Research Note

The Influence of with and without Water Intake on the Physiological Response, Dehydration Rate and Urinary Specific Gravity during the Simulation of Physical Education Class in Summer

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Background: In indoor environments such as gymnasiums, the effect of exposure to solar radiation is less severe, however, heat is more likely to accumulate, and humidity is higher than in outdoor environments. Therefore, the efficiency of heat dissipation by living organisms becomes less efficient, and the environment may be prone to dehydration due to increased sweating. The actual duration of the main events in physical education (P.E.) classes varies across schools. More than 30 minutes of exercise in a hot environment is considered to present sufficient thermal stress for students. In some cases, students cannot consume water due to the time constraints of the class. There are only a few experimental studies on the prevention of dehydration in P.E. classes in Japan. Therefore, it is important to examine the effects of water intake on organisms during P.E. classes.

Objective: This study aimed to examine the effects of water shortage on various physiological responses and subjective symptoms during summer P.E. class.

Methods: Twelve healthy young males (age: 20.3 ± 0.5 years) volunteered to this investigation and play the practice of basketball for 50 minutes under the simulation high school P.E. class in July (temperature: 30.3 ± 0.2 ℃). They were divided into two conditions: one in which they could hydrate freely during the class (WI group, n=6) and another in which they could not be allowed to hydrate (NI group, n=6). Measurements included pulse rate, rating of perceived exertion (RPE), the subjective thirst (ST), body weight, dehydration rate, water intake, urine volume (UV), and urine specific gravity (USG). Those measurements were estimated before the class and after the main exercise and end of the class.

Results: Pulse rate, RPE, USG at the end of class and dehydration rate in the NI group were significantly higher than those in the WI group. There was a significant difference in dehydration rate between groups (WI vs. NI: 0.4 ± 0.5 % vs. 2.1 ± 1.3 %, $p<0.05$). Although the USG of the WI group after class was significantly lower than that of before class ($p<0.05$), there was no significant difference within the NI group. In the NI group, significant positive correlations were found between ST and pulse rate ($r=0.703$, $p<0.05$) and between ST and RPE ($r=0.619$, $p<0.05$). In the WI group, there was no significant correlation among changes in weight, USG, ST, or exercise load index (pulse rate, RPE).

Conclusions: Students who did not drink water during a 50-minute P.E. class indoors at summer temperatures around 30 ℃ were clearly more dehydrated than those who could drink freely.

Keywords: non-hydrating, weight loss, urinary index, physical education class, hot environment

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I. Introduction

Fatal accidents due to heat stroke have been observed in physical education (P.E.), athletic club activities, and extracurricular activities at schools[1]. P.E. classes held outdoors are significantly affected by exposure to solar radiation in summer. Therefore, this environment is likely to increase the heat stress to which students and P.E. teachers are subjected. In indoor environments such as gymnasiums, the effect of exposure to solar radiation is less severe. However, heat can build up inside the gymnasium and humidity can be high in the summer. When humidity is high, heat dissipation is not commensurate with heat production, and body temperature increases.

Subsequently, the amount of sweating increases. If such conditions persist, dehydration is a possibility[1]. Consequently, the efficiency of heat dissipation in humans decreases. Under these conditions, dehydration is likely to occur if perspiration continues to increase. This shows the importance of providing hydration and rest periods during P.E. classes.

The actual duration of the main events in P.E. classes varies across schools. Nevertheless, it has been reported that more than 20 min of moderate-intensity exercise (basketball) in a hot environment can be a sufficient load for students[2]. These guidelines suggest the importance of ad libitum fluid intake or drinking water to prevent dehydration during exercise and sports activities[1]. However, there are only a few experimental studies on the prevention of dehydration in P.E. classes in Japan, including one conducted by Takagi et al.[3] during a swimming class. In addition, instructions pertaining to fluid intake during P.E. vary across schools and with P.E. teachers. In some cases, the students do not consume water because of class time constraints. Therefore, it is important to examine the effects of water intake on organisms during P.E. classes.

