Brief Report

Association between the experience of exertional heat illness (EHI) and living conditions of collegiate student athletes

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SUMMARY Exertional heatstroke (EHS), a severe form of exertional heat illness (EHI), is the third leading cause of death in athletes; thus, early detection and prevention of EHI can help prevent EHS, which is a life-threatening condition. This study aimed to clarify the association between the cognizance of experiencing EHI and living conditions and specific EHI symptoms among collegiate athletes. This study was conducted in October 2022 by administering a questionnaire to 237 male collegiate athletes. Of the 215 (90.7%) respondents, 197 (91.6%) provided valid responses; among them, 88 (44.7%) responded they had experienced EHI, while 109 (55.3%) had not. A history of medical examinations due to EHI, having experienced headaches during summer activities, and having read the EHI manual were factors indicating cognizance of EHI. The number of times meals containing a staple food, main dish, and side dish were eaten in a day was a factor in preventing EHI. Early detection of EHI is important for its prevention, and it is important that athletes themselves have knowledge of symptoms and can correctly self-diagnose EHI. Emphasizing the potential of a well-balanced dietary intake has the potential to prevent EHI is crucial.

Keywords EHI, EHS, male collegiate athletes, cognizance of EHI, self-diagnose EHI, prevention

1. Introduction

As global temperatures increase due to climate change, health hazards caused by heat are increasing. In particular, physical exercise in a hot and humid environment inhibits the heat dissipation system by sweating and increases the core body temperature (*1*). As a result of an increase in core body temperature, exertional heat illnesses (EHI) can occur in various ways, ranging from mild, non-life-threatening conditions, to life-threatening conditions, such as common and exertional heatstroke (*2*). Common heat stroke refers to a sudden increase in core body temperature to 40°C or higher, causing central nervous system dysfunction (*3*). Exertional heatstroke (EHS) is usually caused by strenuous physical activities performed in a hot and humid environment and is characterized by central nervous system dysfunction (such as collapse, convulsions, and coma), followed by organ and tissue damage, and even death in patients with hyperthermia (*4*). The incidence of EHI is estimated to be 1 in 1000

athletes, and it is the third leading cause of death among athletes during physical activities, with epidemiological data indicating a mortality rate of approximately 27% (*5*).

In a study of sports-related deaths in Japanese high schools between 2009-2018, the leading causes were heart-related (47.6%), followed by head and neck injuries (23.8%) and EHS (22.2%) (*6*). Moreover, from 1998-2018, the causes of nontraumatic fatalities among U.S. high school and college football players were psychogenic (57.7%) and EHS (23.6%) (*7*). Other studies found that since 2000, more than 40 American high school football players and 10 college football players have died due to EHI in the United States (*8*). As shown in previous literature, EHI is a leading cause of death during physical activity. Importantly, it is also preventable. Enforcing the correct preventive measures and administering appropriate treatment is a necessity to avoid EHS-related complications. Above all, detection during the stage of mild symptoms of EHI is crucial to prevent its progression to EHS.

Early detection of EHI and rapid cooling (body

cooling by immersion up to the neck in a tub of cold/ice water) were shown to reduce both morbidity and mortality associated with EHI (*8, 9*). Diagnostic signs for early detection of EHI include collapse, confusion, and convulsions; however, these signs and symptoms are likely to be missed if not carefully observed by instructors and staff (*9*). Therefore, athletes themselves should be able to promptly detect and report subjective symptoms.

Prevention is more important than any existing treatment for EHI (*5*); thus, it is necessary to know the risk factors of EHI to implement adequate preventive measures. The current risk factors for EHI include low physical fitness, being overweight, exercising during hot weather, sleep deprivation, improper inadequate acclimatization, high heat index in accordance with Wet Bulb Globe Temperature (WBGT), solar radiation, physical exertion beyond one's physical fitness capacity, inadequate physical activity/rest cycle, lack of proper medical triage, and inadequate treatment (*10*). On the other hand, little attention has been paid to dietary intake as a strategy to prevent EHI.

