

Heat Stroke in Schools

Yutaka HATORI¹

Abstract

During children's development period, their sweating mechanism is still immature and their bodies retain heat easily, making it difficult to understand changes in their physical condition. Moreover, their sweat glands are unable to acclimatize to heat, and so large amounts of salt are lost. Of the 133 cases of accidental death due to heat stroke that occurred in Japan under school supervision between 1975 and 2009, the largest number of cases (35) was related to baseball, followed by rugby, football, judo, and kendo. Regarding the seasons in which heat stroke occurs, cases develop between the end of the rainy season in mid-July and the end of September, with boys aged 15-17 comprising the overwhelmingly largest group of cases. Furthermore, a notable number of heat stroke cases occur when humidity is high even though the temperature is not high.

Heat stroke occurs easily when temperatures and humidity are high, fluid intake is difficult, and there is no movement of air. For this reason, sports activities under the blazing sun and in closed gymnasiums require careful attention to the sports environment and sufficient fluid intake that also replaces lost salt. Furthermore, in the case that a patient presents with impaired consciousness, they should immediately be given emergency medical treatment with heat stroke, heart disease, and cranial nerve dysfunction in mind.

Keywords: Heat stroke, School physical education, Accidental heat stroke death, Heat stroke prevention

¹ Board Member, Kanagawa Prefecture Medical Association, Kanagawa, Japan (yutaka@hatori.or.jp). This article is a revised English version of a paper originally published in the Journal of the Japan Medical Association (Vol.141, No.2, 2012, pages 284-288).

Introduction

In 2010, there was a sudden increase in the number of people taken to hospital by ambulance for heat stroke, but thankfully this figure dropped 27% in the summer of 2011.¹⁾ Although Japan experiences scorching summers every year, in recent years the heat has become increasingly severe due in part to the impact of global warming.

Solar heat accumulates in large city areas covered in asphalt, causing sensory temperatures to rise above actual temperatures due to the heat island phenomenon. Furthermore, with the electricity shortage resulting from the nuclear power plant accident following the Great East Japan Earthquake, the summer of 2011 required strict electricity-saving measures. As people had to turn off their air-conditioners and even refrain from using electrical fans, an increase in heat stroke was concerned. Thus thorough diffusion of knowledge about the mechanisms of heat stroke and prevention methods is essential. Fortunately, summer temperatures of 2011 were comparatively low due to the impact of stalled typhoons in August, but it was difficult to predict summer temperatures of 2012. In 2011, the number of people transported to hospital by ambulance for heat stroke (May 30-October 2) was 3,800 in Tokyo; 3,400 in Saitama/Aichi; 2,700 in Osaka; 2,500 in Kanagawa; and 2,300 in Chiba, and particular care needs to be taken in these regions.

I. What is Heat sStroke?

The *Health Care Manual for Heatstroke* (May 2011 Revised Edition), published by the Ministry of the Environment of Japan, defines heat stroke as follows.²⁾

Heat stroke is a collective term for disorders that develop when, in a high-temperature environment, the balance of fluids and salts (sodium, etc.) within the body is disrupted and the body's internal regulatory function breaks down. Through exercise and physical acts, our bodies are constantly generating heat, while at the same time, our bodies are

also equipped with an efficient regulatory mechanism for controlling abnormal rises in body temperature. When it is hot, peripheral blood vessels expand via the autonomic nerves, thus enabling the distribution of large amounts of blood to the skin and lowering of body temperature through heat transfer to the air. Furthermore, sweating a lot helps to lower body temperature by removing heat through the evaporation of sweat". The basic source of the sweat that is secreted from the surface of the skin is water within the body. This mechanism is also an action of the autonomic nerves. In this way, the distribution of blood in our body changes and water and salt (sodium, etc.) is lost from the body through sweat. If our bodies cannot handle this situation appropriately, our muscles cramp and we faint (so-called "cerebral anemia": a state in which blood flow to the brain is temporarily restricted). Consequently, if the balance between heat generation and release of heat through heat transfer and sweat is disrupted, body temperature rises markedly. Such a state is heat stroke.