This study aimed to examine the effects of water shortage on various physiological responses and subjective symptoms during summer P.E. class.

II. Methods

1. Subjects

Healthy students with no medical history of cardiac or renal disease were recruited from A University in Japan. Twelve healthy young adult males with exercise habits volunteered. They practiced 3-4 times a week (2-3 h per practice session) in athletic clubs. We excluded students with a history of cardiac or renal disease, smoking, or extreme lifestyle disruptions. However, no applicable students were included in this study.

Six of the subjects in the WI group (age: 20.2 ± 0.4 years, weight: 67.4 ± 6.7 kg, height: 175.0 ± 3.2 cm) were allowed to drink water freely in a simulated P.E. class, and six of the subjects in the NI group (age: 20.5 ± 0.5 years, weight: 64.5 ± 6.8 kg, height: 175.7 ± 6.0 cm) were not allowed to drink water. Age and height data were obtained verbally from the subjects on the day of the survey. Weights were measured before the survey. The subjects were randomly assigned to each group.

The subjects were informed of the purpose, methods, and risks associated with the study using a research protocol. A sufficient period (approximately 2 months) was allowed for them to consider participation or non-participation in the study. Finally, the subjects who were contacted about their cooperation were asked to provide written consent to participate in the survey on the day of the survey. This study was conducted during class hours to ensure a safe environment and to be able to respond to accidents. In addition, this study was not a clinical trial in medicine, but a simulation study on school health. Therefore, it is not registered at the experimental registration site. Instead, it was subjected to ethical review by the Research Ethics Committee at the University of Education. This study was conducted with the approval of the Ethical Review Committee for Research Involving Human Subjects, Nara University of Education (approval No.: 28-8).

2. Investigation contents

The survey was conducted on a summer day (July) at 2:45 p.m. in the gymnasium of University A. B high school P.E. class (50 min) was used as a model, and the class was conducted by a person with a high school teaching license (health and physical education) in accordance with the curriculum guidelines. The first 10 min. consisted of greetings, roll calls, an explanation of the class content, preparatory exercises, and preparation. Next, the subjects practiced basketball for 30 min. The class was then concluded with a clean-up, cool-down, a summary of the class briefing, and greeting. The remaining time was spent changing the clothing. Basketball practice consisted of drills (dribbling, passing, and shooting), followed by running shots, 2-on-2, and a mini-game. After the basic drills and 2-on-2, a 1-minute break was taken (rest. 1 and rest. 2, respectively). The

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exercise intensity of those practices ranged from 6.0-9.3 METs[4)]

The subjects were restricted from eating for two hours before the study began. Hydration was allowed. During the breaks, WI group had free access to commercial mineral water (0 kcal energy, 0 g protein, 0 g fat, 0 g carbohydrate, 1.1 mg sodium, 0.72 mg calcium, 0.09 mg potassium, 0.23 mg magnesium / 100 mL). They were kept cold in a cooler box filled with refrigerant. They opened the cooler box and ingested bottled water with their names. None of the subjects urinated during the breaks.

The average climatic conditions during the 50 min period in the gymnasium were air temperature: 30.3 ± 0.2 °C, relative humidity: 61.8 ± 3.7 %, wet bulb globe temperature (WBGT): 27.2 ± 0.2 °C, and globe temperature: 32.1 ± 0.6 °C. WBGT meters (WBGT 203A; Kyoto Electronics Manufacturing) were used to measure weather conditions. These indices were measured four times: at the beginning of the investigation and at rest. 1, rest. 2, and at the end of the investigation. The measuring instrument was positioned approximately 1 m above the floor.

During the survey, an exercise physiologist and a health fitness programmer skilled in first aid were present to ensure safety management. In addition, the survey was conducted when a physician and nurse were in residence at University A, and a safety management system was in place.

3. Measurement items

The measurement items in this investigation were taken immediately before the start of class (=before class, 2:40 p.m.) and immediately after the greeting at the end of class (approximately 48 min after the start of class: after class, 3:33 p.m.). Two breaks (rest. 1 and rest. 2) were taken during the class. In rest. 1 and rest. 2, the pulse rate, rating of perceived exertion, subjective thirst, and fluid intake were measured.