The relationship between individual nutrients such as moderate fluid intake with glucose and sodium (*11*), glutamine supplementation (*12*), and protein intake after exercise (*13*) has been reported on the possibility of preventing or reducing the severity of EHI through nutrition and dietary strategies. However, little has been reported on the relationship between EHI prevention and daily dietary intake.

In this study, we attempted to clarify the relationship between the cognizance of experiencing EHI among college students involved in athletic clubs and their living conditions, including daily eating habits and specific EHI symptoms. We focused on EHI rather than EHS because EHI is recognized as a more common and comprehensive heat-related symptom. In addition, we believe that early detection and response to EHI are important to prevent EHS, which is a serious condition of EHI. We hypothesized that the occurrence of EHI during athletic club activities is associated with various living conditions and daily eating habits. We also aimed to identify factors influencing athletes' cognizance and new risk factors for EHI. We believe that by investigating their living conditions, we can clarify the factors that cause EHI and establish new preventive measures.

2. Materials and Methods

2.1. Study design and data collection

In October 2022, a cross-sectional study was conducted to identify the occurrence of EHI during club activities in the summer and its associated factors by administering a questionnaire to 237 male students involved in athletic clubs at University A. Of the 215 (90.7%) respondents, 197 (91.6%) provided valid responses. Only male students were included in this study, as few female students were involved in athletic club activities at the university.

A statistical power analysis was conducted using IBM SPSS version 28 (Statistical Package for Social Science, Chicago, IL, USA) to ascertain the sample size required for this study. A sample size of 180 was required for 27 explanatory variables with a power of 0.8 and a significance level of 0.05; the sample size for this study met this requirement. Additionally, this study was approved by the Ethics Review Committee of Chubu University (Approval No.: 20220055).

2.2. Survey items

Data collection was performed using a web-based questionnaire designed with an anonymous Google form. A total of 238 items were surveyed in the questionnaire. Paper-based recruitment forms were distributed to members of university athletic clubs to recruit eligible participants. Students who agreed to participate accessed the web survey by scanning the QR code of the Google form URL using their mobile phones. Information on basic attributes, such as gender, faculty affiliation, and club activities, was collected. Questions were also asked regarding the students' previous EHI experiences, lifestyle habits (such as food intake and sleep), and subjective symptoms of EHI experienced during summer club activities. For questions regarding subjective EHI symptoms, the 13 subjective symptoms were defined based on the classification recommended by the Committee on Heat Stroke and Hypothermia of the Japanese Association for Acute Medicine and previous studies (*14*).

To prevent subjects from associating these subjective symptoms with EHI, they were simply asked if they experienced these symptoms during club activities in the summer. This was done to enable clarification of the association between the subject's cognizance of "having EHI" and specific, subjective symptoms.

Daily physical activity was assessed using the International Physical Activity Questionnaire-Short Version (IPAQ-SV), which comprises seven questions regarding how many hours per day and days per week subjects spent walking or engaging in moderate- or high-intensity physical activity during an average week. Activity was categorized into three levels, "high," "moderate," and "low", depending on the intensity, duration, and number of days of physical activity per week (*15*).

2.3. Statistical analysis

The collected data was organized using simple tabulation. To test our hypothesis, Pearson's Chi-squared test was used to analyze the association between the occurrence of EHI as cognized by the subjects and their lifestyle

habits, food intake statuses, and symptoms attributed to EHI experienced during club activities in summer (Tables 2 and 3). Binomial logistic regression analysis (stepwise variable selection method) was performed using the items that were found to be significant, and factors contributing to the occurrence of EHI were extracted.

