# Physiological responses and heat illness surveillance in primary schoolboys during outdoor exercise in physical education class under hot and humid climate: an analytical prospective descriptive study

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# TITLE PAGE

**Title**

Physiological responses and heat illness surveillance in primary schoolboys during outdoor exercise in physical education class under hot and humid climate: an analytical prospective descriptive study

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**Keywords**

Children, cardiovascular responses, thermoregulation, hydration status, tropical climate

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## ABSTRACT

**Objectives** This study aimed to determine thermoregulatory and cardiovascular responses as well as the occurrence of heat illness in children exercising outdoors in physical education class under hot and humid climate. Little information regarding this issue under real-life situation is available, especially in the Southeast Asia.

**Design** Analytical prospective descriptive study

**Setting** A primary school in Bangkok, Thailand

**Participants** A total of 457 schoolboys (age 5.5-12 years) were observed while exercising outdoors during their physical education classes throughout the academic year of 2009, including semesters 1 (between July and September 2009) and 2 (between November 2009 and February 2010).

**Primary and secondary outcome measures** Primary outcome measure was ear temperature. Secondary outcome measures included blood pressure, pulse rate, hydration status and the occurrence of heat-related illness.

**Results** Wet bulb globe temperatures of semesters 1 and 2 were 29.95 ± 1.87◦C and 28.32 ± 2.39◦C, respectively. Outdoor physical activity consisted of skill practice (duration 24.11 ± 11.04 min, intensity < 3 MET) and sport playing (duration 11.48 ± 5.53 min, intensity 2.5-9 MET). After exercise, the percent change in mean arterial pressure and pulse rate increased by 20.16 ± 15.34 and 23.94 ± 19.78%, respectively. Sweat rate was 391.16 ± 186.75 mL/h. Dehydration rate was 0.63 ± 0.26%. Ear temperature increased by 0.66 ± 0.41◦C. There were 20 (4.4%) boys whose ear temperature exceeded 38◦C, 18 of whom did not consume water. The relative risk of increasing body temperature up to 38◦C in overweight subjects was 2.1 fold higher than normal-weight subjects. No evidence of heat illness was found.

**Conclusions** There is a tendency for heat illness during outdoor activities in physical education class in primary school children, especially those who are overweight and have poor hydration status.

## ARTICLE SUMMARY

### 1) Article Focus:

- While children are exercising outdoors in their physical education classes under tropical climate, their thermoregulation and cardiovascular functions may be imposed, leading to development of heat-related illness.

### 2) Key Messages:

- This study reports the physiological responses and the occurrence of heat illness in primary school children during outdoor activities in physical education class under hot and humid conditions.
- The information on physiological responses and heat illness surveillance is required as the basis for preparing an optimal program and providing particular care and prevention of heat illness in physical education class.

### 3) Strengths and Limitations:

- To our knowledge, this is the first published report in the Southeast Asia to provide descriptive information obtained from a large study population on heat illness surveillance and the physiological responses of primary school children under real-life situation while exercising outdoors during their physical education class.
- The limitation of this study is the measurement of core temperature changes. Although ear temperature is not an ideally good approximation of rectal temperature which is generally accepted to be of standard value for core temperature, ear temperature measurement was taken in this study because it is easier to obtain the children's cooperation. Hence ear temperature is more practical than rectal temperature measurement for such a field-based study. Another limitation is the generalization and inference making about the entire population because convenience sampling was used and the subjects were recruited with their parents' permission.

## INTRODUCTION

When exercising in a hot environment, thermal stress imposes some physiological strains, including thermoregulation, cardiovascular functions and subjective responses, on the body to a greater extent than during regular exercise. The body has to provide blood flow for the metabolism of exercising muscles, while increasing skin blood flow and providing a fluid supply for sweating to dissipate the heat produced by the contracting muscles for thermoregulation. When these simultaneous demands cannot be met, the extreme result ensues circulatory failure and a rise in core temperature to lethal levels.[1] This leads to the occurrence of heat illnesses, varying from heat edema, heat rash, heat syncope, heat cramps, heat exhaustion and heat stroke.[1-8] Heat exhaustion is a typical condition in which core temperature rises to 38-40◦C. Heat stroke is the most severe form with core temperature of greater than 40◦C.[6]

A retrospective study in the U.S. emergency departments during the period 1997-2006 found that patients aged 19 years or below accounted for the largest proportion of exertional heat-related illness, the majority of which were associated with performing a sport or exercising.[9] It is traditionally believed that children are at a higher risk for heat-related problems than adults during exercise in the heat due to a number of physiological differences. Children have a greater surface area-to-body mass ratio for heat absorption, a greater metabolic heat production per mass unit and a lower sweating capacity.[6,10] However, these concepts have recently been contradicted by the findings that no thermoregulatory differences exist between children and adults.[9,11-14] The risk of heat illness may be simply explained by exposure and social/behavioral context.[15] Children frequently do not drink enough to replace fluid loss during exercise. Additionally, they are more likely to be exposed to outdoor physical activities. For example, in physical education class, participation is mandatory and activities are often conducted in the late morning and afternoon, the hottest period of the day.

Thus, the susceptibility to heat illness may be raised if the class takes place outdoors. With the influence of global warming, it is predicted that the incidence of heat illness will also become more prevalent.

Most of the previous investigations on pre-pubertal children exercising in the heat have been conducted indoors under controlled climatic conditions to determine the effects of maturational and gender differences.[16-22] Little information on those exercising in field-based environment is available, especially in a tropical region, where the weather is hot and humid almost all year round. Consequently, this study aimed to determine cardiovascular and thermoregulatory responses as well as the occurrence of heat-related illness in primary schoolboys during outdoor exercise in their physical education classes under a tropical climate. This information is required as the basis for preparing an optimal program and providing particular care and prevention of heat illness in physical education class.

## METHODS

### Sample

An analytical prospective descriptive study was conducted using a convenience sample. The study population of this study was schoolboys from grades 1-6 of the Chulalongkorn University Demonstration Elementary School, located in Bangkok, the capital city of Thailand. The study was conducted during the academic year of 2009 which included the first (between July 2009 and September 2009) and second semesters (between November 2009 and February 2010). The survey was conducted by distributing questionnaire, consent form, assent form and patient information sheets to all 778 schoolboys in the school. 496 out of 778 students were allowed to participate in the survey by their parents. However, 39 students did not exercise outdoors during their physical education classes, therefore only 457 surveys were collected in this study (n=108, 89, 88, 73, 68, and 31 for grades 1-6, respectively). All subjects were not sick or injured on the day of the survey or during the

physical education class, had no history of heat-related illness and were able to understand the questionnaire. Informed written consent and assent were obtained from the subjects and their parents. The protocol was approved by Institutional Review Board of the Faculty of Medicine, Chulalongkorn University.

## Measurement

The subjects were observed while performing activities outdoors in their physical education classes conducted in the late morning (9:40 to 11:40 h) or in the afternoon (12:40 to 15:40 h). Data before and after outdoor exercise were recorded only once for each student. The subjects were allowed to drink water *ad libitum* without encouragement and urinate during their physical education classes.

### Climatic conditions

Climatic conditions were recorded every five minutes during the exercise period in the physical education classes. Wet bulb, dry bulb, and black globe temperatures were measured by using wet bulb temperature measuring devices (QUESTEMP 15 °, Quest electronics, U.S.A.). These values were used to calculate the wet bulb globe temperature (WBGT) heat-stress index as follows: wet bulb globe temperature x 0.7 + black globe temperature x 0.2 + dry bulb temperature x 0.1.

### Exercise duration and intensity

Types and duration of activities performed during physical education class were recorded by using video camera (Sony Handycam DCR-HC46, Sony Corporation, Tokyo, Japan). The intensity of each activity was determined as Metabolic Equivalent of Task (MET) value using the table of MET value for each activity given by Ainsworth et al (2000).[23]

### Cardiovascular and thermoregulatory responses

Cardiovascular parameters including blood pressure and pulse rate were measured at the beginning and immediately after exercise by using digital sphygmomanometer (ES-H55, Terumo Corporation, Tokyo, Japan).[1] Ear temperature was measured at the beginning and within 5 minutes after exercise using infrared temperature sensor for ear temperature (Terumo ear thermometer EM-30CH, Terumo Corporation, Tokyo, Japan).[2]

Hydration status

Subjects emptied their bladders before the beginning of exercise. Then they were weighed wearing only their underwear by using an electronic scale accurate to 20 g (Yamato DP-6100GP, Yamato scale Co., Ltd, Akashi, Japan). A batch of 600-ml bottle of water with the student's name was provided for each student without encouragement during exercise. At the end of the exercise, the total fluid intake was measured and urine was collected. After that, sweat was wiped from each subject and weighed again in his underwear. Sweat loss was calculated from the change in body weight plus total fluid intake minus urine output. Sweat rate was then determined as sweat loss per unit of time (mL/h). This calculation does not take into account the weight loss due to irreversible fuel oxidation and respiratory fluid loss, since it was assumed that these would not differ between trials.

Occurrence of heat-related illness

During the exercise period, the students were observed for symptoms and signs that may relate to heat illness. These included mild edema in hands, feet and ankles (heat edema), pruritic rash and papulovesicular skin eruption over the clothed area (heat rash), painful muscle contractions (heat cramps), loss of postural control, dizziness and generalized weakness (heat syncope), profuse sweating, weakness, clammy skin, dizziness, malaise, fatigue, nausea, vomiting and headache (heat exhaustion) and hot skin with or without sweating, confusion, ataxia, irritability and coma (heat stroke).[6-7] Data of the students who suffered from heat-related illness would be recorded in the incident report form. The image of

the event was recorded by using video camera so the physicians can verify the diagnosis thereafter.