Pulse rate was used as an exercise load indicator. It was measured on the external carotid artery for 15 s by palpation and multiplied by four. Normally, a heart rate monitor is used to continuously assess the degree of exercise load. However, there was concern that measuring heart rate with a sensor attached to the chest may be burdensome to the subject during class. Pulse rate is a simple index that can be measured voluntarily by individuals in actual school settings. Hence, exercise intensity in this study was evaluated using pulse rate.

Body weight, dehydration rate, and water intake were used as indicators of the degree of dehydration. Body weight without clothing was measured using a digital scale (Inner Scan 50; TANITA). Body weight was assessed in a private room in which the subjects' privacy was protected. With the subject's consent, the investigation staff checked and recorded the measurement readings from behind the subject. After the class, weight measurements were taken after sweat was thoroughly wiped off with a bath towel. To determine the dehydration rate, the post-exercise weight was subtracted from the pre-exercise weight. This value was divided by the pre-exercise weight. This was calculated by multiplying by 100. Water intake was measured using the remaining volume of the prepared commercial mineral water bottles.

Urine was collected in paper cups to evaluate the degree of dehydration. These were the urine volume (UV) and urine specific gravity (USG). The same method was used for the weight measurements. The water intake and UV were measured using an electronic balance (UX2200H; SHIMADZU). USG was measured in the collected urine using a urine-specific gravity refractometer (PAL-09S; ATAGO).

Two psychological response indices were also evaluated. Rating of perceived exertion (RPE) was adopted as the index of Borg[5)]. The subject then made a verbal declaration. The subjective thirst (ST) was assessed on a visual analog scale, also used in previous studies[6)], with "not thirsty at all" marked on the left end of the 100 mm scale and "very thirsty" on the right end. The subjects marked their status on a line using a ballpoint pen. The distance (in mm) from the left end to the marked point was used as the evaluation index.

4. Statistical analysis

Because ST is an ordinal variable, it was presented as a median and range. The other measurement items were continuous variables and therefore were presented as mean ± standard deviation. Kolmogorov-Smirnov tests were performed on the data for the measurement items of the continuous variables. These results confirmed the normality of the data.

The Kruskal-Wallis test was used for between-group comparisons of ST. The Friedman test was used for within-group comparisons before class, at rest. 1, rest. 2 and after class. In both cases, multiple comparisons were performed using Bonferroni correction. Between-group and within-group comparisons of continuous variables

were performed using mixed-design two-way ANOVA, and simple main effect tests were performed when an interaction was found. Multiple comparisons (Bonferroni method) were performed to determine the significance. In addition, Pearson's product moment correlation coefficient or Spearman's correlation coefficient was calculated and examined to evaluate the relationship between changes in body weight, USG, and ST before and after the class. The statistical significance level was set at 5 % (two-tailed p-value). “III. Results” provides details on the p-values. All statistical comparisons were performed using IBM SPSS Statistics for Windows, version 23.0.

III. Results

Table 1 shows the changes in each measurement index. The first step was to compare groups. There were no significant differences in body weight, pulse rate, RPE, or USG between the groups. The ST in the NI group was significantly higher than that in the WI group after class (p=0.025). There was a significant difference in dehydration rate between groups (WI vs. NI: 0.4 ± 0.5 % vs. 2.1 ± 1.3 %) (p=0.027).

Within-group comparisons were made for each measurement. The pulse rate (WI group, p<0.001; NI group, p=0.001) and RPE (WI group, p<0.001; NI group, p=0.001) in both groups were significantly higher after class than before class.

The weight of the NI group after class was significantly lower than that before class (p=0.013), whereas the same measurements in the WI group after class were not significantly different. The water intake in the WI group was 300.5 ± 126.8 mL at rest. 1 and 318.2 ± 78.3 mL at rest. 2.