The dependent variable was the presence or absence of EHI experience, and the explanatory variables were lifestyle habits, physical activity habits, physical symptoms during club activities in the summer, and nutrient and food intake. A dummy variable with settings of "3 times" = 0 or "less than 2 times" = 1 was used as the explanatory variable for questionnaire item E in Table 2; for K and L in Table 2 and items in Table 3, dummy variables with settings of "Yes" = 0 or "No" = 1 were used. Odds ratios and 95% confidence intervals (95% CI) were calculated for each explanatory variable. In addition, the Kruskal Wallis test was utilized to confirm the difference in the amount of exercise (IPAQ) depending on each club activities. The significance level was set at $P < 0.05$ for all items. The statistical analysis software IBM SPSS version 28 was used for this analysis.

3. Results and Discussion

Participant characteristics are shown in Table 1. All 197 subjects were male, with a mean age of 19.8 years (SD: ± 1.1). 64 participants (32.5%) were in their first year of university, 56 (28.4%) in their second year, 57 (28.9%) in their third year, and 20 (10.2%) in their fourth year; 55 participants (27.9%) played soccer, 31 (15.7%) played handball, 100 (50.8%) played baseball, and 11 (5.6%) played rugby. Eighty-Eight participants (44.7%) responded that they had previously experienced EHI, and 109 (55.3%) responded that they had never experienced EHI. As shown in Table 2, year and club affiliation were not associated with cognizance of experiencing EHI.

Table 2 shows the association between the cognizance of experiencing EHI and attributes, living

conditions (such as sleep, physical activities, and diet), and EHI-related questions. Athletes who reported having meals containing a staple food, main dish, and side dish three times a day were less likely to have experienced EHI than those who had similar meals two or fewer times a day. Most of the athletes who responded as having a history of medical examinations due to EHI also indicated that they had previously experienced EHI. Additionally, athletes who indicated that they had read the EHI Prevention Manual were more likely to report that they had previously experienced EHI than those who indicated that they had not read the manual. Other living conditions, including IPAQ, were not related to EHI experiences (Table 2). Also, there was no difference in the amount of physical activity (IPAQ) by club activity (Data not shown).

Table 3 shows the association between the cognizance of experiencing EHI and subjective symptoms during summer activities. Athletes who reported experiencing "headache," "dizziness," "weakness or fatigue," "abnormally fast breathing," and "fast or weak pulse" during summer activities were more likely to report having had EHI than those who did not experience any of these symptoms. Additionally, 159 athletes (80.7%) reported experiencing some EHI-related symptoms during summer activities, while 38 (19.3%) did not.

Table 4 presents the results of a binomial logistic regression analysis of the factors contributing to the cognizance of experiencing EHI. A history of medical examination due to EHI (odds ratio [OR], 18.607; 95% confidence interval [CI], 4.040-85.693; $P < 0.001$), experiencing headaches during club activities in summer (OR, 3.061; CI, 1.597-5.867; $P < 0.001$), and reading the EHI manual (OR, 0.430; CI, 0.190-0.972; $P = 0.043$) were factors for the cognizance of EHI. Conversely, the number of times meals containing a staple food, main dish, and side were dishes eaten in a day (OR, 2.217; CI, 1.066-4.611; $P = 0.033$) was a factor in the prevention of EHI.

In this cross-sectional study, students in college athletic clubs were surveyed to determine their experience with EHI and its predictors. Medical examination for EHI, headaches during summer club activities, knowledge of EHI and daily eating habits were considered likely to affect cognizance of EHI.

Regarding the experience of EHI among college student athletes, nearly half of the athletes responded that they had previously experienced EHI. However, this question was asked such that the response was based on the athletes' own judgment of whether they had experienced EHI, which may differ from the actual occurrence of EHI. Although all 13 symptoms suspected to be associated with EHI should correspond with whether the athlete was cognizant of EHI or not, only five symptoms of EHI ("headache," "dizziness," "weakness and fatigue," "abnormal fast breathing," and "weak or rapid pulse") corresponded. This likely

Table 1. Basic attributes

Items	*n*	*%*
Total	197	100.0
Age: 19.8 (SD1.12)		
Year in college		
First	64	32.5
Second	56	28.4
Third	57	28.9
Fourth	20	10.2
Club activities		
Soccer	55	27.9
Hand-ball	31	15.7
Baseball	100	50.8
Rugby	11	5.6
Experience of EHI		
No	109	55.3
Yes	88	44.7