## Analysis

Quantitative data were expressed as means ± standard deviation. Cardiovascular responses and change in body weight were presented as percent change. Data analysis before and after the exercise period for body temperature, pulse rate, blood pressure and body weight was done by using the Paired T-test. The differences between the first and second semesters on climatic conditions, body temperature and cardiovascular response were determined by the unpaired t-test. An alpha level of 0.05 was used to determine statistical significance. All statistical analyses were performed by using Statistic Package for the Social Sciences (SPSS for Windows version 17.0, Chicago, IL, USA).

## RESULTS

A total of 457 subjects were participated in this study without any missing data for each variable of interest. Data collection was done in 175 subjects from 37 period classes during the first semester and 282 subjects from 72 period classes during the second semester.

Baseline characteristics of the subjects are shown in table 1. Assessment of body weight in proportion to weight and height with normal standard revealed that 128 out of 457 (28.0%) subjects were overweight.

**Table 1** Baseline characteristics of the subjects

| Characteristics | Average (n=457) | Range (min - max) |
|---|---|---|
| Age (years) | 8.38 ± 1.56 | 5.58 – 11.92 |
| Weight (kg) | 30.81 ± 9.39 | 15.50 – 65.80 |
| Height (cm) | 130.72 ± 10.45 | 107.50 – 159.10 |
| Body mass index (kg/m$^2$) | 17.68 ± 3.35 | 12.04 – 29.78 |
| Body surface area (m$^2$) | 1.05 ± 0.19 | 0.68 – 1.66 |
| Body surface area/body weight (m$^2$/kg) | 0.035 ± 0.004 | 0.024 – 0.044 |
| % Body fat | 21.14 ± 9.16 | 5.41 – 60.06 |

Values are mean ± S.D.

Duration of physical education class was 31.97 ± 11.10 min (28.78 ± 13.64 min and 33.96 ± 8.63 min for semesters 1 and 2, respectively). Outdoor physical activity consisted of skill practice (duration 24.11 ± 11.04 min, intensity < 3 MET) and playing sports (duration 11.48 ± 5.53 min, intensity 2.5-9 MET). Sports played consisted of: chair-ball and football for grades 1 and 2; chair-basketball, mini-rugby football and athletics for grade 3; chair-basketball, football handball and petanque for grade 4; and football, handball and athletics for grades 5 and 6.

Table 2 presents the climatic conditions, cardiovascular responses, ear temperature change and hydration status during outdoor exercise in the physical education class of the primary schoolboys during the first and second semesters.

**Table 2** Climatic conditions, cardiovascular responses, ear temperature change and hydration status during outdoor exercise in physical education class of the primary schoolboys during the first and second semesters.

| Parameters | Semester 1 (n=175) | Semester 2 (n=282) | Throughout the academic year (n=457) |
|---|---|---|---|
| **Climatic conditions** | | | |
| WBGT (°C) | 29.95 ± 1.87 | 28.32 ± 2.39* | 28.87 ± 2.35 |
| Air temperature (°C) | 34.14 ± 2.59 | 33.27 ± 2.49 | 33.56 ± 2.55 |
| Relative humidity (%) | 58.74 ± 7.70 | 51.79 ± 7.32* | 54.15 ± 8.12 |
| **Cardiovascular responses (% change)** | | | |
| Systolic blood pressure | 19.67 ± 19.61† | 16.43 ± 15.70† | 17.67 ± 17.35 |
| Diastolic blood pressure | 24.39 ± 27.80† | 23.17 ± 21.64† | 23.64 ± 24.16 |
| Mean arterial pressure | 21.34 ± 16.17† | 19.43 ± 14.78† | 20.16 ± 15.34 |
| Pulse rate | 23.12 ± 17.14† | 24.45 ± 21.27† | 23.94 ± 19.78 |
| **Ear temperature** | | | |
| Pre-exercise (°C) | 36.52 ± 0.33 | 36.46 ± 0.39 | 36.48 ± 0.37 |
| Post-exercise (°C) | 37.17 ± 0.39† | 37.13 ± 0.44† | 37.14 ± 0.42 |
| Mean difference (°C) | 0.65 ± 0.42 | 0.67 ± 0.40 | 0.66 ± 0.41 |
| Number of students whose BT ≥ 38 °C | n=7 | n=13 | n=20 |
| **Hydration status** | | | |
| Sweat rate (mL/h) | 451.42 ± 224.76 | 353.77 ± 147.14* | 391.16 ± 186.75 |
| Urine output (mL) | 0 | 0 | 0 |
| % Loss of body weight | 0.52 ± 0.23 | 0.70 ± 0.25* | 0.63 ± 0.26 |
| Number of students who consumed water | n=17 | n=1 | n=18 |

Values are presented as mean ± S.D., *p <0.05 between first and second semesters, †p <0.05 between pre- and post-exercise.

Only 18 schoolboys consumed water an average of 212.89 ± 89.65 mL during the classes, 2 of whom had a rise in body temperature up to 38◦C. There were 2 boys (1st - and 4th graders) whose body weight decreased by 2.10%.

There were 20 (4.38%) schoolboys whose ear temperature rose to a value exceeding 38◦C, with a maximum of 38.7◦C. The body temperature of these boys increased by 1.37 ± 0.45◦C from 36.78 ± 0.37◦C to 38.15 ± 0.20◦C. Table 3 presents the number of these subjects categorized according to the factors associated with heat tolerance such as WBGT, body weight, hydration status, exercise intensity and exercise period. The incidence of increasing body temperature up to this level in overweight and normal-weight subjects was 7.0% (9 out of 128 subjects) and 3.3% (11 out of 329 subjects), respectively. Thus, the relative risk of an increase in body temperature up to 38°C in overweight subjects was 2.1 fold higher than normal-weight subjects. However, no subjects experienced heat-related illness during the observation.

**Table 3** Factors associated with heat tolerance that were identified in 20 subjects whose body temperature exceeded 38°C or above after outdoor exercise in physical education class

| Associated factors | Number of subjects |
|---|---|
| **Wet bulb globe temperature** | |
| Less than 29ºC | 7 |
| 29ºC or above | 13 |
| **Body weight** | |
| Overweight | 9 |
| Normal weight | 11 |
| **Hydration status** | |
| Not consume water | 18 |
| Consume water | 2 |
| **Exercise intensity** | |
| Vigorous (football) | 10 |
| Moderate (chair-ball, athletics) | 4 |
| Mild (skill practice) | 6 |
| **Exercise period** | |
| Late morning | 3 |
| Afternoon | 17 |

## DISCUSSION

Physical education is very important for children because engaging in physical activity will provide them with life-long health and well-being. There is a recommendation that children in primary school should spend 150 minutes on physical education each week, from moderate to vigorous physical activity for at least 50% of the physical education time.[24] Our main concern is that if the class is held outdoors in the intense heat, the children may become vulnerable to heat injury. Therefore, in order to prepare an optimal physical education program that is of quality, particular care to quantity and intensity of the exercise should be taken into consideration to prevent heat illness.

This is the first published report in the Southeast Asia to provide descriptive information on the physiological responses of primary school children under real-life situation while exercising outdoors during their physical education class under hot and humid environment. With emphasis on heat illness surveillance, careful monitoring of signs and symptoms of heat illness were also recorded.

The climatic conditions in Bangkok are moderately hot and humid. The subjects of this study were exposed to high levels of heat stress throughout the academic year, given that the WBGT level was above 28°C which the American College of Sports Medicine has defined as a "very high risk for heat exhaustion and heat stroke".[25] Even more disturbing, the WBGT level of the first semester during July to September was above 29ºC which is the critical level defined as "cancel all athletic activities" by the American Academy of Pediatrics.[10] Moreover, WBGT rates in the afternoon were higher than those in the late morning. Therefore, the children are at more risk in having heat-related illnesses when exercising outdoors especially in the afternoon of the first semester.

This study showed that the children were able to maintain an adequate cardiovascular function while performing physical activities outdoors in their physical education classes.

The percent change in mean arterial pressure and pulse rate increased by 20.16 and 23.94 %, respectively. The present study demonstrated that the children had considerably lower heart rate compared to previous reports. In the study of Inbar *et al*. (2004), pre-pubertal boys exhibited the percentage change in heart rate of 137.66% when performing a cycling session at the intensity level of 50 % $VO_2$max for 85 min in 41°C environment and relative humidity at 21%.[26] Similarly, Rivera-Brown *et al*. (2006) found that the percentage change of heart rate was 87.5% in pre-pubertal girls cycling for 60 min at 60% $VO_2$max in a hot and humid outdoor environment (ambient temperature of 33.7 ± 0.4°C, WBGT 30.0 ± 0.3°C and relative humidity of 53.9 ± 2.4%) with energy drinks to prevent dehydration.[12] The large changes in pulse rate obtained from these studies may be due to longer duration and higher intensity of the exercises. On the other hand, in our study, the intensity of playing sports was moderate to vigorous but most of the time, during the physical education class, skill practice was implemented which was of mild intensity.

As for the core temperature, rectal temperature is generally accepted to be of the standard value. Although ear temperature is not an ideally good approximation of rectal temperature, ear temperature measurements can also predict trends in core temperature. Comparative studies in children indicate that ear and rectal temperature have a strong relation to each other. A systemic review comparing infrared ear thermometry with rectal thermometry in children revealed that the pooled mean difference between rectal and ear temperature measurements was small (0.29ºC).[27] Another study reported that the mean difference between rectal and ear temperature measurements was 0.38ºC and 0.4 ºC in febrile and afebrile infants, respectively, and thus ear temperature measurement is recommended in the pediatric emergency setting.[28] In our study, ear temperature measurement was taken because it is more convenient, less time-consuming and, most importantly, easier to obtain

the children's cooperation. Hence ear temperature is more practical than rectal temperature measurement for such a field-based study.