There is heat stroke that occurs amongst elderly people, heat stroke that occurs amongst children in high-temperature environments, heat stroke that occurs during work in hot environments, and heat stroke that occurs during sporting activities. Cases of heat stroke that occur during work have been gradually decreasing compared to before due to improvements in the work environment, but in recent years there seems to be an increasing trend overall due to environmental changes. Furthermore, in relation to school health, while there has been a slightly decreasing trend in the incidence of heat stroke in sporting activities, the speed of this decrease is slowing. Due to the impact of large amounts of heat generation by the muscles and water loss from the body during sports and other physical activity, it is possible for heat stroke to occur even in environments regarded as being cold. In fact, cases of death due to heat stroke have even occurred in the winter month of January. Moreover, cases have also been observed in which heat stroke develops within a comparatively short period of time (from around 30 minutes) after the commencement of activity.³⁾

II. Sweating Mechanisms

Since the source of sweat is the blood component plasma, an adult weighting 65kg has 3L of source for sweat. When sweat is actively released through the secretory ducts, sodium and chlorine are reabsorbed before the sweat reaches the skin's surface, and so sweat with a lower electrolyte concentration than blood plasma (0.4%-0.8%) is released. However, when large amounts of sweating are generated, re-absorption of sodium and chlorine cannot keep up with the pace, and so a thick sweat is secreted, so it is as if salt is being poured out of the body. In particular, people who get insufficient exercise and have no tolerance physical activity secrete thick and sticky sweat with a high concentration of salt. People who live in tropical regions or who are used to exercise acclimatize to heat. The percentage of electrolytes that are reabsorbed by their bodies increases, salt is brought back into their bodies and they are able to secrete a thin hypotonic sweat that does not cause physical disorders.

Except for Hokkaido, the climate in Japan during summer is hot and humid from the Tohoku region to Okinawa, with no regional differences. The saying that "When building a house, keep summer in mind" mentioned in the 14th century *Tsurezuregusa* (Essays in Idleness) expresses the wisdom of people who lived in a time long ago without coolers.

Looking at a field survey conducted by Dr. Masami Asayama of Chukyo Women's University (now Shigakkan University) of high school baseball grounds, it has been reported that baseball youths everywhere from the Tohoku region southwards lose close to 7% of their weight (approximately 4L of sweating) before and after games. Amongst schools recently aiming to compete in the Koshien baseball championships, one high school in Tokyo began training one month before the competition in winter jackets and Okinawan players wear raincoats to train under the blazing sun, but this is not recommended for general school students who have not developed a training foundation. Another high school in Tokyo had

four players in the 5th round game of the 2010 Summer Tokyo Baseball Championships collapse with heat stroke and lost the game. Based on the lessons learned from their experience, the school has since last year revised its fluid intake methods, which requires players to drink 500ml of sports drinks before training and a total of 1.5l to 2l of sports drinks consumed gradually at intervals of 20 minutes to 30 minutes. Furthermore, measures were taken to prevent salt loss in addition to fluid loss by having players take tablets containing salt and other minerals or consume pickled plums.

III. Physical Characteristics of Children during the Growth Period and Sweating (Table 1)

During children's development period, their sweating mechanism is still immature and their bodies retain heat easily, making it difficult to understand changes in their physical condition. Poor physical condition due to lack of sleep on hot, humid nights worsens heat stroke, and it is said that children's sweating systems do not develop if a state of insufficient exercise continues due to studying for exams, etc. When the body cannot acclimatize to heat, a large amount of salt is lost through the sweat glands. Thus water intake alone lowers the concentration of salt in the blood, causing water diuresis (urine with low salt concentrations is excreted) in order for the body to correct this imbalance. Thus it is important to consume salt as well as water.

