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Incidence and factor analysis for the heat-related illness on the Tokyo 2020 Olympic and Paralympic Games

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ABSTRACT

Introduction Among the 43 venues of Tokyo 2020 Olympic Games (OG) and 33 venues of Paralympic Games (PG) were held, the heat island effect was highly expected to cause heat-related illnesses in the outdoor venues with maximum temperatures exceeding 35°C. However, the actual number of heat-related illness cases during the competition was lower than that was initially expected, and it was unclear under what conditions or environment-related heat illnesses occurred among athletes.

Object To clarify the cause and factors contributing to the occurrence of heat-related illness among athletes participating in the Tokyo 2020 Olympic and Paralympic Games.

Method This retrospective descriptive study included 15 820 athletes from 206 countries. From 21 July 2021 to 8 August 2021 for the Olympics, and from 24 August 2021 to 5 September 2021 for the Paralympics. The number of heat-related illness cases at each venue, the incidence rate for each event, gender, home continent, as well as the type of competition, environmental factors (such as venue, time, location and wet-bulb globe temperature (WBGT)), treatment factor and the type of competition were analysed.

Results More number of heat-related illnesses among athletes occurred at the OG (n=110, 76.3%) than at the PG (n=36, 23.7%). A total of 100 cases (100%) at the OG and 31 cases (86.1%) at the PG occurred at the outdoors venues. In the OG, a total of 50 cases (57.9%) occurred during the competition of marathon running and race walking at Sapporo Odori Park. Six of those, were diagnosed with exertional heat illness and treated with cold water immersion (CWI) at OG and one case at PG. Another 20 cases occurred in athletics (track and field) competitions at Tokyo National Olympic Stadium. In total, 10 cases (10.0%) were diagnosed with severe heat illness in the OG and 3 cases (8.3%) in the PG. Ten cases were transferred to outside medical facilities for further treatment, but no case has been hospitalised due to severe condition. In the factor analysis, venue zone, outdoor game, high WBGT (<28°C) and endurance sports have been found to have a higher risk of moderate and severe heat-related illness ($p<0.05$). The incidence rate and severity could be attenuated by proper heat-related illness treatment (CWI, ice towel, cold IV transfusion and oral hydration) reduced the severity of the illness, providing summer hot environment sports.

Conclusion The Tokyo 2020 Olympic and Paralympic summer games were held. Contrary to expectations, we calculated that about 1 in 100 Olympic athletes suffered heat-related illness. We believe this was due to the risk reduction of heat-related illness, such as adequate prevention and proper treatment. Our experience in avoiding heat-related illness will provide valuable data for future Olympic summer Games.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ During the Olympic and Paralympic Summer Games, infectious diseases, especially enteritis virus outbreaks and heat-related illness outbreaks, have been a problem among participating athletes.

WHAT THIS STUDY ADDS

⇒ In the Olympic Games, 72 cases occurred in the high athletic endurance sports (athletics (marathon/race walk), cycling and marathon, swimming, tennis, rowing, triathlon, beach volleyball, hockey, etc), with a significantly higher frequency of moderate and severe degree heat-related illness compared with non-endurance sports. These data will be effectively used to improve sports medical support and heat-related illness prevention for international sports events held in hot environments.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ During the Tokyo 2020 Olympic and Paralympic Summer Games, the incidence of the medical emergency illness itself was reduced due to thorough infection control measures as a result of the COVID-19 outbreak. Exertional heat-related illness can also be avoided in high-risk sports and environments with adequate prevention and initial treatment.

⇒ These data can be used to improve medical care and heat-related illness prevention for international sporting events held in hot environments in the future.

INTRODUCTION

The Tokyo 2020 Olympic and Paralympic Games (Tokyo 2020 Games) opened on 23 July 2021 with 11 420 athletes from 206 countries and regions, approximately 33 000 officials and refugee athletic organisations, after a 1-year postponement due to the COVID-19 global epidemic. The Paralympic Games were attended by 4403 athletes from 162 countries and regions, and approximately 10 000 officials. This was the largest number of athletes in Paralympic history.[1]

Heat-related illnesses have often been a problem at the Summer Olympic and Paralympic Games in the past,[2] starting with Dorando Pietri, who suffered a heat-related illness during the marathon at the 1908 London Games, and 372 athletes and staff members were reported to have suffered heat-related illnesses at the 1992 Atlanta Games. Since 2000, owing to global warming, heat-related illnesses have been cited as a problem for summer games in Athens,[3] Beijing 2008[4] and Rio 2016.[5] Presumably, heat-related illnesses will be a major game risk again in Paris 2024. The occurrence of exercise-induced hyperthermia, especially in endurance sports, such as marathon running and competitive walking, is a challenge for the Summer Olympic Games.

In Tokyo, the main venue for the Tokyo 2020 Games, the heat island phenomenon has progressed and the average temperature has increased by 2.9°C over the past 100 years. In fact, in Odaiba, the number of days with a wet-bulb globe temperature (WBGT) of 30°C or higher has been on the rise for 4 years before the Tokyo 2020 Games, and in 2019, temperatures exceeded 35°C in late July, which was recognised as a serious risk to be avoided for the Tokyo 2020 Games.[6]

Of the 43 venues where the Tokyo 2020 Games were held, 5 of the 10 Heritage Zone venues were outdoors, including the Olympic Stadium, and 10 of the 17 Bay Zone venues were outdoors. Medical shortages at local medical facilities due to the infectious disease outbreak caused by COVID-19 since late July, Olympic medical volunteers and a peak in emergency medical evacuations due to heat-related illnesses, all combined to put a red light on the medical system for the Tokyo 2020 Olympic and Paralympic Games.[7]

However, the final report[1] of the Tokyo 2020 Olympic and Paralympic Games stated that the number of visits to clinics at each venue for heat-related illness was much lower than initially expected, at 100 for Olympic athletes and 36 for Paralympic athletes.[1] However, this report only reports the number of cases and does not provide a detailed analysis of what events caused severe heat-related illnesses, and preventive measures taken, whether there were differences in background factors such as continental origin or whether there were differences in heat-related illness frequency by ambient temperature or venue. The purpose is to clarify the causes and factors of heat-related illness among athletes participating in the Tokyo 2020 Olympic and Paralympic Games.

METHOD

Research design

This is a retrospective descriptive study in which items related to heat-related illness are extracted from multiple records collected by the Tokyo 2020 Organising Committee for the Olympic and Paralympic Games (hereafter referred to as the 'Organising Committee') and analysed for occurrence and environmental factors.

SURVEY PERIOD

The survey covered 19 days from 21 July 2021 to 8 August 2021 during the Olympic Games and 13 days from 24 August 2021 to 5 September 2021 during the Paralympic Games. This was 2 days before the Olympic Games opening ceremony for both sports.