In the present study, there were 95.6% of the schoolboys (437 out of 457 subjects) whose core temperatures were below 38°C. However, there was a risk of heat illness in the children because approximately 4% of the students (20 out of 457 subjects) had a rise in body temperatures of up to 38°C. These children, if exercising for a longer period of time, may have a tendency to develop heat exhaustion which can lead to heat stroke. However, the boys in our study did not exhibit symptoms of heat illness. It was found that a larger proportion of these 20 subjects exercised at WBGT ≥ 29°C, did not consume water, played football/chair-ball/athletics that were of moderate-to-vigorous intensity, or exercised in the afternoon. Moreover, the risk of increasing body temperature up to 38°C in overweight subjects appeared to be approximately 2 fold higher than normal-weight subjects. Therefore, specific to this study, factors affecting high core temperature seem to include: WBGT of 29ºC or greater, overweight, no fluid intake, moderate-to-vigorous exercise intensity, and exercise period during the afternoon. These data support the findings of earlier investigations on the factors affecting heat tolerance capabilities. Heavier subjects exhibited higher core temperatures and had a lower environmental limits compared to normal-weight subjects when exercising in the heat.[29-31] Core temperature increases in proportion to exercise intensity.[1] In regards to when the children should exercise, the result of this study is consistent with previous reports that the worst time of the day to exercise is between 10 am to 6 pm, the hottest period of the day.[32-33]

Hydration status is one of the major factors in improving performance and limiting heat illness in a hot environment when exercising. It is indicated by a balance between fluid intake and sweat loss. A high rate of sweating reduces plasma volume and creates dehydration. If fluid is not replaced, a number of physiological and pathological effects will

occur. There is a study reporting that dehydration rate due to fluid loss up to 2% of bodyweight can result in performance decrements during exercise.[34] Furthermore, dehydration because of fluid loss can occasionally be high as 6-10% of the person's bodyweight and appears to be one of the most common risk factors for heat illness in patients. Core body temperature has been shown to increase by an additional 0.15-0.2 ℃ for every 1% of bodyweight lost to dehydration during exercise.[32]

Noticeably, most of the subjects (96.1%) in this study did not consume water. This finding demonstrates that children did not recognize the need to replenish fluid loss during exercise. However, degree of dehydration in our subjects was mild, suggesting that their sweat rate was not so excessive. In the present study, it was found that the sweat rate was 391.16 ± 186.75 mL/h. In the study of Inbar *et al.* (2004), the sweat rate of pre-pubertal boys was 342 ± 14 mL/h which was lower than in the young adults and older males.[26] These findings are in line with previous studies reporting relatively low sweat rate in children.[35-36]

Although the results of this study cannot speak for the entire population, it can be concluded that primary schoolboys may exhibit adequate cardiovascular and thermoregulatory responses during outdoor physical activity, with an intensity of 2.5-9 MET and exercise duration of about 30 minutes, in physical education class under hot and humid conditions of WBGT 28-30°C. However, there is a tendency for heat illness, especially in overweight children and those with poor hydration status. It is recommended that climatic conditions and students' core temperature be measured before starting physical education class. Children should be informed of the importance of drinking and encouraged to drink enough water before and during exercise. The amount of water consumed can be determined in relation to sweat rate, which, based on the results from this study, is approximately 400 mL

during an hour of exercise under WBGT ranging of 28-30°C. If physical activity intensity is moderate or vigorous, exercise duration should be decreased.

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## COMPETING INTERESTS

All authors hereby declared no competing interests.

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## CONTRIBUTORSHIP STATEMENT

JS contributed to conception and design, field study measurements, data analysis, drafting the article and final approval of the version to be published. SS and PC carried out the field study measurements and were involved in acquisition of data.

## DATA SHARING STATEMENT

There is no additional data available.

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# Heat illness surveillance in schoolboys participating in physical education class in tropical climate: an analytical prospective descriptive study

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# TITLE PAGE

**Title**

Heat illness surveillance in schoolboys participating in physical education class in tropical climate: an analytical prospective descriptive study

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**Keywords**

Children, cardiovascular responses, thermoregulation, hydration status, hot and humid

**Word count**

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## ABSTRACT

**Objectives** This study aimed to determine thermoregulatory and cardiovascular responses as well as the occurrence of heat illness in children exercising outdoors in physical education class under hot and humid climate. Little information regarding this issue under real-life situation is available, especially in the Southeast Asia.

**Design** Analytical prospective descriptive study

**Setting** A primary school in Bangkok, Thailand

**Participants** A total of 457 schoolboys (age 5.5-12 years) were observed while exercising outdoors during their physical education classes throughout the academic year of 2009, including semesters 1 (between July and September 2009) and 2 (between November 2009 and February 2010).

**Primary and secondary outcome measures** Primary outcome measure was tympanic temperature. Secondary outcome measures included blood pressure, heart rate, hydration status and the occurrence of heat-related illness.

**Results** Outdoor physical activity consisted of skill practice (duration 24.11 ± 11.04 min, intensity < 3 METs) and playing sports (duration 11.48 ± 5.53 min, intensity 2.6-8.8 METs). After exercise, tympanic temperature increased by 0.66 ± 0.41◦C. There were 20 (4.4%) students whose ear temperature exceeded 38◦C, 18 of whom did not consume water. The relative risk of increasing body temperature up to 38◦C in overweight students was 2.1 fold higher than normal-weight students. The percent change in mean arterial pressure and heart rate increased by 20.16 ± 15.34 and 23.94 ± 19.78%, respectively. Sweat and dehydration rates were 391.16 ± 186.75 mL/h and 0.63 ± 0.26%, respectively. No evidence of heat illness was found. Wet bulb globe temperatures of semesters 1 and 2 were 29.95 ± 1.87◦C and 28.32 ± 2.39◦C, respectively.

**Conclusions** There is an increased risk for heat illness during outdoor activities in physical education class in primary school children, especially those who are overweight and have poor hydration status.

## ARTICLE SUMMARY

### 1) Article Focus:

- While children are exercising outdoors in their physical education classes under tropical climate, their thermoregulation and cardiovascular functions may be affected, leading to development of heat-related illness.

### 2) Key Messages:

- This study reports the physiological responses and the occurrence of heat illness in primary school children during outdoor activities in physical education class in a tropical climate.
- Such information could have important implications for design of an optimal program as well as prevention of heat illness in physical education classes under hot and humid environment.

### 3) Strengths and Limitations:

- To our knowledge, this is the first published report from Southeast Asia to provide descriptive information obtained from a large study population on heat illness surveillance and the physiological responses of primary school children under real-life situation while exercising outdoors during their physical education class.
- The limitation of this study includes the measurement of core temperature changes and timing of the heart rate assessment. Ear temperature measurement was taken in this study because it is easy to obtain the children's cooperation. Hence ear temperature is more practical than rectal temperature measurement for such a field-based study. Another limitation is the time taken for heart rate samples. The results of this study may not speak for the entire population because convenience sampling was used.

## INTRODUCTION

When exercising in a hot environment, thermal stress imposes physiological strains, including thermoregulation, cardiovascular functions and subjective responses on the body to a greater extent than during regular exercise.[1-4] The body has to provide blood flow for increasing metabolism of muscles, while increasing skin blood flow and providing fluids for sweating.[1] When these simultaneous demands cannot be met, a cascade of events occur, ultimately resulting in circulatory failure and a rise in core temperature to lethal levels.[1] This leads to heat illnesses, varying from heat edema, heat rash, heat syncope, heat cramps, heat exhaustion and heat stroke.[1, 5-11] Heat exhaustion is a condition in which core temperature rises to 38-40◦C. Heat stroke is the most severe form with core temperatures of greater than 40◦C.[9]

A retrospective study in the U.S. emergency departments during the period 1997-2006 found that patients aged 19 years or below accounted for the largest proportion of exertional heat-related illness, the majority of which were associated with performing a sport or exercising.[12] In Southeast Asia, there were 27 adult patients admitted for exertional heat stroke to the Medical Unit, Toa Payoh Hospital, Singapore from January, 1984 to January, 1987.[13] Also, 8 cases were seen during the hot summer of 1987 at Pramongkutklao Hospital, Bangkok, which represented the first report of this syndrome in Thailand.[14] However, reports in children have not been published from Southeast Asia. It is believed that children are at a higher risk for heat-related problems than adults during exercise due to a number of physiological differences. Children have a greater surface area-to-body mass ratio for heat absorption, a greater metabolic heat production per mass unit and a lower sweating capacity.[9,15] However, these concepts have recently been contradicted by the findings that no thermoregulatory differences exist between children and adults.[16-19] The risk of heat illness may be explained by exposure and social/behavioural differences.[20] Children

frequently do not drink enough to replace fluid loss during exercise.[15, 21-22] A study in 10- to 12-year old boys revealed that children developed dehydration due to insufficient drinking while exercising in hot climate.[21] Another study at a summer sports camp found that children experienced minimal to significant dehydration. Yet the level of hydration knowledge did not correlate with hydration status.[22] Additionally, they are more likely to be exposed to outdoor physical activities. Children tend to attend outdoor summer sports camps and spend more time outside.[20] For example, in physical education class, participation is mandatory and activities are often conducted in the late morning and afternoon, the hottest period of the day. Thus, the susceptibility to heat illness may be raised if the class takes place outdoors. With the influence of global warming, it is predicted that the incidence of heat illness will also become more prevalent.[23-24]

Most of the previous investigations on pre-pubertal children exercising in the heat have been conducted indoors under controlled climatic conditions to determine the effects of maturational and gender differences.[25-31] Little information on those exercising in field-based environment is available, especially in a tropical region. Consequently, this study aimed to determine cardiovascular and thermoregulatory responses as well as the occurrence of heat-related illness in primary schoolboys during outdoor exercise in their physical education classes under tropical climate. This information is required as the basis for preparing an optimal program and providing particular care and prevention of heat illness in physical education class.

