjects received log books at the first visit to record their dinners and breakfasts to ensure that they consumed the same dinner the night before each trial and the same breakfast and snacks on the experimental days. Subjects were asked to ingest a thermal sensor for measurement of gastrointestinal temperature about 8 hours before each trial. They were advised to drink sufficient water in the evening before the day of each trial. Urine specific gravity (USG) was measured to ensure that they were euhydrated (USG; < 1.020).

Upon arrival, a blood sample was collected to determine plasma osmolality, hemoglobin, and hematocrit. Each subject wore a heart rate monitor. Blood pressure and body mass were measured before and after running. Then, sweat patches were placed on forearm regions. Gastrointestinal temperature (T_{GI}) and skin temperature were recorded to calculate mean body temperature at 0-min, 5-minute and 10-min.

After baseline measurements, subjects began the 21.1-km running. Fluid stations were arranged according to the hydration protocols. HR, skin temperature and T_{GI} were measured immediately post-exercise and again at 5 minutes and 10 minutes. After running, subjects were collected sweat patch. In addition, body mass was recorded after the run, then the subjects gave a post running blood sample.

Data analyses

The normality of data was tested by using percentile plots. All parameters are presented as mean ± S.D. Differences in the mean value of the parameters between AD and PD were assessed using student's paired t-tests., p-value = 0.05. All data were analyzed by Statistical Package for the Social Science (SPSS 18.0)

Results

Bodyweight change, sweat rate, and environmental parameters

Subjects were hydrated similarly before each trial, which represented by urine specific gravity (USG) was not different. The subjects ran 21.1 km. in the AD and PD trial with body weight change at 1.78 ± 0.57% and 0.98 ± 0.68%, respectively. The mean value of water intake was 0.84 ± 0.51 liter in the AD trial and 1.33 ± 0.64 in the PD trial, which were 39.35% ± 21.32% and 76.55% ± 23.53% when compared to their body weight loss (Table 1). The running pace of the AD trial was slightly lower than PD, but there was not a significant difference *(p>0.05)*, which was 6.031 min/km in AD and 6.133 min/km in the PD trial. Moreover, the environmental conditions of both trials were not different.

Table 1 Sweat, Blood and environmental parameters between both trials (N=8).

	AD		PD	
	Pre	Post	Pre	Post
BW (kg)	71.7 ± 6.8	70.5 ± 6.9	71.6 ± 7.0	71.3 ± 6.8
ΔBW (%)	-	1.8 ± 0.6	-	1.0 ± 0.7*
Sweat rate (L/hr.)	0.9 ± 0.1		0.8 ± 0.3	
Water intake (Liter)	0.8 ± 0.5		1.3 ± 0.5	
% water intake compared with BW loss	39.4 ± 21.3		76.6 ± 23.5*	
Rate of Na+ loss (mg/hr.)	800 ± 470.9		578.4 ± 345.6	
POsm ($mmol•kg^{-1}$)	293.9 ± 4.6	302.4 ± 12.9	296.5 ± 4.5	296.5 ± 4.5
ΔPV (%)	-2.7 ± 2.4		5.1 ± 7.0*	
Environmental conditions				
WBGTo	24.4 ± 4.5		21.7 ± 3.1	
Humidity	88.1 ± 4.7		77 ± 13.5	
Wind velocity	0.08 ± 0.01		0.09 ± 0.04	

*Variables are presented as mean ± S.D., * statistically significant difference (P < 0.05) between AD and PD trials at the corresponding time. POsm = Plasma Osmolality, WBGTo = Wet Bulb Globe Temperature Outdoor.*

Blood pressure and Heart rate

Mean arterial blood pressure (MAP) at the end of the running did not differ between the trials (88.72 ±7.9 mmHg in AD and 96.71 ± 16.8 mmHg in PD). There was no significant difference in heart rate at 0-min between the two drinking interventions. The average HR in the AD trial was 167.4 ±12.8, which was approximately 87.6% of the maximum HR, while it was 152.9±14.7 and 82.42 ±7.7% in the PD trial. However, in the post running period (5-min), the heart rate of subjects in the PD trial notably decreased more than the AD trial (AD; 116.1 ± 22.09 bpm, PD; 92.6 ± 16.4 bpm, *p = 0.02*) (Figure 2). When comparing the changes (%) of heart rate between 0-min and 5-min, the percentage of changing in heart rate was greater in PD (34.4% ± 6.7%) compared with AD (27.8% ± 11.7%).

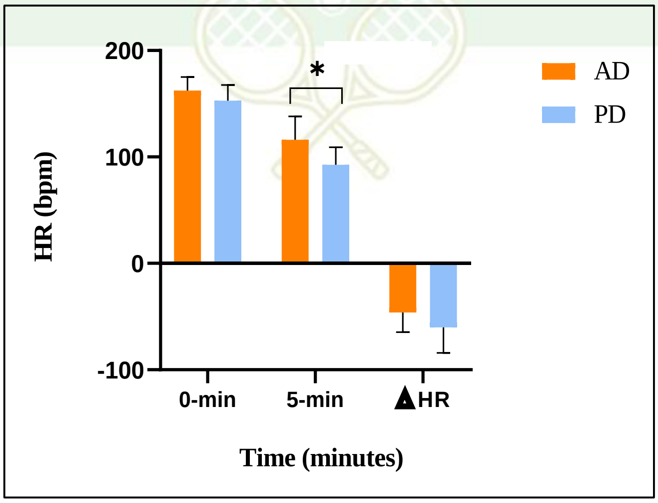

Figure 2. Heart rate after running at 0-min,5-min, and ΔHR between the AD and PD trials. *Statistically significant differences, $p \leq 0.05$, between trials at the same point.