According to statistics compiled by the Japan Sport Council (NAASH), of the 133 cases of accidental death due to heat stroke that occurred in Japan under school supervision between 1975 and 2009, the largest number of cases (35) was related to baseball, followed by rugby, football, judo, kendo, mountaineering, and track and field, indicating that indoor sporting events also require caution (**Fig 1**, left-hand side). Outside of club activities, the incidence of heat stroke stood out for activities carried out over extended period of time such

as mountain climbing, marathon running, and long-distance walking. Regarding the seasons in which heat stroke occurs, cases develop between the end of the rainy season in mid-July and the end of September. Boys comprise the overwhelmingly largest group of heat stroke cases (92.6%); in terms of school grade, the largest number of cases is known to develop amongst 1st and 2nd year high school students (ages 15 - 17) (**Fig 1**, right-hand side). Looking at the figures for 86 heat stroke case examples up until 1990, a notable number of accidents occurred when humidity was high even though the temperature was not high.⁴⁾

The figure shows school-related case examples of heat stroke in Kawasaki City, Kanagawa Prefecture, that occurred during physical education classes or extracurricular activities, etc.

- (1) Summer extracurricular activities at junior high schools: A student collapsed due to heat stroke while running in the daytime. The student were running a return course of approximately 2km each way and their coach was running with them, but approximately 1km from the start the student began to fall behind and declining to the level of disorientation, crouching on the ground and staring blankly. The student was made to rest where they were while the coach returned to the starting point to retrieve their mobile telephone and returned to the student, then called an ambulance. This resulted in a loss of approximately 15 minutes, during which time the student lost consciousness while teammates were loosening the student's clothes and fanning them. In the ambulance, cardiopulmonary resuscitation was performed, but the student died after reaching the hospital.
- (2) Senior high school sports carnival: student died suddenly during the 800m relay event
- (3) Junior high school physical education class: student died suddenly during coordinated group gymnastics
- (4) Junior high school extracurricular activities: in the late-summer heat of September, a

student collapsed during a three-hour-long martial arts event held in the school gymnasium on a public holiday and their consciousness deteriorated. Diagnosed as hyperventilation, the student was treated but showed no improvement and was taken to hospital but sustained brain damage.

In cases (2) and (3), there is also the possibility of sudden death due to cardiac arrhythmia, but in cases (1) and (4), the cause is thought to have definitely been heat stroke.

IV. Pre-sport Self-checklist

Before sporting activities, the following points should be checked and extra care taken if you have any concerns: (1) Is my overall physical condition good? (2) Have I had sufficient sleep? (3) Do I have a cold, fever, diarrhea, or vomiting? (4) Have I consumed sufficient food and fluids yesterday and today? (5) Has my physician placed restrictions on my sporting activities? and (6) Have I developed heat stroke in the past? (Heat stroke reoccurs easily.)

V. Preventing Heat Stroke (Table 2)

In order to prevent heat stroke, a person should eat balanced meals on a routine basis, consuming good-quality protein and necessary vitamins and avoiding an unbalanced diet. Sufficient sleep is needed for recovery from fatigue.⁵⁾

A hat should be worn for protection from direct sunlight; clothing should easily absorb sweat and dissipate heat, be loose, and have V-necks rather than round necks, and shirts should be left un-tucked. For sports in which protective equipment is worn, such as masks and padding in kendo and fencing and catchers' masks and leg guards in baseball, the equipment should be removed during rest breaks.

Sufficient amounts of water, caffeine-less tea, sports drinks, towels, and mobile

telephones should be brought to venues where sports are being played. For venues where a sport is played over a lengthy time period, use of devices such as heat stroke risk monitors and thermometers is recommended (**Fig 2, 3**).

VI. Consuming Fluids in Hot Environments

If the body desires fluids, no limitations should be set. If 2% of body weight is lost (1kg for a person weighing 50kg), the person should be made to consume fluids, even if they resist. Drinking large amounts of water is not a problem, but care should be taken that water intoxication does not occur due to salt insufficiency.

The American College of Sports Medicine (ACSM) recommends having sports players drink as much water as comfortably possible. Between 200ml and 500ml of fluids should be drunk before sporting activity, and 200ml should be drunk during activity for each 0.5kg of weight lost. Athletes should be made to drink 200ml of fluids every 20 minutes. They should drink water—preferably cold water, as this not only cools core body temperature but also is easier for the body to absorb. Adding flavor or sweetness to the water enables large quantities to be consumed (drink, such as sports drinks, that contain a salt concentration of 0.1%-0.2% and a sugar concentration of 3%-5% and are cooled to between 5°C and 15°C). Although between 5g and 7g of sodium are lost through sweating, loss of magnesium and potassium is small, and so the loss of fluids is said to be more problematic than the loss of ions.⁶⁾ Consumption of salt during 60 minutes of continuous exercise is not necessary, but for exercise longer than 60 minutes, replacement of sodium and carbohydrates is required.

