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Clinical paper

Sports activity and paediatric out-of-hospital cardiac arrest at schools in Japan

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Abstract

Background: Sudden cardiac death during exercise or sports is an important problem among young athletes and non-athletes. An understanding of the epidemiological features of sports-related out-of-hospital cardiac arrest (OHCA) among children is crucial for planning approaches for prevention and better outcomes of paediatric OHCAs. We assessed the characteristics and outcomes of sports-related OHCA among children at schools in Japan to prevent sports-related paediatric OHCA at schools.

Methods: The Stop and Prevent cardIac aRrest, Injury, and Trauma in Schools (SPIRITS) is a nationwide, prospective, observational study linking databases of two nationally representative registries. Data on the characteristics and outcomes of sports-related paediatric OHCA at schools in Japan were obtained from these databases.

Results: Between 2008 and 2015, 188 sports-related paediatric OHCAs due to presumed cardiac origin occurred. The greatest proportion of OHCA during or after sports was due to long-distance running (21.8%), followed by soccer/futsal (13.3%), basketball (12.2%), and baseball/rubber-ball baseball (11.2%). We also assessed the association between prehospital factors and one-month survival with favourable neurological outcome after sports-related OHCA. The proportions of ventricular fibrillation as the first documented rhythm, bystander cardiopulmonary resuscitation (CPR), and public-access defibrillation (PAD) were 87.8%, 87.2%, and 63.3%, respectively. Compared with the non-PAD group, the adjusted odds ratio (95% confidence interval) of the PAD group was 3.64 (1.78–7.45).

Conclusions: In Japan, 188 schoolchildren experienced OHCAs of cardiac origin occurring during or after sports activity at schools during the 8-year period. Increasing PAD is essential to enhance better neurological outcome after sports-related OHCA among students.

Keywords: Out-of-hospital cardiac arrest, Basic life support, Student, School, Sports

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Introduction

The occurrence of out-of-hospital cardiac arrest (OHCA) among school-aged children is tragic. Although OHCA among school-aged children accounts for a small subset of overall OHCAs,[1–3] it negatively influences family members, friends, and communities.[4] Therefore, a better understanding of the epidemiological features of OHCA in this age group is crucial for planning evidence-based approaches to prevent and achieve better outcomes of paediatric OHCAs.

Sudden cardiac death (SCD) during exercise or sports is an important health problem among young athletes and non-athletes,[5] and the incidence of sports-related OHCA among these individuals is estimated to be approximately 1–3 per 100,000 per year in the United Sates.[6–9] Since sports-related OHCA is more likely to be witnessed by bystanders in many situations,[10,11] earlier cardiopulmonary resuscitation (CPR) and automated external defibrillator (AED) use by bystanders can be critical in maximizing the survival after OHCA occurs.[11] However, the actual situation of sports-related OHCA among children has not been extensively evaluated in resuscitation science.

We recently launched a nationwide prospective observational study of paediatric OHCAs occurring at school settings in Japan: Stop and Prevent cardIac aRrest, Injury, and Trauma in Schools (SPIRITS).[12] Using this database, this study aimed to assess the characteristics and outcomes of sports-related OHCA among children at schools in Japan and provide fundamental information for preventing sports-related OHCA among children at schools and improving their outcomes worldwide.

Methods

Study design of SPIRITS

The SPIRITS has been described in detail elsewhere.[12] In brief, SPIRITS is a nationwide, prospective, observational study of OHCA paediatric cases using a linking database from two large-scale registries: The Injury and the Accident Mutual Aid Benefit System of JSC and the All-Japan Utstein Registry of the FDMA. The Injury and Accident Mutual Aid Benefit System provides benefits (medical expenses, disability compensation, death compensation, or details of OHCA incident, including timing relative to activity, location, and bystander interventions.) in cases of injury, illness, disease, accident, or death that occur among students and younger children under the supervision of schools or nurseries. It covers most students and younger children attending schools (85.9% nursery school children, 80.7% of kindergarteners, 99.9% of elementary school students, 99.9% of junior-high school students, 98.3% of high school students, and 99.4% of technical college students in 2015; ~17 million students and younger children in Japan). Approximately 1.1 million injuries/accident case data were reported and registered annually from schools nationwide.[13] The All-Japan Utstein Registry is a population-based OHCA registry using the international Utstein-style reporting international guidelines for OHCAs,[14,15] covering the entire population (127 million people) of Japan. In this registry, cardiac arrest is defined as the cessation of mechanical activity confirmed by the absence of circulation signs. Arrests were classified into those of presumed cardiac and non-cardiac origins, and these OHCA data were recorded by emergency-medical-service (EMS) personnel, in cooperation with the physician in charge of the patient. Since prehospital termination of resuscitation by EMS personnel is generally not allowed in Japan, most OHCA patients treated by EMS personnel are transported to hospitals and recorded in this registry, except OHCA patients who are not transported to hospital by EMS (i.e., transported to hospital by family member/bystanders, non-EMS transporting vehicle, or air ambulance). Thus, the SPIRITS database, which was developed by merging the two nationwide registries, has retained the data of most paediatric OHCA cases occurring at school settings in Japan.