## METHODS

### Sample

An analytical prospective descriptive study was conducted using convenience samples. Participants were schoolboys from grades 1-6 of the Chulalongkorn University Demonstration Elementary School, located in Bangkok. The study was conducted during the

academic year of 2009 which included the first (between July 2009 and September 2009) and second semesters (between November 2009 and February 2010). The survey was conducted by distributing questionnaire, consent form, assent form and patient information sheets to all 778 schoolboys in the school. 496 out of 778 students were allowed to participate in the survey by their parents. As 39 students did not participate in the outdoor exercise, they were excluded from the study. Therefore, only 457 surveys were collected in this study (n=108, 89, 88, 73, 68, and 31 for grades 1-6, respectively). All students were healthy on the day of the survey, had no history of heat-related illness and were able to understand the questionnaire. Informed written consent and assent were obtained from the students and their parents. The protocol was approved by Institutional Review Board of the Faculty of Medicine, Chulalongkorn University.

## Measurement

The students were observed while performing activities outdoors in their physical education classes conducted in the late morning (9:40 to 11:40 h) or in the afternoon (12:40 to 15:40 h). Data before and after outdoor exercise were recorded only once for each student. The students were allowed to drink water *ad libitum* without encouragement and urinate during their physical education classes.

### Exercise duration and intensity

Types and duration of outdoor activities performed during physical education class were recorded by using video camera (Sony Handycam DCR-HC46, Sony Corporation, Tokyo, Japan). The intensity of each physical activity which started with skill practice, followed by playing sports, was determined as Metabolic Equivalent of Task (MET) value using the compendium of energy expenditures for youth given by Ridley *et al* (2008).[32]

### Thermoregulatory and cardiovascular responses

Ear temperature was measured at the beginning and within 5 minutes after the completion of exercise [5] using infrared temperature sensor for ear temperature (Terumo ear thermometer EM-30CH, Terumo Corporation, Tokyo, Japan). Calibration of the instrument was done before its use by comparing with rectal core temperature measurements in 5 male volunteers, aged 16-17 years, by using a Biopac MP100 system with SKT100C transducer module, and a thermistor probe (TSD102A, Biopac Systems Inc.) with 1.7 mm of diameter. The thermistor probe was wrapped by plastic film and lubricant gel was applied before inserting to the rectum at a depth around 10 cm. The software for calibrating and collecting data was AcqKnowLedge version 3.8. The tympanic measurements showed a range of 0.1-0.2◦C lower than the rectal temperature.

Cardiovascular parameters including blood pressure and heart rate were measured at the beginning and immediately upon completion of the respective activities by using digital sphygmomanometer (ES-H55, Terumo Corporation, Tokyo, Japan).[1] In each exercise period, 3 to 6 students were assessed for these parameters by 3 examiners; 3 students immediately post-exercise and the rest one after the other. The time taken for heart rate samples to be collected was not more than 2 minutes.

Hydration status

The students emptied their bladders before the beginning of exercise. Then they were weighed wearing only their underwear by using an electronic scale accurate to 20 g (Yamato DP-6100GP, Yamato scale Co., Ltd, Akashi, Japan). A batch of 600-ml bottles of water with the student's name was provided for each student to be used without encouragement during exercise. At the end of the exercise, the total fluid intake was measured and urine was collected. Finally, each student was weighed again wearing only his underwear after sweat was wiped from his body. Sweat loss was calculated from the change in body weight plus total fluid intake minus urine output. Sweat rates were then determined as sweat loss per unit

of time (mL/h). This calculation does not take into account the weight loss due to irreversible fuel oxidation and respiratory fluid loss, since it was assumed that these would not differ between trials.

### Occurrence of heat-related illness

During the exercise period, students were observed for symptoms and signs that may relate to heat illness. These included 1) heat edema: mild edema of hands, feet and ankles; 2) heat rash: pruritic rash and papulovesicular skin eruption over the clothed area; 3) heat cramps: painful muscle contractions; 4) heat syncope: loss of postural control, dizziness and generalized weakness; 5) heat exhaustion: profuse sweating, weakness, clammy skin, dizziness, malaise, fatigue, nausea, vomiting and headache; and 6) heat stroke: hot skin with or without sweating, confusion, ataxia, irritability and coma.[9-10] Data of the students who suffered from heat-related illness would be recorded in the incident report form. The image of the event was recorded by using video camera so the physician can verify the diagnosis.

### Climatic conditions

Climatic conditions were recorded every five minutes during the exercise period in the physical education classes. Wet bulb, dry bulb, and black globe temperatures were measured by using wet bulb temperature measuring devices (QUESTEMP 15 °, Quest electronics, U.S.A.). The wet bulb globe temperature (WBGT) index was used to evaluate environmental heat stress and was calculated using the following formula: wet bulb globe temperature x 0.7 + black globe temperature x 0.2 + dry bulb temperature x 0.1.[1]

## Analysis

Quantitative data were expressed as means ± standard deviation. Cardiovascular responses and change in body weight were presented as percent change. Data analysis before and after the exercise period for body temperature, heart rate, blood pressure and body weight was done by using the Paired T-test. As semesters 1 and 2 were during rainy and winter

seasons, respectively, the differences between the two semesters were determined for ear temperature, cardiovascular response, hydration status and climatic conditions by using the Independent samples T-test. An alpha level of 0.05 was used to determine statistical significance. All statistical analyses were performed by using Statistic Package for the Social Sciences (SPSS for Windows version 17.0, Chicago, IL, USA).

**RESULTS**

A total of 457 students participated in this study without any missing data for each variable of interest. Data collection was done in 175 students from 37 period classes during the first semester and 282 students from 72 period classes during the second semester.

Baseline characteristics of the students are shown in Table 1. Assessment of body weight status was determined by using Thai national growth chart. As BMI references for Thai children are not available, weight for height reference has been used. Overweight is defined as a weight for height of +1.5 S.D. to +2 S.D., corresponding to BMI of 17.99 to 22.42 for the height ranging from 107 to 160 cm.[33] It was revealed that 128 out of 457 (28.0%) students were overweight.

**Table 1** Baseline characteristics of the students

| Characteristics | Semester 1 (n=175) | Semester 2 (n=282) | Total (n=457) | Total Range (max - min) |
|---|---|---|---|---|
| Age (years) | 9.13 ± 1.44 | 7.92 ± 1.45 | 8.38 ± 1.56 | 5.58 – 11.92 |
| Weight (kg) | 34.45 ± 10.32 | 28.55 ± 7.98 | 30.81 ± 9.39 | 15.50 – 65.80 |
| Height (cm) | 135.34 ± 10.38 | 127.85 ± 9.43 | 130.72 ± 10.45 | 107.50 – 159.10 |
| Body mass index ($kg/m^2$) | 18.45 ± 3.64 | 17.20 ± 3.07 | 17.68 ± 3.35 | 12.04 – 29.78 |
| Body surface area ($m^2$) | 1.13 ± 0.20 | 1.00 ± 0.16 | 1.05 ± 0.19 | 0.68 – 1.66 |
| Body surface area/ body weight ($m^2/kg$) | 0.034 ± 0.004 | 0.036 ± 0.004 | 0.035 ± 0.004 | 0.024 – 0.044 |
| % Body fat | 24.88 ± 10.49 | 18.81 ± 7.34 | 21.14 ± 9.16 | 5.41 – 60.06 |

Values are mean ± S.D.

Duration of physical education class was 31.97 ± 11.10 min (28.78 ± 13.64 min and 33.96 ± 8.63 min for semesters 1 and 2, respectively). Outdoor physical activity consisted of skill practice (duration 24.11 ± 11.04 min, intensity < 3 METs) and playing sports (duration 11.48 ± 5.53 min, intensity 2.6-8.8 METs). Sports played consisted of: chair-ball and soccer for grades 1 and 2; chair-basketball, mini-rugby football and athletics for grade 3; chair-basketball, soccer, handball and petanque for grade 4; and soccer, handball and athletics for grades 5 and 6.

Table 2 presents the exercise intensity, ear temperature change, cardiovascular responses, hydration status, and climatic conditions during outdoor exercise in the physical education class of the primary schoolboys during the first and second semesters.

**Table 2** Exercise intensity, ear temperature change, cardiovascular responses, hydration status and climatic conditions during outdoor exercise in physical education class of the primary schoolboys during the first and second semesters