Table 2. Association between cognizance of experiencing EHI and basic attributes, living conditions, *etc.*

Items	Experience of EHI		Total	P-Value
	No *n* (%) 109 (55.3)	Yes *n* (%) 88 (44.7)	*n* (%) 197 (100.0)	
Basic attributes				
Year in college				0.287
First	37 (57.8)	27 (42.2)	64 (32.5)	
Second	25 (44.6)	31 (55.4)	56 (28.4)	
Third	35 (61.4)	22 (38.6)	57 (28.9)	
Fourth	12 (60.0)	8 (40.0)	20 (10.2)	
Club activities				0.324
Soccer	36 (65.5)	19 (34.5)	55 (27.9)	
Hand-ball	17 (54.8)	14 (45.2)	31 (15.7)	
Baseball	51 (51.0)	49 (49.0)	100 (50.8)	
Rugby	5 (45.5)	6 (54.5)	11 (5.6)	
Lifestyle, etc.				
A. Average amount of sleep				0.798
More than 7 hours	29 (56.9)	22 (43.1)	51 (25.9)	
Less than 7 hours	80 (54.8)	66 (45.2)	146 (74.1)	
B. Training Environment				0.650
Outdoor	93 (56.0)	73 (44.0)	166 (84.3)	
Indoor	16 (51.6)	15 (48.4)	31 (15.7)	
C. IPAQ				0.706
Low	10 (62.5)	6 (37.5)	16 (8.1)	
Moderate	11 (61.1)	7 (38.9)	18 (9.1)	
High	88 (54.0)	75 (46.0)	163 (82.7)	
D. Frequency of breakfast intake				0.565
Every day	70 (56.9)	53 (43.1)	123 (62.4)	
Sometimes skipped	39 (52.7)	35 (47.3)	74 (37.6)	
E. Number of times meals containing a staple food, main dish, and side dish were eaten per day				0.049*
Three times	36 (66.7)	18 (33.3)	54 (27.4)	
Less than 2 times	73 (51.0)	70 (49.0)	143 (72.6)	
F. Daily food intake [breakfast]				0.773
Skip	5 (62.5)	3 (37.5)	8 (4.1)	
Small serving	35 (50.7)	34 (49.3)	69 (35.0)	
Just right serving	55 (56.7)	42 (43.3)	97 (49.2)	
Large serving	14 (60.9)	9 (39.1)	23 (11.7)	
G. Daily food intake [lunch]				0.347
Skip	0 (0.0)	1 (100.0)	1 (0.5)	
Small serving	8 (47.1)	9 (52.9)	17 (8.6)	
Just right serving	71 (59.7)	48 (40.3)	119 (60.4)	
Large serving	30 (50.0)	30 (50.0)	60 (30.5)	
H. Daily food intake [dinner]				0.845
Skip	1 (50.0)	1 (50.0)	2 (1.0)	
Small serving	2 (40.0)	3 (60.0)	5 (2.5)	
Just right serving	40 (53.3)	35 (46.7)	75 (38.1)	
Large serving	66 (57.4)	49 (42.6)	115 (58.4)	
I. Frequency of intake [sports drinks]				0.633
Often	9 (50.0)	9 (50.0)	18 (9.1)	
Never	100 (55.9)	79 (44.1)	179 (90.9)	
J. Frequency of intake [energy drinks]				0.571
Often	4 (66.7)	2 (33.3)	6 (3.0)	
Never	105 (55.0)	86 (45.0)	191 (97.0)	
EHI Related				
K. History of medical examination for EHI				< 0.01**
No	107 (61.5)	67 (38.5)	174 (88.3)	
Yes	2 (8.7)	21 (91.3)	23 (11.7)	
L. Read the EHI countermeasures manual				0.029*
No	94 (59.1)	65 (40.9)	159 (80.7)	
Yes	15 (39.5)	23 (60.5)	38 (19.3)	

indicates that the subjects did not correctly understand the symptoms of EHI.