Number of participants

Of the 11 420 Olympic athletes and 4403 Paralympic athletes participating in the Tokyo 2020 Games, 136 cases of heat-related illnesses diagnosed by doctors who visited the Games site clinics were included in the analysis (cases occurring at press venues, athletes' villages, etc, were excluded)

Data acquisition methods and ethical considerations

In this study, data collected and managed by the Medical Services Department of the Organising Committee were used, and the data were obtained after removing personal information that could identify individuals. The research results analysed in this study will contribute to the construction of a medical system for future international sporting events, and the data will be anonymised such that individuals, countries and facilities cannot be identified when the data are released.

Data collection

Data provided by the Medical Services Department, Athletic Administration Bureau of the Organising Committee, included (1) Medical Operations Manager (MOM) daily reports (number of cases handled by MOMs assigned to each venue), (2) J-SPEED (extreme situation survey) data (non-athlete response reports) and (3) Electronic Medical Records (EMR) data (athlete medical records). Other records included in the analysis were (4) hospital visit data at the destination hospital, (5) main operation centre—functional coordination centre data (medical coordination division coordination data) and (6) destination hospital insurance medical records of the Medical Services Department, and the Athletic Administration Bureau of the Organising Committee. A multifaceted verification of the diagnosis and treatment of injuries and illnesses was conducted.

In the extraction process, data were collated, and records with missing data, blanks, duplicate cases or incomplete records were excluded from the study. WBGT for each venue was measured outside the room, as published by the Ministry of the Environment on its official website.[8 9]

Examination items

The following items were examined: (1) date, (2) venue, (3) event name, (4) time of occurrence, (5) continent of origin, (6) gender, (7) years by decade, (8) chief problem, (9) physician diagnosis, (10) severity classification, (11) vital signs at the initial visit, (12) treatment, (13) transportation methods (ambulance, other), (14) admissions to the medical facility, (15) transport to medical facilities, (16) whether transported to a medical facility, (17) hospitalisation and treatment at medical facilities, (18) outcome and (19) WBGT at the venue.

Statistical analysis

Based on the number of athletes participating in each event and the number of heat-related illness cases, the heat-related illness incidence rate and the incidence rate per 1000 athletes were calculated. ORs (95% CI) for heat-related illness incidence per 1000 athletes were used for marathons and walking during the Olympic Games and for track and field during the Paralympic Games.

For patient background characteristics, continuous variables represent the median (IQR) and categorical variables represent the number of cases (%). Fisher's exact establishment test was used for gender, age, venue, outdoor/indoor, time category of occurrence, WBGT value of the venue at the time of occurrence and competition category, and a p value less than 0.05 was considered significant. JMP V.13.2.1 (SAS Institute, Cary, North Carolina, USA) was used for all the statistical analyses.

Competition venues and competition zones

The Olympic and Paralympic Games venues for Tokyo 2020 consisted of two zones: the 'Heritage Zone' in the upper inland area of Tokyo Bay, which carries on the legacy of the 1969 Games, and the 'Tokyo Bay Zone' on the Odaiba waterfront, which symbolises the city's future. Although the two zones spread around the athletes' villages are geographically close, there has long been a concern that the Tokyo Bay Zone in Odaiba has a higher ambient temperature due to weather conditions. With 17 competition venues and 10 outdoor competitions in the Bay Zone, it was considered a high-risk area for heat-related illnesses.

Medical system for Tokyo 2020 Olympic Games

The goal of the Tokyo 2020 Olympic Games was to provide equal access to emergency medical care for all participants without burdening the local emergency medical system.

The medical system was established in accordance with the 'Manual of Sports Emergency Medicine',[10] 'Olympic Games Model Formulary' and 'Olympic Games Pharmacy Guide'[11] recommended by the International Olympic Committee. In addition, a system of close collaboration with the Tokyo Metropolitan Government's Olympic and Paralympic Preparation Bureau was established, and a medical system was developed in accordance with the 'Guidelines for Medical and Rescue Planning for Large-Scale Events' prepared by the Tokyo Metropolitan Government and the recommendations of the 'Academic Coalition for the Study of Emergency and Disaster Medical Systems in the 2020 Tokyo Olympic and Paralympic Games (AC2020)', and the system was developed in accordance with the guidelines and medical treatment manuals proposed by AC2020.

First aid and medical treatment system at each venue

A total of 140 clinics (including polyclinics) were established at 53 locations at each of the Tokyo 2020 Olympic Games venues (competition and non-competition venues) and athletes' villages (main and branch villages). Each venue was assigned a Venue Medical Officer (VMO) and Deputy VMO (DVMO). Additionally, an Athlete Medical Supervisor (AMSV) was assigned to each competition venue.

The VMOs were in overall charge of medical care at each venue, while the AMSVs were sports doctors from domestic athletic organisations. Nurses, physical therapists and athletic trainers familiar with the sport were dispatched to the athletes' clinics. Emergency physicians were dispatched with the cooperation of the emergency medicine departments of nearby university hospitals in Tokyo, Kanagawa, Saitama and Chiba, along with nurses and paramedics, and a first-aid station was deployed for spectators. In the event of an accident in the field, a medical support team consisting of paramedics and volunteers was formed to transport patients. A system was in place to provide first aid to patients with heat-related illnesses, including cooling and rehydration, trauma packing and primary resuscitation. A total of 6542 people participated in the Tokyo Olympics and Paralympics, including doctors (n=2217), nurses (n=1836), pharmacists (n=57), paramedics (n=1187), physical therapists (n=664), other medical personnel and volunteers. However, due to restrictions imposed by COVID-19 on the secondment of volunteers from their respective medical institutions, the number of participants had to be reduced from the originally planned 740 per day to approximately 500.

Transportation system from convention venues to outside medical facilities

A backup system was established to provide advanced medical care at convention-affiliated hospitals in the event that transportation from conventional clinics to outside medical institutions is necessary. Eight general hospitals in Tokyo and 27 hospitals outside Tokyo were secured as cooperative convention hospitals. In the event of a serious accident or illness, if the treatment was complicated, the patient was transported to a hospital other than the designated hospital. We also contacted the Medical Coordination Headquarters within the Medical Services Department of the Tokyo Organising Committee for the Tokyo Olympics to coordinate transportation to other medical institutions.

In cases requiring treatment at primary or secondary emergency medical facilities, treatment methods were selected according to the patient's situation and symptoms, including those requiring hospitalisation, returning to the athletes' village after treatment, continuing treatment at a polyclinic and returning to a medical facility the next day or later.