| Parameters | Semester 1 (n=175) | Semester 2 (n=282) | Throughout the academic year (n=457) | Total Range (min-max) |
|---|---|---|---|---|
| **Exercise intensity** | | | | |
| Skill practice (METs) | <3 | <3 | <3 | <3 |
| Playing sports (METs) | 2.6-8.8 | 2.6-8.8 | 2.6-8.8 | 2.6-8.8 |
| **Ear temperature** | | | | |
| Pre-exercise (°C) | 36.52 ± 0.33 | 36.46 ± 0.39 | 36.48 ± 0.37 | 34.70-37.80 |
| Post-exercise (°C) | 37.17 ± 0.39† | 37.13 ± 0.44† | 37.14 ± 0.42 | 36.10-38.70 |
| Mean difference (°C) | 0.65 ± 0.42 | 0.67 ± 0.40 | 0.66 ± 0.41 | 0-3 |
| Number of students whose BT ≥ 38 °C | n=7 | n=13 | n=20 | |
| **Cardiovascular responses** | | | | |
| Systolic blood pressure | | | | |
| Pre-exercise (mmHg) | 103.67±14.37 | 106.88±15.14 | 105.65±14.92 | 56-159 |
| Post-exercise (mmHg) | 122.05±13.35 | 122.86±13.55 | 122.55±13.47 | 80-168 |
| % Change | 19.67 ± 19.61† | 16.43 ± 15.70† | 17.67 ± 17.35 | 0-98.61 |
| Diastolic blood pressure | | | | |
| Pre-exercise (mmHg) | 63.08 ± 9.69 | 63.67 ± 11.60 | 63.45±10.91 | 30-109 |
| Post-exercise (mmHg) | 77.19 ± 13.84 | 77.12 ± 13.08 | 77.15±13.36 | 41-130 |
| % Change | 24.39 ± 27.80† | 23.17 ± 21.64† | 23.64 ± 24.16 | 12.12-210 |
| Mean arterial pressure | | | | |
| Pre-exercise (mmHg) | 76.61 ± 9.49 | 78.08 ± 10.99 | 77.51 ± 10.46 | 43.33-119.33 |
| Post-exercise (mmHg) | 92.14 ± 11.26 | 92.36 ± 11.67 | 92.28±11.50 | 54-141 |
| % Change | 21.34 ± 16.17† | 19.43 ± 14.78† | 20.16 ± 15.34 | 0-99.34 |
| Heart rate | | | | |
| Pre-exercise (beats/min) | 91.30 ± 13.40 | 90.08 ± 15.03 | 90.55 ± 14.42 | 45-136 |
| Post-exercise (beats/min) | 111.04±14.16 | 110.19±15.27 | 110.52±14.84 | 70-153 |
| % Change | 23.12 ± 17.14† | 24.45 ± 21.27† | 23.94 ± 19.78 | 4.17-138.78 |
| **Hydration status** | | | | |
| Sweat rate (mL/h) | 451.42 ± 224.76 | 353.77 ± 147.14* | 391.16 ± 186.75 | 0-1,480.31 |
| Urine output (mL) | 0 | 0 | 0 | 0 |
| % Loss of body weight | 0.52 ± 0.23 | 0.70 ± 0.25* | 0.63 ± 0.26 | 0-2.10 |
| Number of students who consumed water | n=17 | n=1 | n=18 | |
| **Climatic condition** | | | | |
| WBGT (°C) | 29.95 ± 1.87 | 28.32 ± 2.39* | 28.87 ± 2.35 | 23.68-33.85 |
| Air temperature (°C) | 34.14 ± 2.59 | 33.27 ± 2.49 | 33.56 ± 2.55 | 28.20-39.77 |
| Relative humidity (%) | 58.74 ± 7.70 | 51.79 ± 7.32* | 54.15 ± 8.12 | 36.04-73.87 |

Values are presented as mean ± S.D., * $p < 0.05$ between first and second semesters,
† $p < 0.05$ between pre- and post-exercise.

The maximal heat stress level was found during an afternoon class in the first semester (WBGT of 33.85 and relative humidity of 48.50%), where 5 students (5th graders) were observed while playing handball. The peak responses post-exercise during this class included ear temperature of 37.1◦C, and percent changes in systolic and diastolic blood pressure and heart rate of 56.98, 84.75 and 13.89%, respectively.

Significant difference ($P$<0.05) in sweat rate was found between first semester morning (370.07 ± 182.15 mL/h, n=49) and afternoon sessions (483.06 ± 232.33 mL/h, n=126). The sweat rate of overweight students throughout the year was 437.97 ± 179.27 mL/h. It was significantly ($P$<0.05) higher in semester one (494.05 ± 208.50 mL/h, n=60) than in semester two (388.49 ± 131.66 mL/h, n=68).

Only 18 students consumed water, an average of 212.89 ± 89.65 mL during the classes, 2 of whom had a rise in ear temperature up to 38◦C. There were 2 students (1st - and 4th graders) whose body weight decreased by 2.10%.

There were 20 (4.38%) students whose ear temperature rose to a value exceeding 38◦C, with a maximum of 38.7◦C. The body temperature of these boys increased by 1.37 ± 0.45◦C from 36.78 ± 0.37◦C to 38.15 ± 0.20◦C. Table 3 presents conditions found in these students. These include WBGT, body weight, water consumption, exercise intensity and exercise period. The incidence of increasing body temperature up to this level in overweight and normal-weight students was 7.0% (9 out of 128 students) and 3.3% (11 out of 329 students), respectively. Thus, the relative risk of an increase in body temperature up to 38°C in overweight students was 2.1 fold higher than normal-weight students. However, no students experienced heat-related illness during the observation.

**Table 3** Conditions found in 20 students whose body temperature exceeded 38°C or above during outdoor exercise in physical education class

| Conditions | Number of students |
|---|---|
| **Wet bulb globe temperature** | |
| Less than 29ºC | 7 |
| 29ºC or above | 13 |
| **Body weight** | |
| Overweight | 9 |
| Normal weight | 11 |
| **Water consumption** | |
| Not consume water | 18 |
| Consume water | 2 |
| **Exercise intensity** | |
| Vigorous (football) | 10 |
| Moderate (chair-ball, athletics) | 4 |
| Mild (skill practice) | 6 |
| **Exercise period** | |
| Late morning | 3 |
| Afternoon | 17 |

## DISCUSSION

Physical education is important for children because engaging in physical activity will provide them with life-long better health.[34] There is a recommendation that children in primary school should spend 150 minutes on physical education each week, ranging from moderate to vigorous for at least 50% of the physical education time.[35] Our main concern is that if the class is held outdoors in intense heat, the children may become vulnerable to heat injury. Therefore, in order to prepare an optimal physical education program, particular care to quantity and intensity of the exercise should be taken to prevent heat illness.

This is the first published report from Southeast Asia to provide descriptive information on the physiological responses of primary school children under real-life situation while exercising outdoors during their physical education class in hot and humid environment.

The climatic conditions in Bangkok are moderately hot and humid. The students of this study were exposed to high levels of heat stress throughout the academic year, given that the WBGT level was above 28°C which the American College of Sports Medicine has defined as a "very high risk for heat exhaustion and heat stroke".[36] Even more disturbing, the WBGT level of the first semester during July to September was above 29ºC which is the critical level defined as "cancel all athletic activities" by the American Academy of Pediatrics.[15] Moreover, WBGT rates in the afternoon were higher than those in the late morning. Therefore, the high values of heat stress index, especially in the afternoon of the first semester, seem to pose a risk in having heat-related illnesses to the students when exercising outdoors. However, this study demonstrated no significant differences in any variables post-exercise except for sweat rate which was higher in the afternoon than in the late morning during the first semester.

In this study, the students were able to maintain adequate cardiovascular function while performing physical activities outdoors. The present study demonstrated that the children had considerably lower heart rate responses compared to previous reports. In the study of Inbar *et al.* (2004), pre-pubertal boys exhibited the percent change in heart rate of 137.66% when performing a cycling session at the intensity level of 50 % $VO_2$max for 85 min in 41°C environment and relative humidity at 21%.[37] Similarly, Rivera-Brown *et al.* (2006) found that the percent change of heart rate was 87.5% in pre-pubertal girls cycling for 60 min at 60% $VO_2$max in a hot and humid outdoor environment (ambient temperature of 33.7 ± 0.4°C, WBGT 30.0 ± 0.3°C and relative humidity of 53.9 ± 2.4%) with energy drinks to prevent dehydration.[17] The large changes in heart rate obtained from these studies may be due to longer duration and higher intensity of exercises. On the other hand, in our study, the intensity of playing sports was moderate to vigorous but most of the time, during the physical education class, skill practice was implemented which was of mild intensity. The lower heart rates could also be the result of the timing of the assessment post-exercise, a significant limitation of the study. Out of 457 students, 306 students were assessed immediately and 151 were done within 2 minutes.

One of the limitations of the study is that we did not take rectal temperature as a measure for core temperature. However, ear temperature measurements can also predict trends in core temperature.[38-39] Comparative studies in children indicate that ear and rectal temperature have strong correlation [40-43] with the pooled mean difference of 0.29°C.[42] In our study, ear temperature measurement was taken because it is more convenient, less time-consuming and, most importantly, easier to obtain the children's cooperation. Hence ear temperature is more practical than rectal temperature measurement for such a field-based study.

In the present study, there were 95.6% of the students (437 out of 457 students) whose ear temperatures were below 38°C. However, there was a risk of heat illness in the children because approximately 4% of the students (20 out of 457 students) had a rise in body temperatures of up to 38°C. These students, if exercising for a longer period of time, may have a tendency to develop heat exhaustion which can lead to heat stroke. However, the students in our study did not exhibit symptoms of heat illness. As shown in Table 3, it was found that a larger proportion of these 20 students exercised at WBGT ≥ 29°C, did not consume water, played soccer/chair-ball/athletics that were of moderate-to-vigorous intensity, or exercised in the afternoon. Moreover, the risk of increasing body temperature up to 38°C in overweight students appeared to be approximately 2 fold higher than normal-weight students. These data support the findings of earlier investigations on the factors affecting heat tolerance capabilities such as body composition and exercise intensity.[1, 44-46] Heavier children exhibited higher core temperatures and had a lower environmental limits compared to normal-weight children when exercising in the heat.[44-46] The reason is that less heat is required to elevate the body core temperature of those with higher adiposity.[29] Results of this study are consistent with previous reports that the worst time of the day to exercise is between 10 am to 6 pm, the hottest period.[47-48]

Hydration status is one of the major factors in improving performance and limiting heat illness in a hot environment when exercising.[1] Dehydration rate due to fluid loss up to 2% of bodyweight can result in performance decrements during exercise.[49] Furthermore, dehydration because of fluid loss can occasionally be as high as 6-10% of the person's bodyweight and appears to be one of the most common risk factors for heat illness in patients.[49] Core body temperature has been shown to increase by an additional 0.15-0.2 °C for every 1% of bodyweight lost to dehydration during exercise.[47]

The present data showed a higher sweat rate in semester one than semester two. This can be explained by a higher WBGT and relative humidity in semester 1. As a result, the capability of heat loss by radiation, convection and evaporation is reduced to a greater extent, causing higher sweat rate. Noticeably, most of the students (96.1%) in this study did not consume water. This finding demonstrates that children did not recognize the need to replenish fluid loss during exercise. However, degree of dehydration in our students was mild, suggesting that their sweat rate was not excessive (391.16 ± 186.75 mL/h). In the study of Inbar *et al.* (2004), the sweat rate of pre-pubertal boys was 342 ± 14 mL/h which was lower than in the young adults and older males.[37] These findings are in line with previous studies reporting relatively low sweat rate in children.[50-51]

Although the results of this study cannot speak for the entire population, it can be concluded that primary schoolboys may exhibit adequate cardiovascular and thermoregulatory responses during outdoor physical activity, with an intensity of 2.5-9 MET and exercise duration of about 30 minutes, in physical education class under hot and humid conditions of WBGT 28-30°C. However, there is an increased risk for heat illness, especially in overweight children and those with poor hydration status. It is recommended that climatic conditions be measured before starting physical education class. Children should be informed of the importance of drinking and encouraged to drink enough water before and during exercise. The amount of water consumed can be determined in relation to sweat rate, which, based on the results from this study, is approximately 400 mL during an hour of exercise under WBGT ranging of 28-30°C. Teachers should allow students to have frequent drinking breaks, and prepare modified play-to-rest ratios as well as inclusion of more shaded or ventilated areas. Immediate medical attention should be provided for student's health and safety. Even though this research did not demonstrate any incidence of heat illness in school

children participating in physical education class but results were implied only in a city which may obscure such findings. Further investigation in suburban and rural areas is still needed.