Of these subjects, those who reported having headaches during summer activities were three times more likely to have experienced EHI than those who did not. While headache is a moderate symptom of EHI, it is important to be able to recognize even minor symptoms, such as "dizziness" and "muscle cramps," as EHI-related

(*16*). As these symptoms suspected to be EHI-related can also be caused by non-EHI factors, it is likely that they are less related to whether the student athlete has experienced EHI. However, any suspicious symptoms should be regarded as a sign of EHI, especially if they occur during physical activities in the summer, and it is necessary to update student athletes' cognizance of EHI so they can better judge the aforementioned symptoms. A

Table 3. Association between cognizance of experiencing EHI and symptoms during club activities in summer

Symptoms Response	Experience of EHI		Total	*P*-Value
	No	Yes		
	n (%)	*n* (%)	*n* (%)	
	109 (55.3)	88 (44.7)	197 (100.0)	
Headache				0.001**
No	61 (67.8)	29 (32.2)	90 (45.7)	
Yes	48 (44.9)	59 (55.1)	107 (54.3)	
Dry mouth				0.437
No	28 (50.9)	27 (49.1)	55 (27.9)	
Yes	81 (57.0)	61 (43.0)	142 (72.1)	
Dizziness				0.038*
No	62 (62.6)	37 (37.4)	99 (50.3)	
Yes	47 (48.0)	51 (52.0)	98 (49.7)	
Weakness and fatigue				0.048*
No	60 (62.5)	36 (37.5)	96 (48.7)	
Yes	49 (48.5)	52 (51.5)	101 (51.3)	
Difficulty concentrating or thinking clearly				0.227
No	54 (60.0)	36 (40.0)	90 (45.7)	
Yes	55 (51.4)	52 (48.6)	107 (54.3)	
Nausea				0.058
No	75 (60.5)	49 (39.5)	124 (62.9)	
Yes	34 (46.6)	39 (53.4)	73 (37.1)	
Muscle cramp				0.250
No	61 (59.2)	42 (40.8)	103 (52.3)	
Yes	48 (51.1)	46 (48.9)	94 (47.7)	
Abnormally fast breathing				0.042*
No	76 (60.8)	49 (39.2)	125 (63.5)	
Yes	33 (45.8)	39 (54.2)	72 (36.5)	
Weak or rapid pulse				0.031*
No	78 (60.9)	50 (39.1)	128 (65.0)	
Yes	31 (44.9)	38 (55.1)	69 (35.0)	
Numbness of the lips				0.333
No	88 (57.1)	66 (42.9)	154 (78.2)	
Yes	21 (48.8)	22 (51.2)	43 (21.8)	
Strange behavior				0.552
No	88 (56.4)	68 (43.6)	156 (79.2)	
Yes	21 (51.2)	20 (48.8)	41 (20.8)	
Fainting				0.609
No	91 (56.2)	71 (43.8)	162 (82.2)	
Yes	18 (51.4)	17 (48.6)	35 (17.8)	
Hallucinating				0.921
No	91 (55.5)	73 (44.5)	164 (83.2)	
Yes	18 (54.5)	15 (45.5)	33 (16.8)	
Exhibiting any symptom				0.473
No	23 (60.5)	15 (39.5)	38 (19.3)	
Yes	86 (54.1)	73 (45.9)	159 (80.7)	

**P < 0.01; *P < 0.05.

Table 4. Odds ratios for cognizance of experiencing EHI with respect to lifestyle habits, subjective symptoms, *etc.*

Items	Odds ratio	Confidence Interval		*P*-Value
		Lower Limit	Upper Limit	
• History of medical examination for EHI [a]	18.607	4.040	85.693	< 0.001**
• Number of times meals containing a staple food, main dish, and side dish were eaten per day[b]	2.217	1.066	4.611	0.033*
• Read the EHI manual[c]	0.430	0.190	0.972	0.043*
• Experienced headaches during club activities in summer[a]	3.061	1.597	5.867	< 0.001**

**P < 0.01; *P < 0.05; [a]No = 0, Yes = 1; [b]3 times = 0, Less than 2 times = 1; [c]Yes = 0, No = 1.

relationship emerged between participants who indicated having read the EHI manual and those who indicated they had experienced EHI in the past, which suggests that these students already had a sound knowledge of EHI, which in turn enabled them to recognize their own symptoms.