In case of life-threatening trauma or illness, the VMO, AMSV and the Medical Coordination Headquarters decided to transport the patient to a tertiary emergency medical facility near the competition venue.

Diagnosis and definition of heat-related illness

The diagnosis of a heat-related illness was extracted according to the heat-related illness guidelines established by the Japanese Society of Emergency Medicine (hereafter referred to as 'heat-related illness guidelines'), which were described according to the diagnosis made by the venue clinic physician. Based on these guidelines, the patients were classified into three severity levels according to their symptoms and treatment.

'Mild' heat-related illnesses are cases with symptoms such as dizziness, profuse sweating, fainting and muscle pain that improve only with medical attention and cooling.

Moderate heat-related illnesses, include symptoms such as headache, nausea, vomiting, poor concentration, diarrhoea, fatigue, collapse, fainting, mood discomfort and impaired judgement, which required cooling and oral rehydration/infusion and continued treatment at a secondary care facility.

Cases of severe heat-related illness with symptoms such as high body temperature, impaired consciousness, cerebellar symptoms, convulsions, impaired limb movement and shock require emergency transport to a tertiary medical institution.

Also included in the definition of 'severe' heat-related illnesses are those with exercise-induced hyperthermia[12–15] who have a high body temperature of 39.5°C or higher during exercise and are deemed to require cold water immersion (CWI) treatment with an ice bath in a heat deck.

Definition of endurance sports

In this study, endurance sports are defined as sports that require endurance for extended periods of time rather than physical activity for short periods of time. There is no clear division of time or degree for defining endurance sports. For example, a 100-metre run is not an endurance sport, but a marathon is classified as one.

Heat-related illness prevention at the games

Since the Summer Olympics were held in hot and humid subtropical Asia, heat-related illnesses were recognised as a major risk for the games, and various heat-related illness prevention measures were implemented throughout the games. Based on WBGT measurement results and information from each venue, athletes were alerted via smartphones and other devices. Tokyo is also in the top typhoon season, and there were concerns about the impact of typhoons on the competition schedule, but this was addressed by changing the schedule of some events, such as the triathlon. In particular, during the competition period, the maximum daytime temperature in the vicinity of Odaiba, Tokyo, was approximately 35°C, and the elevated daytime WBGT value was 28°C or higher, which raised concerns regarding heat-related illnesses. The competition times were changed from midday to early evening for some events and to early morning for the marathon and walk races to allow for cooler temperatures. In addition, as a countermeasure against heat, each venue was equipped with sufficient oral rehydration solutions, athlete lounges, portable coolers and fans. In addition, heat decks were installed in the medical rooms for high-intensity sports events and ice baths were provided in the medical rooms of 32 venues. In addition, along with ice-cold ice towels, oral rehydration solutions and infusions were provided as an initial response to provide thorough heat-related illness prevention management for endurance athletes.[16]

RESULTS

Comparison of the number of heat-related illness cases at the Olympic and Paralympic Games and frequency of occurrence by date

The number of heat-related illness cases among athletes at the Olympic and Paralympic Games was 100 (76.3%) and 36 (23.7%), respectively, with more cases occurring at the Olympic Games. However, the incidence rate per 100 participating athletes was 0.88 (100/11 420) for the Olympic Games and 0.8 (36/4403) for the Paralympics. Rather, the number of heat-related illness cases was higher than expected given that the Paralympics were held at a time when WBGT was declining.

Figure 1 shows the number of heat-related illness cases based on maximum WBGT. The total number of athletes participating in the Olympics reached 10 000 each day. On 25 and 28 July 2021 and on 2 August 2021, when the maximum WBGT exceeded 32°C, more than five heat-related illness cases occurred each day in the track and field events (National Stadium), high-intensity tennis events (Ariake venue), rowing events (Water Forest Stadium) and triathlon events (Odaiba venue; figure 1).

Figure 2 shows the number of heat-related illness cases in the Paralympics by maximum WBGT by date and by athlete participants. From 24 August 2021 to 30 August 2021, when the maximum WBGT was high, 19 cases (53%) of heat-related illnesses were reported in track and field events at the National Stadium. In other endurance sports, three cases were reported in triathlon events (Odaiba venue) and two in rowing (Umi-no-Mori Water Stadium). In addition, although not endurance sports, there were four cases of heat-related illnesses among wheelchair users in outdoor shooting, which had a long contact surface with the trunk, one case of indoor table tennis and one case of indoor sitting volleyball (figure 2).

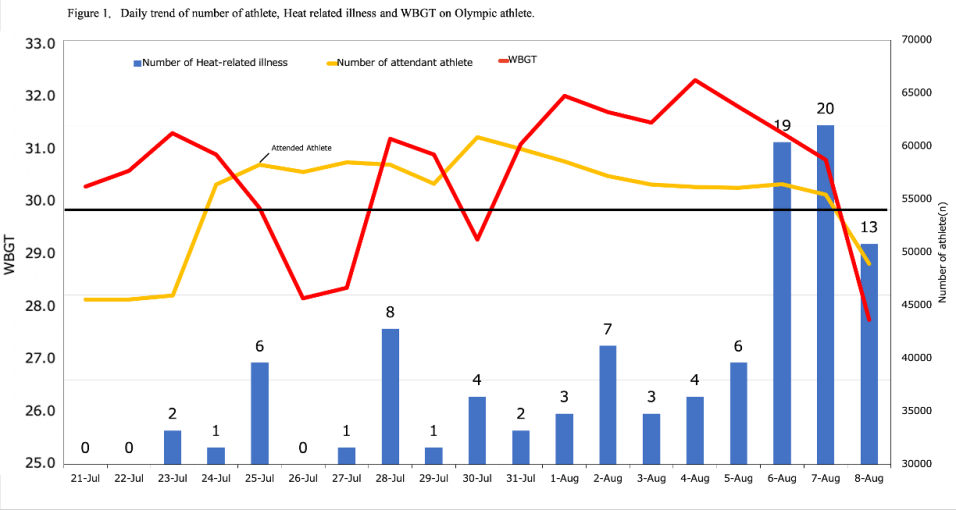

Figure 1 Daily trend of number of athletes, heat-related illness and WBGT on Olympic athletes. WBGT, wet-bulb globe temperature.

Comparison of heat-related illness rates by sport

The heat-related illness incidence rates for the Olympic Games calculated by the number of participants in each sport (table 1). In the Olympic Games, 4.48% (50 cases) occurred in the marathon/walking race (Sapporo Odori Park), where high exercise intensity continues for a long duration, and 0.13% (20 cases) in the short-distance track and field events at the Olympic Stadium, which together with track and field events accounted for 4.61%. Cycling and marathon swimming were next with 2.78% and 1.96% incidence rates, respectively. In the Paralympics, on the other hand, triathlon had the highest rate at 1.47%, while track and field and marathon athletics had a rate of 0.17% (table 1).