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## COMPETING INTERESTS

All authors hereby declared no competing interests.

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## CONTRIBUTORSHIP STATEMENT

JS contributed to conception and design, field study measurements, data analysis, drafting the article and final approval of the version to be published. SS and PC carried out the field study measurements and were involved in acquisition of data.

## DATA SHARING STATEMENT

There is no additional data available.

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# Heat illness surveillance in schoolboys participating in physical education class in tropical climate: an analytical prospective descriptive study

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# TITLE PAGE

**Title**

Heat illness surveillance in schoolboys participating in physical education class in tropical climate: an analytical prospective descriptive study

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## ABSTRACT

**Objectives** This study aimed to determine thermoregulatory and cardiovascular responses as well as the occurrence of heat illness in children exercising outdoors in physical education class under hot and humid climate. Little information regarding this issue under real-life situation is available, especially in the Southeast Asia.

**Design** Analytical prospective descriptive study

**Setting** A primary school in Bangkok, Thailand

**Participants** A total of 457 schoolboys (age 5.5-12 years) were observed while exercising outdoors during their physical education classes throughout the academic year of 2009, including semesters 1 (between July and September 2009) and 2 (between November 2009 and February 2010).

**Primary and secondary outcome measures** Primary outcome measure was tympanic temperature. Secondary outcome measures included blood pressure, heart rate, hydration status and the occurrence of heat-related illness.

**Results** Outdoor physical activity consisted of skill practice (duration 24.11 ± 11.04 min, intensity < 3 METs) and playing sports (duration 11.48 ± 5.53 min, intensity 2.6-8.8 METs). After exercise, tympanic temperature increased by 0.66 ± 0.41◦C. There were 20 (4.4%) students whose ear temperature exceeded 38◦C, 18 of whom did not consume water. The relative risk of increasing body temperature up to 38◦C in overweight students was 2.1 fold higher than normal-weight students. The percent change in mean arterial pressure and heart rate increased by 20.16 ± 15.34 and 23.94 ± 19.78%, respectively. Sweat and dehydration rates were 391.16 ± 186.75 mL/h and 0.63 ± 0.26%, respectively. No evidence of heat illness was found. Wet bulb globe temperatures of semesters 1 and 2 were 29.95 ± 1.87◦C and 28.32 ± 2.39◦C, respectively.

**Conclusions** There is an increased risk for heat illness during outdoor activities in physical education class in primary school children, especially those who are overweight and have poor hydration status.

## ARTICLE SUMMARY

### 1) Article Focus:

- While children are exercising outdoors in their physical education classes under tropical climate, their thermoregulation and cardiovascular functions may be affected, leading to development of heat-related illness.

### 2) Key Messages:

- This study reports the physiological responses and the occurrence of heat illness in primary school children during outdoor activities in physical education class in a tropical climate.
- Such information could have important implications for design of an optimal program as well as prevention of heat illness in physical education classes under hot and humid environment.

### 3) Strengths and Limitations:

- To our knowledge, this is the first published report from Southeast Asia to provide descriptive information obtained from a large study population on heat illness surveillance and the physiological responses of primary school children under real-life situation while exercising outdoors during their physical education class.
- The limitation of this study includes the measurement of core temperature changes and timing of the heart rate assessment. Ear temperature measurement was taken in this study because it is easy to obtain the children's cooperation. Hence ear temperature is more practical than rectal temperature measurement for such a field-based study. Another limitation is the time taken for heart rate samples. The results of this study may not speak for the entire population because convenience sampling was used.

## INTRODUCTION

When exercising in a hot environment, thermal stress imposes physiological strains, including thermoregulation, cardiovascular functions and subjective responses on the body to a greater extent than during regular exercise.[1-4] The body has to provide blood flow for increasing metabolism of muscles, while increasing skin blood flow and providing fluids for sweating.[1] When these simultaneous demands cannot be met, a cascade of events occur, ultimately resulting in circulatory failure and a rise in core temperature to lethal levels.[1] This leads to heat illnesses, varying from heat edema, heat rash, heat syncope, heat cramps, heat exhaustion and heat stroke.[1, 5-11] Heat exhaustion is a condition in which core temperature rises to 38-40◦C. Heat stroke is the most severe form with core temperatures of greater than 40◦C.[9]

A retrospective study in the U.S. emergency departments during the period 1997-2006 found that patients aged 19 years or below accounted for the largest proportion of exertional heat-related illness, the majority of which were associated with performing a sport or exercising.[12] In Southeast Asia, there were 27 adult patients admitted for exertional heat stroke to the Medical Unit, Toa Payoh Hospital, Singapore from January, 1984 to January, 1987.[13] Also, 8 cases were seen during the hot summer of 1987 at Pramongkutklao Hospital, Bangkok, which represented the first report of this syndrome in Thailand.[14] However, reports in children have not been published from Southeast Asia. It is believed that children are at a higher risk for heat-related problems than adults during exercise due to a number of physiological differences. Children have a greater surface area-to-body mass ratio for heat absorption, a greater metabolic heat production per mass unit and a lower sweating capacity.[9,15] However, these concepts have recently been contradicted by the findings that no thermoregulatory differences exist between children and adults.[16-19] The risk of heat illness may be explained by exposure and social/behavioural differences.[20] Children

frequently do not drink enough to replace fluid loss during exercise.[15, 21-22] A study in 10- to 12-year old boys revealed that children developed dehydration due to insufficient drinking while exercising in hot climate.[21] Another study at a summer sports camp found that children experienced minimal to significant dehydration. Yet the level of hydration knowledge did not correlate with hydration status.[22] Additionally, they are more likely to be exposed to outdoor physical activities. Children tend to attend outdoor summer sports camps and spend more time outside.[20] For example, in physical education class, participation is mandatory and activities are often conducted in the late morning and afternoon, the hottest period of the day. Thus, the susceptibility to heat illness may be raised if the class takes place outdoors. With the influence of global warming, it is predicted that the incidence of heat illness will also become more prevalent.[23-24]

Most of the previous investigations on pre-pubertal children exercising in the heat have been conducted indoors under controlled climatic conditions to determine the effects of maturational and gender differences.[25-31] Little information on those exercising in field-based environment is available, especially in a tropical region. Consequently, this study aimed to determine cardiovascular and thermoregulatory responses as well as the occurrence of heat-related illness in primary schoolboys during outdoor exercise in their physical education classes under tropical climate. This information is required as the basis for preparing an optimal program and providing particular care and prevention of heat illness in physical education class.

## METHODS

### Sample

An analytical prospective descriptive study was conducted using convenience samples. Participants were schoolboys from grades 1-6 of the Chulalongkorn University Demonstration Elementary School, located in Bangkok. The study was conducted during the

academic year of 2009 which included the first (between July 2009 and September 2009) and second semesters (between November 2009 and February 2010). The survey was conducted by distributing questionnaire, consent form, assent form and patient information sheets to all 778 schoolboys in the school. 496 out of 778 students were allowed to participate in the survey by their parents. As 39 students did not participate in the outdoor exercise, they were excluded from the study. Therefore, only 457 surveys were collected in this study (n=108, 89, 88, 73, 68, and 31 for grades 1-6, respectively). All students were healthy on the day of the survey, had no history of heat-related illness and were able to understand the questionnaire. Informed written consent and assent were obtained from the students and their parents. The protocol was approved by Institutional Review Board of the Faculty of Medicine, Chulalongkorn University.

**Measurement**

The students were observed while performing activities outdoors in their physical education classes conducted in the late morning (9:40 to 11:40 h) or in the afternoon (12:40 to 15:40 h). Data before and after outdoor exercise were recorded only once for each student. The students were allowed to drink water *ad libitum* without encouragement and urinate during their physical education classes.

Exercise duration and intensity

Types and duration of outdoor activities performed during physical education class were recorded by using video camera (Sony Handycam DCR-HC46, Sony Corporation, Tokyo, Japan). The intensity of each physical activity which started with skill practice, followed by playing sports, was determined as Metabolic Equivalent of Task (MET) value using the compendium of energy expenditures for youth given by Ridley *et al* (2008).[32]

Thermoregulatory and cardiovascular responses

Ear temperature was measured at the beginning and within 5 minutes after the completion of exercise [5] using infrared temperature sensor for ear temperature (Terumo ear thermometer EM-30CH, Terumo Corporation, Tokyo, Japan). Calibration of the instrument was done before its use by comparing with rectal core temperature measurements in 5 male volunteers, aged 16-17 years, by using a Biopac MP100 system with SKT100C transducer module, and a thermistor probe (TSD102A, Biopac Systems Inc.) with 1.7 mm of diameter. The thermistor probe was wrapped by plastic film and lubricant gel was applied before inserting to the rectum at a depth around 10 cm. The software for calibrating and collecting data was AcqKnowLedge version 3.8. The tympanic measurements showed a range of 0.1-0.2◦C lower than the rectal temperature.