It is not surprising that most athletes who reported a history of medical examination due to EHI cognized their experience of EHI; however, it can also be interpreted that they did not cognize EHI until they were examined and diagnosed with EHI at a hospital. While early detection and prompt response (rehydration, cold water immersion) are the best ways to prevent serious illness and death due to EHI (*9,17*), it is also likely that the patients were already seriously ill by the time they were transported to the hospital. A history of EHI has also been noted as a risk factor for EHI, and it is vital to detect and respond to early EHI symptoms before they become more serious (*18*). Moreover, clinical changes in EHI are subtle, and early detection by athletic instructors and others, such as team staff, teammates, and bystanders, is difficult as signs may be overlooked (*9*). Therefore, it is of utmost importance that athletes themselves become highly cognizant and able to self-diagnose and self-report EHI at an early stage; to achieve this, athletes need to be taught how to correctly recognize the various symptoms indicative of EHI.

This study clarified that daily eating habits is important for preventing EHI. The number of times meals containing a staple food, main dish, and side dish were eaten in a day was associated with whether the athlete experienced EHI or not. Athletes who reported having meals containing a staple food, main dish, and side dish less than twice a day had more than twice the risk of experiencing EHI compared with those who reported having these meals three times a day. This highlights the importance of a balanced intake of all three meals in preventing EHI. A systematic review of previous studies reported that the more frequent the number of meals consisting of a staple food, main dish, and side dish, the higher the intake of energy, protein, and various vitamins and minerals, which is consistent with the Dietary Reference Intakes for Japanese individuals (*19,20*). The results of this survey suggest that the athletes who answered that they consumed a meal consisting of a staple food, main dish, and side dish "three times" a day were likely to have had a well-balanced daily diet.

In general, the amount of physical activity is thought to vary depending on the sports activities, and the incidence of sports-related deaths, including EHI, has also been reported to vary by activity (*6,21*). Therefore, the experiences of EHI were examined by club activities in four categories, but no relationship was found.

Early detection is key to preventing EHI; this requires the individual to be cognizant of EHI and promptly informing those around them for swift response.

Therefore, having knowledge of the EHI symptoms and the ability to self-diagnose are vital. Additionally, guidance on a well-balanced dietary intake by having three balanced meals (each containing a staple food, main dish, and side dish) per day should be emphasized, especially considering the likelihood of preventing EHI. Both athletic training instructors/leaders and athletes should be educated about these factors from an early stage. In addition to the existing EHI countermeasure manuals, posters and pamphlets should be prepared and distributed, and workshops should be held to inform people about the symptoms of EHI, enable them to correctly detect and report EHI at an early stage, and promote the recommendation of a well-balanced dietary intake.

A limitation of this study is that no gender comparisons were made, as the data was only gathered from male athletes. Only male athletes were surveyed in this study, as the university where the study was conducted had very few female students who were involved in athletic club activities. Additionally, the sample size of this study is limited, and further research is needed to generalize the results. Moreover, the results may not be representative of the general public, as climates, lifestyles, and social conditions vary depending on the country and region.

In conclusion, a well-balanced intake of all three meals may reduce the incidence of EHI. It was also noted that athletes need to accurately understand the symptoms of EHI. Detecting and preventing EHI at an early stage necessitates urgent education for athletes on well-balanced food intake and accurately identifying EHI symptoms through workshops, as well as the creation and distribution of materials relevant to these topics.

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