Comparing the frequency of heat-related illness per 1000 participants, track and field (marathon and walking) had the highest frequency of heat-related illnesses for each Olympic sport (179.3 participants, followed by cycling (55.6), marathon and competitive swimming (39.2), tennis (26.3), sport climbing (25.0) and archery (23.4) (table 1).

In Paralympic sports, triathlon was the most popular sport at 29.4%, followed by shooting at 26.0%, wheelchair tennis at 19.2%, rowing at 18.5%, athletics (track and field and marathon) at 16.6% and 5-a-side soccer at 12.8% (table 2).

Analysis of factors contributing to the occurrence of heat-related illness

The frequency of heat-related illness occurrence according to severity and its factors was analysed. The total number of patients with heat-related illnesses was classified into three levels of severity (Grade I, II and III) according to the diagnostic criteria of the Japanese

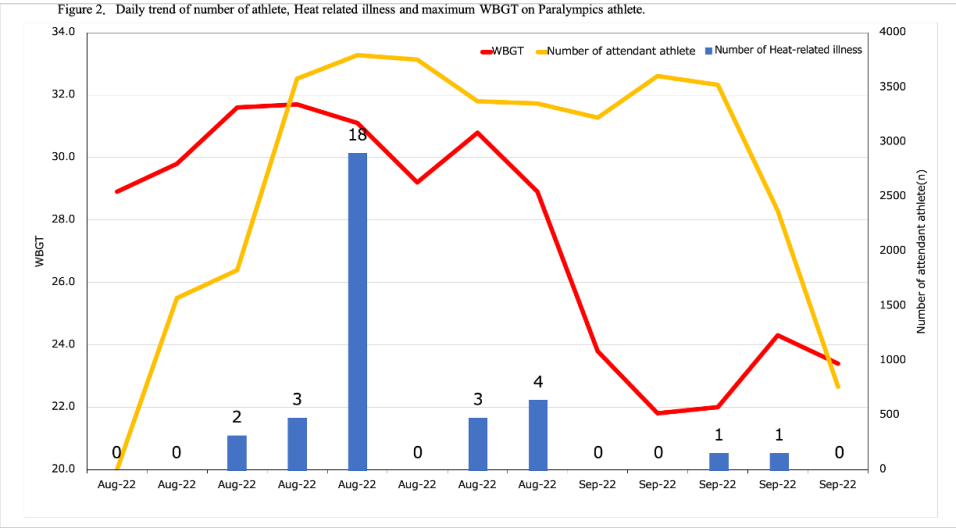

Figure 2 Daily trend of number of athletes, heat-related illness and maximum WBGT on Paralympic athletes. WBGT, wet-bulb globe temperature.

Table 1 Incidence rate of heat-related illness by sports on Olympic Games

Olympic	Number of heat stroke (n)	Number of persons in games	Incidence rate (%)	Incidence of 1000 athletes	OR (95% CI)
Athletics (marathon/race walk)	50	368	3.40	135.9	13.87 (9.46 to 20.33)
Cycling	1	18	2.78	55.6	
Marathon swimming	2	51	1.96	39.2	
Tennis	5	190	0.29	26.3	
Sport climbing	1	40	0.63	25.0	
Archery	3	128	0.26	23.4	
Rowing	10	528	0.32	18.9	
Triathlon	2	109	0.61	18.3	
Athletics (track and field)	20	1670	0.13	12.0	
Beach volleyball	1	96	0.07	10.4	
Equestrian	2	235	0.07	8.5	
Golf	1	120	0.10	8.3	
Canoe sprint	1	249	0.07	4.0	
Hockey	1	432	0.02	2.3	
Total	100	3866	38.66	25.9	

ORs are calculated for Olympics for Athletics (marathon/race walk) versus other sports.

Association of Emergency Medicine. Statistical analysis of the number of cases of moderate and severe heat-related illnesses (degree III) and the factors that caused them showed that the number of cases of degrees II and III were significantly higher. At the Olympics, 50 (50.0%) cases of mild degree I heat-related illnesses and 40 (40.0%) cases of moderate degree II heat-related illnesses accounted for 93% of all cases, whereas only 10 (10.0%) cases of severe degree III heat-related illnesses occurred. Only 4.0% of patients had severe symptoms and required a visit to an outside medical facility, as determined by the venue physician. Furthermore, none of the patients required hospitalisation (table 3).

Table 4 shows the results of the analysis of factors contributing to the occurrence of heat-related illnesses at the Olympic Games in terms of severity. Heat-related illness occurrence factors are classified into patient-side factors (gender, age, continent of origin), environment-side factors (competition venue zone, indoor/outdoor, time of occurrence, WBGT), discipline-side factors (endurance sports and non-endurance sports) and treatment-side factors (ice bath, ice towel, ambulance

Table 2 Incidence rate of heat-related illness by sports on Paralympic Games

Paralympics	Number of heat stroke (n)	Number of persons in games	Incidence rate (%)	Incidence of 1000 athletes	OR (95% CI)
Triathlon	3	102	1.47	29.4	
Shooting	4	154	0.32	26.0	
Wheelchair tennis	2	104	0.21	19.2	
Rowing	2	108	0.62	18.5	
Athletics (track and field/marathon)	19	1144	0.17	16.6	1.81 (0.94 to 3.49)
Football 5-a-side	1	78	0.26	12.8	
Cycling	2	233	0.21	8.6	
Sitting volleyball	1	187	0.05	5.3	
Table tennis	1	278	0.04	3.6	
Swimming	1	605	0.02	1.7	
Total	36	2993	81.14	12.0	

ORs are calculated for Paralympics for athletics (track and field/marathon) versus other sports.