In Japan, at least one AED has been installed in almost all elementary, junior-high, and high schools as of 2015 (36,000 schools throughout the country).[16] In addition, the proportion of schools that provided basic life support training to teaching staff, including instructions on how to use an AED, is approximately 90%.[16]

Study subjects

This study included children who experienced OHCA of presumed cardiac origin during or after sports at elementary school (age 6–12 years), junior high school (age 12–15 years), high school (age ≥15 years), and technical college (age ≥15 years) in Japan between 1 April 2008 and 31 December 2015. OHCAs that occurred after EMS arrival and had no resuscitation attempts were excluded (Fig. 1).

Definition of cause of cardiac arrest

The aetiology of cardiac arrest was determined using complementary diagnostic information from the Injury and the Accident Mutual Aid Benefit System in this study, and the diagnosis of eligible patients such as long QT syndrome and hypertrophic cardiomyopathy was confirmed by official medical certificates, including death certificates. In this study, the arrest was presumed to be of cardiac origin by the exclusion diagnosis, unless it was caused by definitive diagnosis based on medical certificates and death certificates by physicians. In addition, this study defined that the first documented rhythm was VF when an AED detected VF in prehospital settings. Furthermore, if their diagnosis was due to presumed cardiac arrest, we identified idiopathic ventricular fibrillation using first rhythm documented by on-scene EMS personnel before arriving at the hospital.

Data collection

We obtained the following data from the SPIRITS database: type of sports, circumstances of collapse (during or within 1 h of cessation of sports activity),[17–19] date and time of emergency call by bystanders (9:00 am–4:59 pm, 5:00 pm–8:59 am), resuscitation time course including contact with patient by EMS personnel or hospital arrival, educational level (elementary school, junior-high school, high school/technical college), sex (boys, girls), location of arrest (schoolyard, ground out of school, gymnasium in school, gymnasium out of school, pool in school, street, other place in school), activity at the time of arrest (in class, extracurricular activities), witness of arrest (bystanders, and not witnessed), origin of arrest, first documented rhythm (ventricular fibrillation [VF], pulseless electrical activity [PEA], asystole, and unknown), initiation of bystander-cardiopulmonary resuscitation (CPR) (yes, no), application of public-access AED PADs (yes, no), shocks by a public-access AED (yes, no), and outcomes such as prehospital return of spontaneous circulation (ROSC) (yes, no), 1-month survival (yes, no), and neurological status 1 month after the event (yes, no).