Taking salt tablets does not seem suitable for people who are unused to exercise. It is known that if a person's sweat gland activity and acclimatization to exercise are insufficient, taking salt tablets can have the reverse effect of generating sweat with a dense concentration of electrolytes. While a person suffering cramps or convulsions needs to be given water with a

high salt concentration (normal saline solution), an ambulance should also be called as soon as possible.

VII. General Precautions for Sporting Activities

In 2012, it was expected not to be possible to use air-conditioning in closed spaces such as gymnasiums. On June 13, 2003—a hot, humid day—a member of a junior high school sumo wrestling club in Akita Prefecture died of heat stroke during training at indoor facilities. In gymnasiums, where convection flow is small; especial care needs to be taken with table tennis—which requires doors and windows to be closed—badminton, and kendo and fencing—which require players to wear protective gear that prevents their facial expressions from being seen clearly. Except for official matches, doors and windows need to be opened to enhance ventilation. For outdoor sporting events, too, training should be concentrated in the early mornings and evenings after dusk on days that are hot and humid with no breeze. Heat stroke occurs easily under conditions where temperatures and humidity are high, fluid intake is difficult, and there is no movement of air. Thus especial care needs to be taken with jogging under a blazing sun (baseball, football, etc.), activities on the ocean on sunny days with no wind (yachting), and sporting activities in closed gymnasiums (kendo, judo, table tennis, badminton, etc.).

VIII. When Heat Stroke is Suspected, Take Action Immediately

If the person with suspected heat stroke is fully conscious, they should be given cold water to cool their body from within. In addition, they should be rested in a cool, well-ventilated place such as in the shade of a tree in the hope of generating insensible perspiration, sprayed with water using an atomizer, etc., fanned, and thoroughly cooled until they begin to shiver. A characteristic of the human body is that it can endure low temperatures

but not high temperatures. In order to send cool blood to the brain, which is the most important organ of the body, wet towels and ice packs, etc. should be placed against the person's head to cool the internal carotid arteries leading to the brain. Since it is difficult for a person to drink if their level of consciousness is unstable, active treatment such as intravenous drips are necessary. An ambulance must be called and the person transported to a medical institution.

Resumption of exercise should take place after several days of rest to enable sufficient recovery and should commence with light exercise in a cool place, with the exercise load increased gradually. People who have experienced heat stroke are said to be susceptible to recurrences. Although heat stroke may be difficult to distinguish from other conditions, such as hyperventilation syndrome, in the case that a patient presents with impaired consciousness, they should be given emergency medical treatment as quickly as possible with heat stroke, heart disease (arrhythmia), and cranial nerve dysfunction in mind.

References

- 1) Fire and Disaster Management Agency: Heat Stroke Information.
http://www.fdma.go.jp/neuter/topics/fieldList9_2.html Accessed May, 2013. (in Japanese)
- 2) Ministry of the Environment: Health Care Manual for Heatstroke (May 2011 Revised Edition). http://www.env.go.jp/chemi/heat_stroke/manual.html Accessed May, 2013. (in Japanese)
- 3) Ministry of Health, Labour and Welfare: Heat Stroke Prevention Manual for the Workplace.
<http://www.mhlw.go.jp/new-info/kobetu/roudou/gyousei/anzen/0906-1.html> Accessed May, 2013. (in Japanese)
- 4) JAPAN SPORT COUNCIL: School Safety Web
<http://jpnsport.go.jp/anzen/home/tabid/102/default.aspx> Accessed May, 2013. (in Japanese)

- 5) Inaba Y. (supervising editor): Heat Stroke Countermeasures Manual. X-Knowledge, Tokyo, 2011. (in Japanese)
- 6) American College of Sports Medicine: <http://www.acsm.org/> Accessed May, 2013.