The UV of the NI group after class was significantly lower than that before class (p=0.018), whereas the same measurements in the WI group were not significantly different before and after class. Although the USG of the WI group after class (1.023 ± 0.006 g / mL) was significantly lower than that of before class (1.026 ± 0.006 g / mL, p<0.001), there was no significant difference within the NI group (before vs. after: 1.024 ± 0.004 g / mL vs. 1.024 ± 0.004 g / mL).

After class, ST in WI was significantly lower than before class (p=0.028), rest. 1 (p=0.028), rest. 2 (p=0.028); the same measurement at rest. 2 was significantly lower than at rest. 1 (p=0.043). However, no significant differences were observed in the NI group.

The correlation coefficients calculated for the changes in weight, USG, ST, and exercise load index are shown in **Table 2**. In the NI group, significant positive correlations were found between ST and pulse rate (r=0.703, p=0.011) and between ST and RPE (r=0.619, p=0.032). In the WI group, there was no significant correlation among changes in weight, USG, ST, or exercise load index. In both groups, there was a significant positive correlation between the pulse rate and RPE (NI group: r=0.890, p<0.001; WI group: r=0.785, p=0.002).

IV. Discussion

Changes in the measurement items in physiological and psychological responses were examined during an

Table 1 Changes in the measurement items during P.E. class

	NI group (n=6)				WI group (n=6)			
measurement items (unit)	before class	rest. 1	rest. 2	after class	before class	rest. 1	rest. 2	after class
pulse rate (bpm)	71 ± 8	93 ± 22	129 ± 31 *1	110 ± 17 *1	65 ± 9	91 ± 23	111 ± 31	97 ± 18 *1
body weight (kg)	64.48 ± 6.81	—	—	63.10 ± 6.50 *1	67.35 ± 6.65	—	—	67.09 ± 6.82
dehydration rate(%)	—	—	—	2.1 ± 1.3	—	—	—	0.4 ± 0.5 *4
water intake (mL)	—	0	0	—	—	300.5 ± 126.8	318.2 ± 78.3	—
UV (mL)	110.0 ± 37.1	—	—	45.8 ± 15.4 *1	109.8 ± 72.7	—	—	63.7 ± 32.8
USG (g/mL)	1.024 ± 0.004	—	—	1.024 ± 0.004	1.026 ± 0.006	—	—	1.023 ± 0.006 *1
RPE	8 ± 2	11 ± 2	15 ± 2 *1, *2	16 ± 2 *1, *2	7 ± 2 *1	10 ± 3 *1	13 ± 3 *1, *2	13 ± 3 *1, *2
ST (mm)	49	34	57	72	68	54	48 *2	37 *1, *2, *3, *4

NI group: non-hydrating conditions, WI group: conditions for hydration

UV: urine volume, USG: urine specific gravity, RPE: rating of perceived exertion, ST: the subjective thirst

ST is shown as median, and other measures are shown as mean ± standard deviation.

*1: vs. before class (p<0.05), *2: vs. rest. 1 (p<0.05), *3: vs. rest. 2 (p<0.05), *4: vs. NI group (p<0.05)

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Table 2 Correlation coefficients between measurement items in both groups

	NI group (n=6)						WI group (n=6)				
	1	2	3	4	5		1	2	3	4	5
1 pulse rate	—					1 pulse rate	—				
2 body weight	.078	—				2 body weight	.252	—			
3 USG	-.002	-.250	—			3 USG	-.294	.065	—		
4 RPE	.890 *	.063	-.080	—		4 RPE	.785 *	.145	.064	—	
5 ST	.703 *	.378	.191	.619 *	—	5 ST	-.482	.319	.123	-.491	—

NI group: non-hydrating conditions, WI group: conditions for hydration

USG: urine specific gravity, RPE: rating of perceived exertion, ST: the subjective thirst

*p<0.05

indoor P.E. class in the summer. The results showed that the NI group, which did not consume water during class, had significantly lower body weight and UV after class than before class. The dehydration rate and thirst index of the NI group were significantly higher than that of the WI group, which drank water freely. However, there were no significant differences in body weight or UV before and after the class in the WI group. In addition, the ST after class was significantly lower than that before class and at rest. 1 and rest. 2. Clear differences were observed in the degree of dehydration and ST with and without water intake during class.