Table 3 Patient background and risk factor of heat-related illness severity on Olympic athlete

Olympic		Total n=100 (%)		Minor degree n=50 (%)		Moderate degree n=40 (%)		Severe degree n=10 (%)		P value
Patient factor										
Gender*	Male	54	(54.0)	27	(27.0)	23	(23.0)	4	(4.0)	0.84
	Female	46	(46.0)	23	(23.0)	17	(17.0)	6	(6.0)	
Age†	20s	69	(69.0)	28	(28.0)	35	(35.0)	6	(6.0)	0.003
	30s	30	(30.0)	21	(21.0)	5	(5.0)	4	(4.0)	
	40s	1	(1.0)	1	(1.0)	0	(0.0)	0	(0.0)	
Home continents†	European	37	(37.0)	22	(22.0)	9	(9.0)	6	(6.0)	
	American	28	(28.0)	9	(9.0)	17	(17.0)	2	(2.0)	
	Asian	20	(20.0)	8	(8.0)	11	(11.0)	1	(1.0)	
	African	11	(11.0)	10	(10.0)	1	(1.0)	0	(0.0)	
	Oceanian	4	(4.0)	1	(1.0)	2	(2.0)	1	(1.0)	
Environment factor										
Venue zone†	Tokyo bay zone‡	27	(27.0)	4	(4.0)	18	(18.0)	5	(5.0)	<0.0001
	Heritage zone§	22	(22.0)	5	(5.0)	17	(17.0)	0	(0.0)	
	Sapporo Odori Park (marathon/race walk)	50	(50.0)	41	(41.0)	4	(4.0)	5	(5.0)	
	Other venue (Kasumigaseki Country Club)	1	(1.0)	0	(0.0)	1	(1.0)	0	(0.0)	
Location*	Outdoors venue	100	(100.0)	50	(50.0)	40	(40.0)	10	(10.0)	0.00
	Indoors venue	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	
Time†	Morning game (7:00 to 12:00)	58	(60.0)	33	(33.0)	16	(16.0)	9	(9.0)	0.29
	Afternoon game (12:00 to 18:00)	26	(23.0)	12	(12.0)	13	(13.0)	1	(1.0)	
	Evening game (18:00 to 22:00)	17	(17.0)	6	(6.0)	11	(11.0)	0	(0.0)	
WBGT (°C)*	21°C<WBGT<28°C	49	(49.0)	29	(29.0)	16	(16.0)	4	(4.0)	0.05
	28°C≤WBGT	51	(51.0)	21	(21.0)	24	(24.0)	6	(6.0)	
Sports factor										
Athletic classification*	Endurance sports	72	(72.0)	43	(43.0)	19	(19.0)	10	(10.0)	0.002
	Non-endurance sports	28	(28.0)	7	(7.0)	21	(21.0)	0	(0.0)	
Endurance sports	Athletics (marathon/race walk)	50	(50.0)	41	(41.0)	4	(4.0)	5	(5.0)	
	Rowing	10	(10.0)	0	(0.0)	7	(7.0)	3	(3.0)	
	Tennis	5	(5.0)	1	(1.0)	3	(3.0)	1	(1.0)	
	Marathon swimming	2	(2.0)	0	(0.0)	2	(2.0)	0	(0.0)	
	Cycling	1	(1.0)	1	(1.0)	0	(0.0)	0	(0.0)	

Continued

Table 3 Continued

Olympic		Total n=100 (%)		Minor degree n=50 (%)		Moderate degree n=40 (%)		Severe degree n=10 (%)		P value
	Triathlon	2	(2.0)	0	(0.0)	2	(2.0)	0	(0.0)	
	Beach volleyball	1	(1.0)	0	(0.0)	0	(0.0)	1	(1.0)	
	Hockey	1	(1.0)	0	(0.0)	1	(1.0)	0	(0.0)	
Non-endurance sports	Athletics (track and field)	20	(20.0)	4	(4.0)	16	(16.0)	0	(0.0)	
	Archery	3	(3.0)	2	(2.0)	1	(1.0)	0	(0.0)	
	Equestrian	2	(2.0)	1	(1.0)	1	(1.0)	0	(0.0)	
	Golf	1	(1.0)	0	(0.0)	1	(1.0)	0	(0.0)	
	Canoe sprint	1	(1.0)	0	(0.0)	1	(1.0)	0	(0.0)	
	Sport climbing	1	(1.0)	0	(0.0)	1	(1.0)	0	(0.0)	
Treatment factor										
	CWI	6	(6.0)	0	(0.0)	0	(0.0)	6	(6.0)	
	Intravenous injection	5	(5.0)	0	(0.0)	4	(4.0)	1	(1.0)	
	Ice towel	35	(35.0)	15	(15.0)	18	(18.0)	2	(2.0)	
	Ambulance transportation	4	(4.0)	1	(1.0)	1	(1.0)	2	(2.0)	
	Hospitalisation (<2 days)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	

Endurance sports: athletics (marathon/race walk), cycling and marathon, swimming, tennis, rowing, triathlon, beach volleyball and hockey; non-endurance sports: athletics (track and field), sport climbing, archery, equestrian, golf and canoe sprint.
*Between the group; in the I degree and II degree/III degree Fisher's exact probability test.
†Among the group; in the I degree and II degree/III degree Fisher's exact probability test.
‡Tokyo Bay Zone; Aomi Urban Sports Park, Oi Hockey Stadium, Shiokaze Park, Ariake Urban Sports Park, Yumenoshima Park Archery, Odaiba Marine Park, Ariake Tennis Park, Sea Forest Waterway.
§Heritage Zone, Olympic Stadium & Equestrian Park.
CWI, cold water immersion; WBGT °C, wet-bulb globe temperature occurred at heat-related illness.

Table 4 Patient background and risk factor of heat-related illness on Paralympics athlete

Paralympics		Total n=36 (%)		Minor degree n=15 (%)		Moderate degree n=21 (%)		Severe degree n=0 (%)		P value
Patient factor										
Gender*	Male	22	(61.1)	7	(19.4)	12	(33.3)	3	(8.3)	1,00
	Female	14	(38.9)	6	(16.7)	8	(22.2)	0	(0.0)	
Age†	10s	1	(2.8)	0	(0.0)	1	(2.8)	0	(0.0)	
	20s	15	(41.7)	6	(16.7)	7	(19.4)	2	(5.6)	
	30s	11	(30.6)	4	(11.1)	6	(16.7)	1	(2.8)	
	40s	7	(19.4)	3	(8.3)	4	(11.1)	0	(0.0)	
	50s	2	(5.6)	0	(0.0)	2	(5.6)	0	(0.0)	
Home continents†	Asian	6	(16.7)	3	(8.3)	3	(8.3)	0	(0.0)	
	African	6	(16.7)	2	(5.6)	3	(8.3)	1	(2.8)	
	American	8	(22.2)	2	(5.6)	5	(13.9)	1	(2.8)	
	Oceanian	6	(16.7)	2	(5.6)	4	(11.1)	0	(0.0)	
	European	10	(27.8)	4	(11.1)	5	(13.9)	1	(2.8)	
Environment factor										
Venue zone†	Tokyo bay zone‡	10	(27.8)	4	(11.1)	6	(16.7)	0	(0.0)	0.48
	Heritage zone§	20	(55.6)	7	(19.4)	13	(36.1)	0	(0.0)	
	Other venue	6	(16.7)	4	(11.1)	2	(5.6)	0	(0.0)	
Location*	Outdoors venue	31	(86.1)	14	(38.9)	17	(47.2)	0	(0.0)	0.38
	Indoors venue	5	(13.9)	1	(2.8)	4	(11.1)	0	(0.0)	
Occurrence time†	Morning game (7:00 to 12:00)	21	(58.3)	8	(22.2)	13	(36.1)	0	(0.0)	0.90
	Afternoon game (12:00 to 18:00)	11	(30.6)	5	(13.9)	6	(16.7)	0	(0.0)	
	Evening game (18:00 to 22:00)	4	(11.1)	2	(5.6)	2	(5.6)	0	(0.0)	
WBGT (°C)*	21°C〜28°C	16	(44.4)	15	(41.7)	1	(2.8)	0	(0.0)	0.0004
	28°C〜	20	(55.6)	5	(13.9)	12	(33.3)	3	(8.3)	
Sports factor										
Athletic classification*	Endurance sports	30	(83.3)	10	(27.8)	17	(47.2)	3	(8.3)	0.68
	Non-endurance sports	6	(16.7)	3	(8.3)	3	(8.3)	0	(0.0)	
Endurance sports	Athletics (track and field marathon)	19	(52.8)	6	(16.7)	12	(33.3)	1	(2.8)	
	Triathlon	3	(8.3)	0	(0.0)	1	(2.8)	2	(5.6)	
	Rowing	2	(5.6)	0	(0.0)	2	(5.6)	0	(0.0)	
	Cycling	2	(5.6)	2	(5.6)	0	(0.0)	0	(0.0)	