Table 1. Conditions being susceptible to Heat stroke

- Persons with weak physical strength (new students or new recruits)
- Persons who are overweight
- Persons in poor physical condition
- Persons who cannot acclimatize to heat
- Persons who have a fever (cold, etc.)
- Persons who are injured
- Persons who personality-wise are very patient, serious, and/or withdrawn, etc.

Figure 1. Occurrence tendency for accidental death due to heat stroke under school supervision (1975–2009)

スポーツ種目別発生傾向	Occurrence Tendency by Type of Sport	ソフトボール	Softball
部活動の場合	In the Case of Club Activities	テニス	Tennis
学年・性別発生傾向	Occurrence Tendency by School Grade/Gender	相撲	Sumo
野球	Baseball	その他	Other
ラグビー	Rugby	女	Female
サッカー	Soccer	男	Male
柔道	Judo	小3	Grade 3 e.s.*

剣道	Kendo	小 5	Grade 5 e.s.
山岳	Mountaineering	小 6	Grade 6 e.s.
陸上	Track and field	中 1	Grade 1 j.h.
ハンドボール	Handball	中 2	Grade 2 j.h.
バレーボール	Volleyball	中 3	Grade 3 j.h.
バスケットボール	Basketball	高 1	Grade 1 h.s.
卓球	Table Tennis	高 2	Grade 2 h.s.
アメフト	American Football	高 3	Grade 3 h.s.
レスリング	Wrestling	高専	t.c.

*List of abbreviations: e.s., elementary school; j.h., junior high school; h.s., high school; t.c., technical college

Table 2. Eight conditions for heat stroke prevention

1. Prevent heat stroke through knowledge
2. Unreasonable exercise in hot weather causes accidents
3. Be very careful of sudden rises in temperature
4. Consume lost fluids and sodium
5. Know health and sweat amounts by weight
6. Choose light clothing for coolness
7. Poor physical condition causes accidents
8. Don't panic, but provide emergency first aid swiftly

Figure 2. Measuring the environmental temperature on a school playground

A: August thermometer; B: Globe thermometer; C: Wet Bulb Globe Temperature (WBGT) Meter

Figure 3. Comparison of heat stroke prevention guidelines for exercise and daily life

Wet Bulb Globe Temperature (WBGT) heat index

Outdoors: $WBGT = 0.7 \times \text{wet bulb temperature} + 0.2 \times \text{globe temperature} + 0.1 \times \text{dry-bulb temperature}$

Indoors: $WBGT = 0.7 \times \text{wet-bulb temperature} + 0.3 \times \text{globe temperature}$

“Dry bulb temperature” is the temperature, while “wet bulb temperature” is the temperature affected by humidity and “globe temperature” reflects radiation heat.

“Temperature standard” is officially calculated using WBGT, but since this is difficult for laypeople, it is also possible to simply apply temperature (dry bulb temperature). When making decisions based on “temperature”, the ranking goes up one level stricter when humidity is high.

運動時のガイドライン	Guidelines for Exercising
スポーツしているときに起こる熱中症を予測	Predicting the occurrence of heat stroke while playing sport
生活時のガイドライン	Guidelines for Daily Life
ふだんの生活で起こる熱中症を予測	Predicting the occurrence of heat stroke in everyday life
熱中症予防のための運動指針 (日本体育協会)	Indicators for Exercise to Prevent Heat stroke (Japan Sports Association)
温度基準	Temperature standard
運動は原則禁止	Exercise is prohibited as a general rule
湿球度 (°C)	Wet bulb temperature
乾球度 (°C)	Dry bulb temperature
厳重警戒	Strong precautions necessary

警戒	Caution necessary
危険	Dangerous
注意	Attention necessary
ほぼ安全	Mostly safe
一般的な「気温」	General “temperatures”
日常生活における熱中症予防指針 ver.1 (日本生気象学会)	Indicators for Heat Stroke Prevention in Daily Life Ver. 1 (Japanese Society of Biometeorology)