Thermoregulatory parameters

Before performing the experiments, the mean body temperature of AD and PD trials were not significantly different. At the end of the running, the mean body temperature was lower in the PD trial at 0-min. Then, it remained constantly lower in the PD trial in 5-min, and 10-min compared to the AD trial. $(p < 0.05)$ Figure 3.

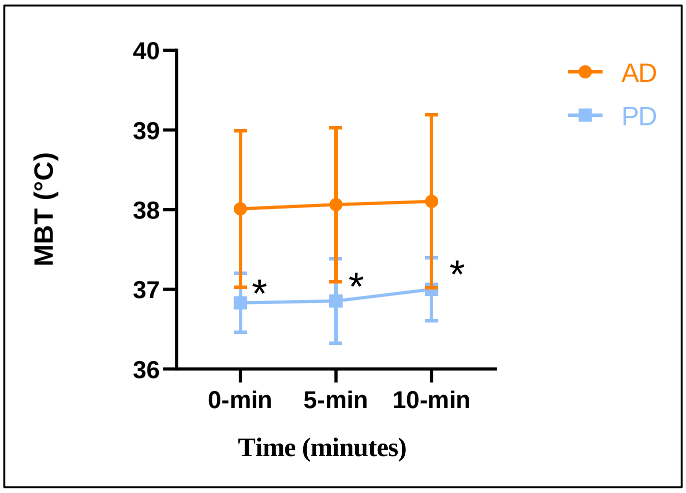

Figure 3. Mean Body Temperature (Tb) at the end of the running session, after half-marathon at 5 minutes and 10 minutes. * Statistically significant differences, $p \leq 0.05$, between trials at the same point.

Discussion

The aim of this study was to compare the effect of fluid replacement protocols between *ad libitum* and personalized drinking on physiological recovery after half-marathon running. First, we found that the runners completed the AD trial with a higher degree of weight loss than PD trial.

Second, the results illustrated the benefit of personalized fluid replacement in terms of faster heart rate recovery and maintaining thermoregulation after half-marathon running.

It is well known that hypohydration among athletes can occur when body water losses from sweating exceed fluid consumption. Hypohydration alters physiological function by increasing heart rate and core temperature. Our findings indicated that both trials could prevent %BW loss more than 2%. However, %bodyweight loss in the AD trial was obviously higher than the PD trial. This could be the result from the role of sodium in the PD intervention during exercise, which assisted in fluid absorption, maintained total body water (TBW), reduced urine output, and plasma volume retention (Sawka et al., 2007, pp. 377-390) represented by the expansion of plasma volume in PD trials was greater than the AD trial almost 7 % (Table 1).

Another important finding from this study is the faster recovery in heart rate at the post-5-min-running in the PD trial. Additionally, the percentage of the heart rate reduction between 0-min and 5-min was significantly greater in the PD compared with the AD trial. Previous studies found that higher sodium concentrations caused better rehydration by reducing net negative fluid balance, water retention at kidneys via antidiuretic hormone, maintaining plasma volume, and increasing thirst (Maughan & Leiper, 1995, pp. 311-319; Merson, Maughan, & Shirreffs, 2008, p. 585). Since hydration protocol in the present study during PD trial was individually assessed by sweat matching, the average of contained sodium was higher (34 ± 17.0 mmol/L) than the study of Venderlei et al. (19.50 mmol/L). Thus, it is possible that higher sodium concentration could attenuate cardiovascular strain in the post-exercise period.

At present, little is known how sodium replacement affects thermoregulation during exercise and in the recovery phase. Some studies investigated the effect of sodium during exercise on thermoregulation and performance, but there has been a debate about the benefits of sodium supplement. One key finding of this study is that the mean body temperature of the PD trial remained significantly lower than the AD trial in 0-min, 5-min and 10-min. Thus, our results may help explain how sodium intake during exercise preserves blood volume during the post-exercise period and maintain heat dissipation via convection and evaporation.

Matching sodium sweat loss for individuals might be a key main advantage for thermoregulation and cardiovascular function. However, longer recovery period observation and comparing *ad libitum* hydro-electrolyte drinking need further studies. Besides, the different intensities, longer running duration, gender, age, and environmental conditions should be investigated further.

Conclusion

In summary, personalized fluid replacement during half-marathon running could demonstrate an effective way in attenuating cardiovascular and thermoregulatory strain better than *ad libitum* drinking in the recovery period after half-marathon. The benefit of personalized fluid replacement is likely accompanied with adequate sodium concentration.

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