Cardiovascular parameters including blood pressure and heart rate were measured at the beginning and immediately upon completion of the respective activities by using digital sphygmomanometer (ES-H55, Terumo Corporation, Tokyo, Japan).[1] In each exercise period, 3 to 6 students were assessed for these parameters by 3 examiners; 3 students immediately post-exercise and the rest one after the other. The time taken for heart rate samples to be collected was not more than 2 minutes.

Hydration status

The students emptied their bladders before the beginning of exercise. Then they were weighed wearing only their underwear by using an electronic scale accurate to 20 g (Yamato DP-6100GP, Yamato scale Co., Ltd, Akashi, Japan). A batch of 600-ml bottles of water with the student's name was provided for each student to be used without encouragement during exercise. At the end of the exercise, the total fluid intake was measured and urine was collected. Finally, each student was weighed again wearing only his underwear after sweat was wiped from his body. Sweat loss was calculated from the change in body weight plus total fluid intake minus urine output. Sweat rates were then determined as sweat loss per unit

of time (mL/h). This calculation does not take into account the weight loss due to irreversible fuel oxidation and respiratory fluid loss, since it was assumed that these would not differ between trials.

### Occurrence of heat-related illness

During the exercise period, students were observed for symptoms and signs that may relate to heat illness. These included 1) heat edema: mild edema of hands, feet and ankles; 2) heat rash: pruritic rash and papulovesicular skin eruption over the clothed area; 3) heat cramps: painful muscle contractions; 4) heat syncope: loss of postural control, dizziness and generalized weakness; 5) heat exhaustion: profuse sweating, weakness, clammy skin, dizziness, malaise, fatigue, nausea, vomiting and headache; and 6) heat stroke: hot skin with or without sweating, confusion, ataxia, irritability and coma.[9-10] Data of the students who suffered from heat-related illness would be recorded in the incident report form. The image of the event was recorded by using video camera so the physician can verify the diagnosis.

### Climatic conditions

Climatic conditions were recorded every five minutes during the exercise period in the physical education classes. Wet bulb, dry bulb, and black globe temperatures were measured by using wet bulb temperature measuring devices (QUESTEMP 15 °, Quest electronics, U.S.A.). The wet bulb globe temperature (WBGT) index was used to evaluate environmental heat stress and was calculated using the following formula: wet bulb globe temperature x 0.7 + black globe temperature x 0.2 + dry bulb temperature x 0.1.[1]

## Analysis

Quantitative data were expressed as means ± standard deviation. Cardiovascular responses and change in body weight were presented as percent change. Data analysis before and after the exercise period for body temperature, heart rate, blood pressure and body weight was done by using the Paired T-test. As semesters 1 and 2 were during rainy and winter

seasons, respectively, the differences between the two semesters were determined for ear temperature, cardiovascular response, hydration status and climatic conditions by using the Independent samples T-test. An alpha level of 0.05 was used to determine statistical significance. All statistical analyses were performed by using Statistic Package for the Social Sciences (SPSS for Windows version 17.0, Chicago, IL, USA).

**RESULTS**

A total of 457 students participated in this study without any missing data for each variable of interest. Data collection was done in 175 students from 37 period classes during the first semester and 282 students from 72 period classes during the second semester.

Baseline characteristics of the students are shown in Table 1. Assessment of body weight status was determined by using Thai national growth chart. As BMI references for Thai children are not available, weight for height reference has been used. Overweight is defined as a weight for height of +1.5 S.D. to +2 S.D., corresponding to BMI of 17.99 to 22.42 for the height ranging from 107 to 160 cm.[33] It was revealed that 128 out of 457 (28.0%) students were overweight.

**Table 1** Baseline characteristics of the students

| Characteristics | Semester 1 (n=175) | Semester 2 (n=282) | Total (n=457) | Total Range (max - min) |
|---|---|---|---|---|
| Age (years) | 9.13 ± 1.44 | 7.92 ± 1.45 | 8.38 ± 1.56 | 5.58 – 11.92 |
| Weight (kg) | 34.45 ± 10.32 | 28.55 ± 7.98 | 30.81 ± 9.39 | 15.50 – 65.80 |
| Height (cm) | 135.34 ± 10.38 | 127.85 ± 9.43 | 130.72 ± 10.45 | 107.50 – 159.10 |
| Body mass index ($kg/m^2$) | 18.45 ± 3.64 | 17.20 ± 3.07 | 17.68 ± 3.35 | 12.04 – 29.78 |
| Body surface area ($m^2$) | 1.13 ± 0.20 | 1.00 ± 0.16 | 1.05 ± 0.19 | 0.68 – 1.66 |
| Body surface area/ body weight ($m^2/kg$) | 0.034 ± 0.004 | 0.036 ± 0.004 | 0.035 ± 0.004 | 0.024 – 0.044 |
| % Body fat | 24.88 ± 10.49 | 18.81 ± 7.34 | 21.14 ± 9.16 | 5.41 – 60.06 |

Values are mean ± S.D.

Duration of physical education class was 31.97 ± 11.10 min (28.78 ± 13.64 min and 33.96 ± 8.63 min for semesters 1 and 2, respectively). Outdoor physical activity consisted of skill practice (duration 24.11 ± 11.04 min, intensity < 3 METs) and playing sports (duration 11.48 ± 5.53 min, intensity 2.6-8.8 METs). Sports played consisted of: chair-ball and soccer for grades 1 and 2; chair-basketball, mini-rugby football and athletics for grade 3; chair-basketball, soccer, handball and petanque for grade 4; and soccer, handball and athletics for grades 5 and 6.

At the high exercise intensity of 8.8 MET, duration of playing sports was 11.43 ± 5.23 min and WBGT was 28.35 ± 2.01°C. Sports with such high intensity included chair-ball (n= 45; 1st graders=24, 2nd graders=21), soccer (n=110; 1st graders=30, 2nd graders=41, 3rd graders=22, 4th graders=9 and 6th graders=8) and mini-rugby football (n=1, 3rd grader).

Table 2 presents the exercise intensity, ear temperature change, cardiovascular responses, hydration status, and climatic conditions during outdoor exercise in the physical education class of the primary schoolboys during the first and second semesters.

**Table 2** Exercise intensity, ear temperature change, cardiovascular responses, hydration status and climatic conditions during outdoor exercise in physical education class of the primary schoolboys during the first and second semesters

| Parameters | Semester 1 (n=175) | Semester 2 (n=282) | Throughout the academic year (n=457) | Total Range (min-max) |
|---|---|---|---|---|
| **Exercise intensity** | | | | |
| Skill practice (METs) | <3 | <3 | <3 | <3 |
| Playing sports (METs) | 2.6-8.8 | 2.6-8.8 | 2.6-8.8 | 2.6-8.8 |
| **Ear temperature** | | | | |
| Pre-exercise (°C) | 36.52 ± 0.33 | 36.46 ± 0.39 | 36.48 ± 0.37 | 34.70-37.80 |
| Post-exercise (°C) | 37.17 ± 0.39† | 37.13 ± 0.44† | 37.14 ± 0.42 | 36.10-38.70 |
| Mean difference (°C) | 0.65 ± 0.42 | 0.67 ± 0.40 | 0.66 ± 0.41 | 0-3 |
| Number of students whose BT ≥ 38 °C | n=7 | n=13 | n=20 | |
| **Cardiovascular responses** | | | | |
| Systolic blood pressure | | | | |
| Pre-exercise (mmHg) | 103.67±14.37 | 106.88±15.14 | 105.65±14.92 | 56-159 |
| Post-exercise (mmHg) | 122.05±13.35 | 122.86±13.55 | 122.55±13.47 | 80-168 |
| % Change | 19.67 ± 19.61† | 16.43 ± 15.70† | 17.67 ± 17.35 | 0-98.61 |
| Diastolic blood pressure | | | | |
| Pre-exercise (mmHg) | 63.08 ± 9.69 | 63.67 ± 11.60 | 63.45±10.91 | 30-109 |
| Post-exercise (mmHg) | 77.19 ± 13.84 | 77.12 ± 13.08 | 77.15±13.36 | 41-130 |
| % Change | 24.39 ± 27.80† | 23.17 ± 21.64† | 23.64 ± 24.16 | 12.12-210 |
| Mean arterial pressure | | | | |
| Pre-exercise (mmHg) | 76.61 ± 9.49 | 78.08 ± 10.99 | 77.51 ± 10.46 | 43.33-119.33 |
| Post-exercise (mmHg) | 92.14 ± 11.26 | 92.36 ± 11.67 | 92.28±11.50 | 54-141 |
| % Change | 21.34 ± 16.17† | 19.43 ± 14.78† | 20.16 ± 15.34 | 0-99.34 |
| Heart rate | | | | |
| Pre-exercise (beats/min) | 91.30 ± 13.40 | 90.08 ± 15.03 | 90.55 ± 14.42 | 45-136 |
| Post-exercise (beats/min) | 111.04±14.16 | 110.19±15.27 | 110.52±14.84 | 70-153 |
| % Change | 23.12 ± 17.14† | 24.45 ± 21.27† | 23.94 ± 19.78 | 4.17-138.78 |
| **Hydration status** | | | | |
| Sweat rate (mL/h) | 451.42 ± 224.76 | 353.77 ± 147.14* | 391.16 ± 186.75 | 0-1,480.31 |
| Urine output (mL) | 0 | 0 | 0 | 0 |
| % Loss of body weight | 0.52 ± 0.23 | 0.70 ± 0.25* | 0.63 ± 0.26 | 0-2.10 |
| Number of students who consumed water | n=17 | n=1 | n=18 | |
| **Climatic condition** | | | | |
| WBGT (°C) | 29.95 ± 1.87 | 28.32 ± 2.39* | 28.87 ± 2.35 | 23.68-33.85 |
| Air temperature (°C) | 34.14 ± 2.59 | 33.27 ± 2.49 | 33.56 ± 2.55 | 28.20-39.77 |
| Relative humidity (%) | 58.74 ± 7.70 | 51.79 ± 7.32* | 54.15 ± 8.12 | 36.04-73.87 |

Values are presented as mean ± S.D., *p <0.05 between first and second semesters, †p <0.05 between pre- and post-exercise.