Continued

Table 4 Continued

Paralympics		Total n=36 (%)		Minor degree n=15 (%)		Moderate degree n=21 (%)		Severe degree n=0 (%)		P value
	Wheelchair tennis	2	(5.6)	2	(5.6)	0	(0.0)	0	(0.0)	
	Football 5-a-side	1	(2.8)	0	(0.0)	1	(2.8)	0	(0.0)	
	Swimming	1	(2.8)	0	(0.0)	1	(2.8)	0	(0.0)	
Non-endurance sports	Shooting	4	(11.1)	2	(5.6)	2	(5.6)	0	(0.0)	
	Sitting volleyball	1	(2.8)	1	(2.8)	0	(0.0)	0	(0.0)	
	Table tennis	1	(2.8)	0	(0.0)	1	(2.8)	0	(0.0)	
Treatment factor										
	CWI	3	(8.3)	0	(0.0)	0	(0.0)	3	(8.3)	
	Intravenous injection	1	(2.8)	0	(0.0)	4	(11.1)	1	(2.8)	
	Ice towel	35	(97.2)	15	(41.7)	18	(50.0)	2	(5.6)	
	Ambulance transportation	3	(8.3)	1	(2.8)	2	(5.6)	0	(0.0)	
	Hospitalisation (<2 days)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	

Endurance sports: athletics (Track and field marathon), cycling, wheelchair tennis, rowing, triathlon, football 5-a-side and swimming; non-endurance sports: table tennis, sitting volleyball and shooting.
*Between the group, in the I degree and II degree/III degree Fisher's exact probability test.
†Among the group, in the I degree and II degree/III degree Fisher's exact probability test.
‡Tokyo Bay Zone; Aomi Urban Sports Park, Tokyo Aquatics Centre, Makuhari Messe Hall A, Sea Forest Waterway, Ariake Tennis Park and Odaiba Marine.
§Heritage Zone, Olympic Stadium and Tokyo Metropolitan Gymnasium; Other, Fuji international Speedway and Asaka Shooting Range.
CWI, cold water immersion; WBGT °C, wet-bulb globe temperature occurred at heat-related illness.

transport, length of hospital stay), which are divided into each item below.

Relationship between factors on the athlete's side and heat-related illness severity

We compared the frequency of occurrence by sex, age and continent of origin (continental Europe, America, Asia, Africa and Oceania) as factors on the athlete side. First, there was no gender difference in the Olympic Games, with 55 (47.4%) men and 61 (52.6%) women. By age, there were significantly more participants in their 20s, which may reflect the age structure of the Olympic athletes (p<0.003).

By continent, 37% of the registrants were from Europe, 28% from the USA and 20% from Asia. However, due to the large number of participants from the same region, none of the factors were associated with the frequency of moderate or severe cases of degree II or higher.

Association between environmental factors and heat-related illness severity

All venues where heat-related illnesses occurred at the Olympic Games were outdoor venues, and in addition, all 10 third-degree severe cases were at outdoor competitions. Of these, five occurred at outdoor competition venues in the Tokyo Bay Zone and five occurred at the Sapporo endurance competition venue. In Olympic competitions, 60% of cases occurred in the morning, 23% in the afternoon and 17% in the evening; 49 cases occurred when WBGT was between 21°C and 28°C, and 51 cases occurred when WBGT was 28°C or higher, with no significant difference; and those with WBGT above 28°C had a significantly higher incidence of heat-related illness of moderate severity (p<0.05; table 3).

Association of heat-related illness severity with factors by competition

In Olympic sports, 72 cases of heat-related illnesses occurred in high-weight endurance sports, and the frequency of II-degree and III-degree heat-related illnesses was significantly higher than that of 28 cases in non-endurance sports (p=0.0002).

The incidence of heat-related illnesses in endurance sports was 20 (20%) in track and field, 50 (50.0%) in athletics (marathon, competitive walking), 10 (10.0%) in rowing, 5 (4.3%) in tennis and 3 (1.7%) in archery, equestrian, triathlon, marathon swimming, golf, field hockey, canoe sprint, beach volleyball, sport climbing, canoe sprint and beach volleyball. Beach volleyball, sport climbing and bicycling accounted for 1 (0.9%). The incidence of heat-related illness of degree II or higher was higher in endurance sports, as well as in track and field. During the Olympic Games, heat-related illnesses occurred only in outdoor sports, with a higher incidence in track and field events with high exercise intensity, followed by those in competition venues along the Tokyo Bay area (table 3).

Association between treatment factors and heat-related illness severity

In the Olympic Games, patients with mild heat-related illnesses were administered an oral rehydration solution and ice towels. In addition, CWI by immersion was administered to six patients (6.0%) in degree III (severe cases). Four patients (4.0%), including three after CWI by immersion, were transported by ambulance. However, not a single patient was admitted to an outside medical facility for outpatient care (table 3).

Factor analysis of heat-related illness outbreaks at the Paralympic Games

The lower part of table 4 shows the impact of severity on the occurrence of heat-related illness in the Paralympic Games. Similarly, 15 cases (41.7%) of degree I heat-related illnesses and 20 cases (55.5%) of degree II heat-related illnesses occurred in the Paralympic Games. There were three cases (8.3%) of degree III heat-related illness, and none of the CWI patients were transported to an outside medical facility (table 4).