The intensity of exercise in this study, RPE of the NI group marked more than 15 (equivalent to "hard")[5] at rest. 2 and after class, and pulse rate indicated that the group presented a moderate or greater exercise load. The physiological and psychological burdens were considered to be high. Although there were no significant differences between the groups in these indices, the mean values of the WI group and the changes in indices within the group were lower than those of the NI group. The subjects in this study were members of a university athletic team. Therefore, a higher level of exercise load could be observed in those with less basic physical fitness than that of the subjects in this study.

The degree of dehydration differed significantly between the two groups, with the dehydration rate in the NI group being significantly higher than in the WI group. In addition, the mean dehydration rate in the NI group was 2.1 %. This level of dehydration rate should be noted from the viewpoint of decreased exercise ability and the onset of various symptoms related to consciousness[1) 7)].

There was no significant difference in USG findings before and after class in the NI group. In the WI group, the values measured after class were significantly lower than those before class. The subjects in the WI group drank approximately 400-800 mL of water during the 30-minutes exercise during P.E. This may have diluted urinary constituents. In contrast, Sawka et al.[8] reported that a USG of 1.02 g / mL or higher indicates dehydration. Based on findings from previous studies[8], in this study, both groups were already concerned about dehydration before the P.E. class. One of the contributing factors is thought to be low fluid intake during the school day prior to P.E.[9]. In the WI group, who drank freely during the P.E., it was presumed that they were able to recover their fluid state, albeit only slightly.

In actual school P.E. and athletic club activities, there may be cases in which the thermal environment is more severe than in this study, or in which the main exercise lasts for more than 30 min. WBGT measured in this study was 27.2 ± 0.2 °C, which is the "alert (active rest)" level indicated by the Japan Sports Association[1]. This environment was one in which it was desirable to take active breaks and replenish water and salt as needed to increase the risk of heat stroke. The guidelines recommend taking a break every 30 min during strenuous exercise. It has been shown that even 30 min of exercise in an environment such as the one used in this study may lead to a level of caution against the onset of various symptoms due to dehydration. Therefore, it is necessary to incorporate fluid intake and rest into P.E. classes.

In the NI group, there was a significant correlation between the ST and pulse rate, RPE. Plasma volume decreases with increased sweating[10) 11)]. Furthermore, decreases in plasma and blood volume have been reported to decrease cardiac output[12]. This may cause an increase in heart rate at the cost of maintaining circulating blood volume[13]. It is a concern that under conditions such as those in the NI group and with a longer exercise duration than that in this study, ST would be even greater and could lead to an excessive burden on the cardiovascular system. In contrast, the WI group was able to recover the water lost through sweating through water intake. Hence,

there was no significant correlation between changes in body weight, USG, ST, and exercise load index.

This study had several limitations. Increasing the number of subjects and changing the type of drinking water used should be considered. There may be those who do not belong to an athletic club, are not heat resistant, and have a low level of physical fitness in P.E. Studies involving women should also be conducted. As core temperatures and complaints in women are affected by the menstrual cycle, investigations should be conducted in both women and men. It is necessary to examine these subjects in the future. In addition, by broadening the age range of the target population, useful information can be disseminated for summer P.E. classes from kindergarten to high school students to ascertain the actual situation and provide guidance on prevention.

V. Conclusions

This study, which simulated a P.E. class in an indoor environment during summer, revealed the following: The rates of dehydration and ST were significantly higher when students did not consume water than when they had free access to water. Although the USG showed different changes before and after class in both groups, the mean value was above 1.02 in both groups. In addition, a significant positive correlation was found between ST and pulse rate, RPE in the group that did not consume water during class. These results indicate that students who did not drink water during a 50-minute P.E. class indoors at summer temperatures around 30 ℃ were clearly more dehydrated than those who could drink freely.

Disclosure of state of COI

No conflicts of interest to be declared.

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