The maximal heat stress level was found during an afternoon class in the first semester (WBGT of 33.85 and relative humidity of 48.50%), where 5 students (5th graders) were observed while playing handball. The peak responses post-exercise during this class included ear temperature of 37.1◦C, and percent changes in systolic and diastolic blood pressure and heart rate of 56.98, 84.75 and 13.89%, respectively. The sweat rate was 642.37±193.33 mL/h and fluid intake was 198.20±7.68 mL.

Significant difference ($P$<0.05) in sweat rate was found between first semester morning (370.07 ± 182.15 mL/h, n=49) and afternoon sessions (483.06 ± 232.33 mL/h, n=126). The sweat rate of overweight students throughout the year was 437.97 ± 179.27 mL/h. It was significantly ($P$<0.05) higher in semester one (494.05 ± 208.50 mL/h, n=60) than in semester two (388.49 ± 131.66 mL/h, n=68).

Only 18 students consumed water, an average of 212.89 ± 89.65 mL during the classes, 2 of whom had a rise in ear temperature up to 38◦C. There were 2 students (1st - and 4th graders) whose body weight decreased by 2.10%.

There were 20 (4.38%) students whose ear temperature rose to a value exceeding 38◦C, with a maximum of 38.7◦C. The body temperature of these boys increased by 1.37 ± 0.45◦C from 36.78 ± 0.37◦C to 38.15 ± 0.20◦C. Table 3 presents conditions found in these students. These include WBGT, body weight, water consumption, exercise intensity and exercise period. The incidence of increasing body temperature up to this level in overweight and normal-weight students was 7.0% (9 out of 128 students) and 3.3% (11 out of 329 students), respectively. Thus, the relative risk of an increase in body temperature up to 38°C in overweight students was 2.1 fold higher than normal-weight students. However, no students experienced heat-related illness during the observation.

**Table 3** Conditions found in 20 students whose body temperature exceeded 38°C or above during outdoor exercise in physical education class

| Conditions | Number of students |
|---|---|
| **Wet bulb globe temperature** | |
| Less than 29ºC | 7 |
| 29ºC or above | 13 |
| **Body weight** | |
| Overweight | 9 |
| Normal weight | 11 |
| **Water consumption** | |
| Not consume water | 18 |
| Consume water | 2 |
| **Exercise intensity** | |
| Vigorous (football) | 10 |
| Moderate (chair-ball, athletics) | 4 |
| Mild (skill practice) | 6 |
| **Exercise period** | |
| Late morning | 3 |
| Afternoon | 17 |

## DISCUSSION

Physical education is important for children because engaging in physical activity will provide them with life-long better health.[34] There is a recommendation that children in primary school should spend 150 minutes on physical education each week, ranging from moderate to vigorous for at least 50% of the physical education time.[35] Our main concern is that if the class is held outdoors in intense heat, the children may become vulnerable to heat injury. Therefore, in order to prepare an optimal physical education program, particular care to quantity and intensity of the exercise should be taken to prevent heat illness.

This is the first published report from Southeast Asia to provide descriptive information on the physiological responses of primary school children under real-life situation while exercising outdoors during their physical education class in hot and humid environment.

The climatic conditions in Bangkok are moderately hot and humid. The students of this study were exposed to high levels of heat stress throughout the academic year, given that the WBGT level was above 28°C which the American College of Sports Medicine has defined as a "very high risk for heat exhaustion and heat stroke".[36] Even more disturbing, the WBGT level of the first semester during July to September was above 29ºC which is the critical level defined as "cancel all athletic activities" by the American Academy of Pediatrics.[15] Moreover, WBGT rates in the afternoon were higher than those in the late morning. Therefore, the high values of heat stress index, especially in the afternoon of the first semester, seem to pose a risk in having heat-related illnesses to the students when exercising outdoors. However, this study demonstrated no significant differences in any variables post-exercise except for sweat rate which was higher in the afternoon than in the late morning during the first semester. Interestingly, under the maximal WBGT of 33.8 °C, the students were able to maintain effective thermoregulation by heat loss through sweating,

thus, when coupled with fluid consumption, making them withstand such the heat stress with exercise.

In this study, the students were able to maintain adequate cardiovascular function while performing physical activities outdoors. The present study demonstrated that the children had considerably lower heart rate responses compared to previous reports. In the study of Inbar *et al*. (2004), pre-pubertal boys exhibited the percent change in heart rate of 137.66% when performing a cycling session at the intensity level of 50 % $VO_2$max for 85 min in 41°C environment and relative humidity at 21%.[37] Similarly, Rivera-Brown *et al*. (2006) found that the percent change of heart rate was 87.5% in pre-pubertal girls cycling for 60 min at 60% $VO_2$max in a hot and humid outdoor environment (ambient temperature of 33.7 ± 0.4°C, WBGT 30.0 ± 0.3°C and relative humidity of 53.9 ± 2.4%) with energy drinks to prevent dehydration.[17] The large changes in heart rate obtained from these studies may be due to longer duration and higher intensity of exercises. On the other hand, in our study, the intensity of playing sports was moderate to vigorous but most of the time, during the physical education class, skill practice was implemented which was of mild intensity. The lower heart rates could also be the result of the timing of the assessment post-exercise, a significant limitation of the study. Out of 457 students, 306 students were assessed immediately and 151 were done within 2 minutes.

One of the limitations of the study is that we did not take rectal temperature as a measure for core temperature. However, ear temperature measurements can also predict trends in core temperature.[38-39] Comparative studies in children indicate that ear and rectal temperature have strong correlation [40-43] with the pooled mean difference of 0.29°C.[42] In our study, ear temperature measurement was taken because it is more convenient, less time-consuming and, most importantly, easier to obtain the children's cooperation. Hence ear

temperature is more practical than rectal temperature measurement for such a field-based study.

In the present study, there were 95.6% of the students (437 out of 457 students) whose ear temperatures were below 38°C. However, there was a risk of heat illness in the children because approximately 4% of the students (20 out of 457 students) had a rise in body temperatures of up to 38°C. These students, if exercising for a longer period of time, may have a tendency to develop heat exhaustion which can lead to heat stroke. However, the students in our study did not exhibit symptoms of heat illness. As shown in Table 3, it was found that a larger proportion of these 20 students exercised at WBGT ≥ 29°C, did not consume water, played soccer/chair-ball/athletics that were of moderate-to-vigorous intensity, or exercised in the afternoon. Moreover, the risk of increasing body temperature up to 38°C in overweight students appeared to be approximately 2 fold higher than normal-weight students. These data support the findings of earlier investigations on the factors affecting heat tolerance capabilities.[1, 44-46] Heavier children exhibited higher core temperatures and had a lower environmental limits compared to normal-weight children when exercising in the heat.[44-46] Core temperature increases in proportion to exercise intensity.[1] Results of this study are consistent with previous reports that the worst time of the day to exercise is between 10 am to 6 pm, the hottest period.[47-48]

Hydration status is one of the major factors in improving performance and limiting heat illness in a hot environment when exercising.[1] Dehydration rate due to fluid loss up to 2% of bodyweight can result in performance decrements during exercise.[49] Furthermore, dehydration because of fluid loss can occasionally be as high as 6-10% of the person's bodyweight and appears to be one of the most common risk factors for heat illness in patients.[49] Core body temperature has been shown to increase by an additional 0.15-0.2 °C for every 1% of bodyweight lost to dehydration during exercise.[47]

The present data showed a higher sweat rate in semester one than semester two. This can be explained by a higher WBGT and relative humidity in semester 1. As a result, the capability of heat loss by radiation, convection and evaporation is reduced to a greater extent, causing higher sweat rate. Noticeably, most of the students (96.1%) in this study did not consume water. This finding demonstrates that children did not recognize the need to replenish fluid loss during exercise. However, degree of dehydration in our students was mild, suggesting that their sweat rate was not excessive (391.16 ± 186.75 mL/h). In the study of Inbar *et al.* (2004), the sweat rate of pre-pubertal boys was 342 ± 14 mL/h which was lower than in the young adults and older males.[37] These findings are in line with previous studies reporting relatively low sweat rate in children.[50-51]

Although the results of this study cannot speak for the entire population, it can be concluded that primary schoolboys may exhibit adequate cardiovascular and thermoregulatory responses during outdoor physical activity, with an intensity of 2.5-9 MET and exercise duration of about 30 minutes, in physical education class under hot and humid conditions of WBGT 28-30°C. However, there is an increased risk for heat illness, especially in overweight children and those with poor hydration status. It is recommended that climatic conditions be measured before starting physical education class. Children should be informed of the importance of drinking and encouraged to drink enough water before and during exercise. The amount of water consumed can be determined in relation to sweat rate, which, based on the results from this study, is approximately 400 mL during an hour of exercise under WBGT ranging of 28-30°C. Teachers should allow students to have frequent drinking breaks, and prepare modified play-to-rest ratios as well as inclusion of more shaded or ventilated areas. Immediate medical attention should be provided for student's health and safety. Even though this research did not demonstrate any incidence of heat illness in school

children participating in physical education class but results were implied only in a city which may obscure such findings. Further investigation in suburban and rural areas is still needed.

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## COMPETING INTERESTS

All authors hereby declared no competing interests.

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## CONTRIBUTORSHIP STATEMENT

JS contributed to conception and design, field study measurements, data analysis, drafting the article and final approval of the version to be published. SS and PC carried out the field study measurements and were involved in acquisition of data.

## DATA SHARING STATEMENT

There is no additional data available.

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