Association between athlete factors and heat-related illness severity

Athlete factors were compared by continent of registration (Continental Europe, America, Asia, Africa and Oceania) for gender, age and frequency of occurrence. In the Paralympics, 22 (61.1%) patients were en and 14 (38.9%) were women, with no significant differences by gender. Regarding age factors, there was a tendency for Paralympic participants to vary in age from their 20s to 40s, which may reflect the age structure of Paralympic athletes.

Association between environmental factors and heat-related illness severity

Thirty-one (86.1%) of the Paralympic cases occurred outdoors and five (13.9%) occurred indoors (table 4). No association was found between the venue and the occurrence of heat-related illnesses of moderate or greater severity. No significant association was found between outdoor/indoors and illness severity. However, when the WBGT was 28°C or higher, the occurrence of heat-related illnesses of degree II (moderate or higher) was significantly higher (p=0.0004; table 4).

Association between factors and severity by sport

In the Paralympics (n=36), athletics (track and field, marathon) accounted for half of the cases (19 cases, 52.8%), followed by rowing (2 cases, 5.6%), triathlon (3 cases, 8.3%), cycling (2 cases, 5.6%), shooting (4 cases, 11.1%), wheelchair tennis (2 cases, 5.6%), swimming, competitive sitting volleyball, pentathlon soccer and table tennis were reported in 1 case (2.8%; table 4). However, there was no difference in whether the sport was endurance sport or not (p=0.68).

Association between treatment factors and heat-related illness

At the Paralympics, there were three cases (8.3%) of degree III: severe cases that required CWI with an ice bath as treatment at the venue, and none of them were transported to an outside medical facility at the physician's discretion due to symptom improvement after CWI treatment. There were also three cases (8.3%) transported by ambulance, but none were hospitalised.

DISCUSSION

This study revealed that the frequency of heat-related illnesses and related illnesses in the Olympic Games held in Asia in midsummer 2021 was 100 cases and 36 cases in the Paralympic Games. The incidence of heat-related illnesses among all Olympic and Paralympic athletes (15 823) was 8.6 per 1000, but only 7.5% of heat-related illness cases were transported by ambulance to outside medical facilities, indicating that thorough prevention and initial treatment reduced the progression of serious illness and the burden on athletes and local healthcare.

Heat-related illnesses are most likely to occur in endurance sports. At the Olympics, 50 cases of heat-related illnesses occurred in long-distance athletes (marathon walking) and 72 cases (72%) in endurance sports, such as rowing, tennis, equestrian, triathlon, marathon swimming and cycling.

In addition, environmental factors such as a high WBGT in outdoor venues also contribute to more severe heat-related illnesses.

Although all athletes trained for midsummer heat in Japan, heat-related illness cases occurred in all competitions and outdoor venues as outside temperatures exceeded 30°C (86°F) for consecutive days. However, at the Olympics, in addition to six cases in endurance athletics (marathon, walking), there were only eight cases (8%) in rowing and beach volleyball, and five cases at the Paralympics, including triathlon, track and field, rowing and 5-a-side soccer, indicating that preventing severe heat-related illness due to cooling may help relieve the burden on local healthcare during the COVID-19 pandemic.

In particular, there were only nine cases of heat-related illness requiring a visit to a medical facility from a clinic, and no participants were hospitalised during the Olympic and Paralympic Games.

Furthermore, in late August, when the Paralympics were held, WBGT remained high at 0.8 per 100 Paralympic athletes, and during the week beginning 24 August 2021, both climate and WBGT were high, increasing the risk of wheelchair and endurance sports, and heat-related illness was not only outdoor as in the Olympics, but also occurred indoors. However, after 31 August 2021, the WBGT dropped dramatically as temperatures dropped, and only one case of heat-related illness occurred. In the Paralympics, there were only three heat-related illness outbreaks of moderate or higher severity, indicating that para-athletes have difficulty managing their physical condition when competing outdoors during periods of high WBGT.

Dermon *et al*[17] reported a higher incidence of heat-related illnesses in wheelchair athletes than in able-bodied athletes due to altered vasomotor control, large trunk area, proximity to the ground, high radiant heat and impaired body temperature control in disabled sports. Furthermore, the risk of heat-related illnesses is high both indoors and outdoors. Therefore, in midsummer sports competitions for the disabled, it is necessary to take measures against heat-related illnesses according to the degree of disability.

In the 1908 London Games, Dorando Pietri finished first, but was disqualified after being rescued by officials because he collapsed and attempted to finish in a daze, and in the 1912 Helsinki Olympics, Shizo Kanakuri, for example. WBGT values and heat-related illness risks at outdoor sports events in midsummer are reported to be high at outdoor sports events . In addition, at the 1984 Los Angeles Olympics, the image of Gabriela Andersen reaching the finish line in a daze was broadcasted worldwide, clearly demonstrating the relationship between marathon running and heat-related illness. Subsequently, during the Summer Games in Atlanta,[2] Athens,[18] Beijing[19] and Rio de Janeiro,[3] many heat-related illness cases occurred in the marathon, making it an issue for case management at the Summer Olympics.[4] In this study, a total of 50 heat-related illness cases occurred during the endurance events, despite the fact that the events were moved from Tokyo to Sapporo, where the WBGT was high, and the competition started early in the morning. However, sufficient precautionary measures were taken to reduce the risk of heat-related illnesses among athletes without resulting in serious illnesses.

Nakamura *et al*[7] investigated the relationship between the number of emergency medical transports due to heat-related illness, the number of hospitalisations due to COVID-19 and maximum WBGT over the past 5 years and found that the frequency of mild-to-moderate heat-related illnesses increased from 20 July 2021 to 10 August 2021 (during the Olympic period) and that the Tokyo rule was applied more frequently during this period. It was also pointed out in advance that the number of cases of mild-to-moderate heat-related illnesses usually increased between 20 July 2021 and 10 August 2021. However, the aforementioned thorough heat-related illness prevention measures and early cooling of players led to the avoidance of emergency medical care within this period. It is undeniable that heat-related illnesses would have been a major risk if spectators had been present. The no-spectator games disappointed many athletes and spectators around the world, but it was by no means an incorrect decision.

One of the reasons why the Tokyo Games were successfully completed without major heat-related illness outbreaks or undue burden on local emergency medical services was the thoroughness of the heat-related illness countermeasures. In reviewing the competition operation, the venue and time were changed to take into account the high temperatures and the characteristics of the competitions, as the games were held during an extremely hot season in Japan from July to September. In the tennis competition, the competition time was moved back, the women's soccer final changed from daytime to night-time and the competition venue also changed. In golf competitions, the competition time was moved up or shortened.

However, it was regrettable that many cases of exercise-induced hyperthermia occurred in women's marathons due to the high WBGT despite the increased competition time.

Heat countermeasures for athletes, National Olympic Committees (NOCs), International Sport Federations (IFs), etc, included the use of cool vests for para-athletes and officials, preparation of athlete lounges, portable coolers and the installation of fans and cool mist fans in various locations in the venue. For athletes in wheelchairs, coolants were placed on the installation surfaces of their trunks. In addition, oral rehydration solutions and other beverages were prepared at each venue to prevent heat-related illnesses, and tablets were distributed to encourage the necessary salt supplementation.

In the event of heat-related illnesses, athletes quickly cooled down at the clinic (a medical clinic on the competition site) for initial treatment. In particular, cooling with cooling towels, intravenous drips and oral rehydration solutions were effective in replenishing extracellular fluid. In the 12 events with high physical intensity and 18 events with high risk of heat-related illness, medical ice baths were prepared in the medical rooms at the competition venues, and athletes with hyperthermia with a rectal temperature of 39.5°C or higher were quickly immersed in cold water on their trunks under careful training. All the medical reports from the various venues indicate that rapidly lowering the body temperature was extremely effective in alleviating symptoms, as reported by Hosokawa *et al*.[20]

The Tokyo 2020 Games considered heat-related illness to be one of the risks and took all possible precautions. Heat-related illness countermeasures are effective in preventing serious illnesses and reducing the burden on local medical facilities.

Limitations of this study include the use of medical data from a limited time period, the Olympic and Paralympic Games, and the fact that detailed information on vital signs and age details were not available. Obtaining vital signs and age details would allow for more detailed analysis.

Conclusion

The Tokyo 2020 Olympic Games were held for 19 days from 22 July 2021 to 12 August 2021, and the Tokyo 2020 Paralympic Games were held for 12 days from 24 August 2021 to 5 September 2021. There were a total of 100 Olympic heat-related illness cases and 36 Paralympic heat-related illness cases. Approximately 0.9 out of every 100 participating athletes suffered heat-related illness.

In high-intensity sports, particularly marathons and walking, 179.3 out of every 1000 athletes developed heat-related illness. As for factors contributing to the occurrence, heat-related illness occurred more frequently in outdoor competitions and endurance sports with high outside temperatures (high WBGT), but careful preparation by medical personnel, including early cooling, prevention of dehydration and dissemination of WBGT information, resulted in only 8% of the cases being Grade III: severe cases and 10% being Grade II: moderate cases. In addition, the rate of emergency medical treatment for heat-related illness was 6% at the Olympics and 2.8% at the Paralympics, minimising the burden on the local medical system.

We believe that the heat-related illness countermeasures taken and the experience gained will be very valuable data for holding international sporting events in midsummer in the midst of global warming and will also be valuable for the 2024 Paris Olympics and Paralympics Summer Games.

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REFERENCES

1 Wada KT, Smith D, *et al*. Preventing heat illness in the anticipated hoy climate of the tokyo 2020 summer olympic games. *Environ Health Prev Med* 2020;22:68.
2 Shimizu K, Gilmour S, Mase H, *et al*. COVID-19 and heat illness in tokyo, japan: implications for the summer olympic and paralympic games in 2021. *Int J Environ Res Public Health* 2021;18:3620.
3 Centers for DiseaseControl and Preventionn.d. Prevention andmanagement of heat-related illness. among spectators and staff during theolympic games—atlanta. *Morb Mortal Wkly Rep*;45:631–3.
4 Zhang J-J, Wang L-D, Chen Z, *et al*. Medical care delivery at the Beijing 2008 Olympic Games. *World J Emerg Med* 2011;2:267–71.
5 Organising Committee for the Olympic and Paralympic Games. Weather information for the olympic and paralympic games in rio de janeiro 2016. 2016. Available: https://inside.fei.org/system/files/RIO%20Weather%20forecast_0.pdf
6 Peiser B, Reilly T. Environmental factors in the summer Olympics in historical perspective. *J Sports Sci* 2004;22:981–1001;
7 Nakamura S, Wada K, Yanagisawa N, *et al*. Health risks and precautions for visitors to the tokyo 2020 olympic and paralympic games. *Travel Med Infect Dis* 2018;22:3–7.
8 Ministry of the Environment. Tokyo 2020 heat stroke prevention information historical data. 2021. Available: https://www.wbgt.env.go.jp/tokyo2020/jp/
9 Sugawara M, Manabe Y, Yamasawa F, *et al*. Athlete medical services at the marathon and race walking events during tokyo 2020 olympics. *Front Sports Act Living* 2022;4:872475.
10 McDonagh DOS, Zideman DA. *The IOC manual of emergency sports medicine*. John Wiley & Sons.2015,
11 The tokyo organising committee of the olympic and paralympic games: olympic games pharmacy guide. n.d. Available: https://www.sailing.org/tools/documents/PharmacyGuideOlympicEnglishFirstEdition190719-[27321].pdf
12 Belval LN, Casa DJ, Adams WM, *et al*. Consensus statement-prehospital care of exertional heat stroke. *Prehosp Emerg Care* 2018;22:392–7.
13 Casa DJ, DeMartini JK, Bergeron MF, *et al*. National athletic trainers' association position statement: exertional heat illnesses. *J Athl Train* 2015;50:986–1000.
14 Watson PS. *IIRM medical care manual*. Norfolk: International Institute for Race Medicine, 2015.
15 Longo DL, Epstein Y, Yanovich R. Heatstroke. *N Engl J Med* 2019;380:2449–59.
16 Wadano Y. Medical system at the tokyo 2020 paralympic games. *Jpn J Rehabil Med* 2020;57:492–6.
17 Derman W, Runciman P, Eken M, *et al*. Incidence and burden of illness at the Tokyo 2020 Paralympic Games held during the COVID-19 pandemic: a prospective cohort study of 66 045 athlete days. *British Journal of Sports Medicine* 2022:bjsports-2022-106312.
18 Tokyo organizing committee for the olympic and paralympic games. tokyo 2020 games : reflections on the tokyo 2020 games. n.d. Available: https://www.tokyo2020.jp/ja/news/news-20211222-03-ja/index.html
19 Wetterhall SF. Medical care delivery at the 1996 olympic games. *JAMA* 1998;279:1463.
20 Hosokawa Y, Adami PE, Stephenson BT, *et al*. Prehospital management of exertional heat stroke at sports competitions for Paralympic athletes. *British Journal of Sports Medicine* 2022;56:599–604.