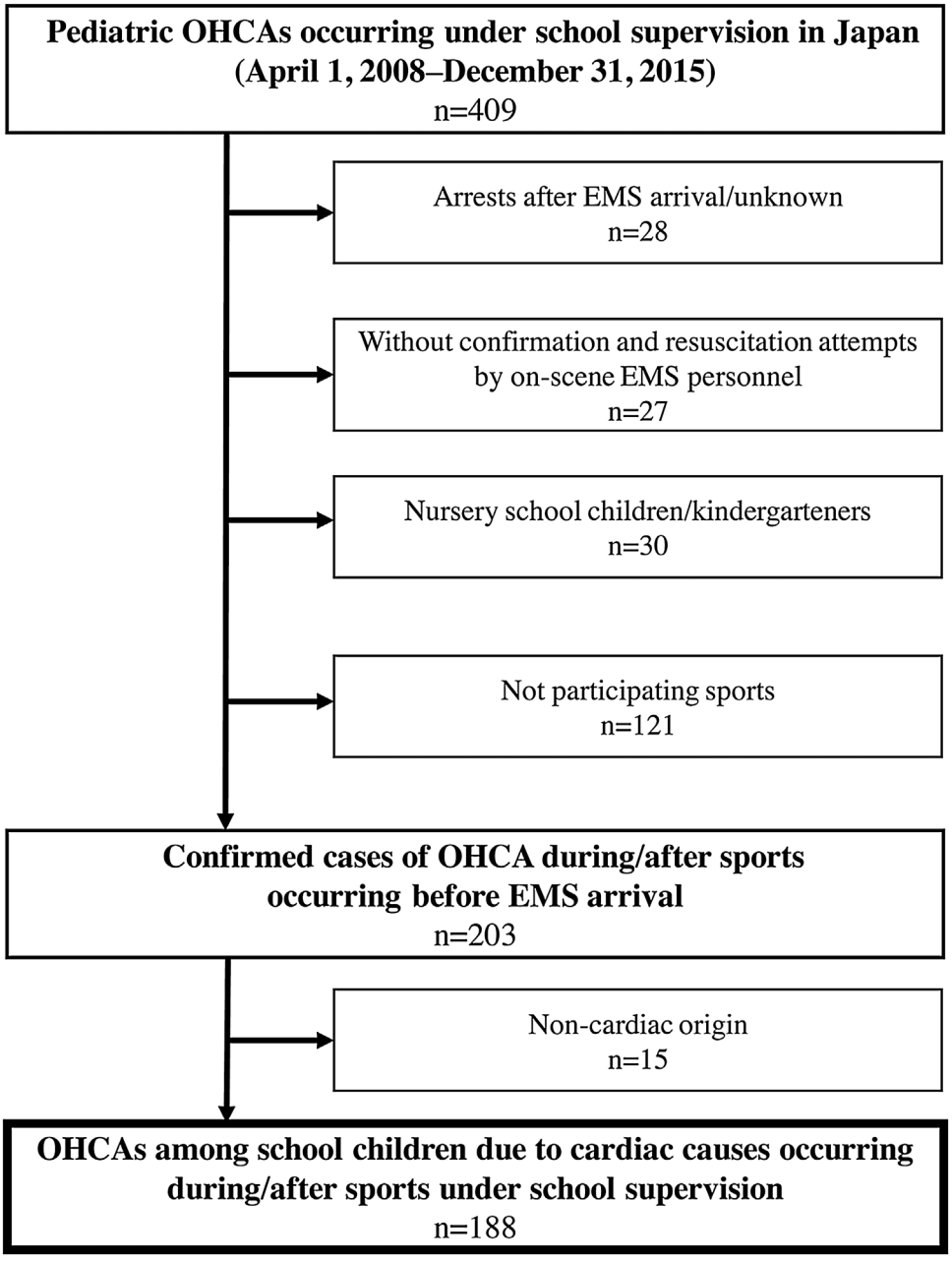

Fig. 1 – Selection of eligible patients with OHCA (1 April 2008-31 December 2015). OHCA, out-of-hospital cardiac arrest; EMS, emergency medical service.

Outcome measures

The primary endpoint of this study was one-month survival with favourable neurological outcome after OHCA. All OHCA survivors were followed up for up to one month after the event, and neurological status was assessed by the physician in charge, using the Glasgow–Pittsburgh cerebral performance category (CPC) scale: category 1, good cerebral performance; category 2, moderate cerebral disability; category 3, severe cerebral disability; category 4, coma or vegetative state; and category 5, death. A favourable neurological outcome was defined as a CPC of 1 or 2.[14,15] Secondary endpoints were prehospital ROSC and one-month survival after OHCA.

Statistical analysis

Summary statistics were expressed as median (interquartile range) for numerical variables and percentages for categorical variables. In this study, we assessed characteristics and outcomes according to educational level, because educational curriculums differ by educational level in Japan. Among the eligible OHCA children, the patient and EMS characteristics and outcomes of sports-related OHCAs were calculated according to the education level, and Kruskal–Wallis test for numerical variables and the χ^2 test or Fisher's exact test for categorical variables were used to analyse statistical differences. A crude and multivariate logistic regression

model was used to assess the association between prehospital factors (sex, educational level, initiation of bystander CPR, and public-access defibrillation) and one-month survival with favourable neurological outcome after sports-related OHCA, and to calculate odds ratios (ORs) and their 95% CIs. The annual incidence rate of sports-related OHCA per 100,000 students was calculated separately for the 3 educational levels (i.e., elementary school, junior high school, and high school/technical college), and the Poisson regression model was applied for trend analysis. All tests were two-tailed and a P-value of <0.05 was considered statistically significant. Statistical analyses were conducted using STATA version 15MP (Stata Corp., College Station, TX, USA).

Ethics

The Ethics Committees of Osaka University approved the study protocols. Personal identifiers were removed from the database. The requirement for informed consent was waived because we collected already-anonymised registry data.

Results

During the 8-year study period, 409 OHCA patients were observed under the supervision of schools (Fig. 1). After excluding OHCA cases meeting our exclusion criteria, 203 OHCAs occurring before EMS arrival were confirmed in this study. Of them, excluding victims with having non-cardiac origins, 188 OHCAs due to presumed cardiac origin among school children occurred during or after sports. The overall annual incidence rate was 0.172 per 100,000 students, and the trend remained stable during the study period (Supplementary Table 1). As for educational level, the overall incidence rate was 0.036 in elementary school, 0.217 in junior high school, and 0.389 in high school/technical college, respectively, and the trends did not change during the study period.

Fig. 2 shows the OHCA origin of arrest among children during or after sports. Among 188 victims, idiopathic ventricular fibrillation was the most common (133 [70.7%]), followed by hypertrophic cardiomyopathy (12 [6.4%]), commotio cordis (10 [5.3%]), long QT syndrome (5 [2.7%]), and Wolff-Parkinson-White syndrome (4 [2.1%]).

Table 1 shows the number of paediatric OHCAs at schools by type of sports and education levels. Overall, the greatest proportion of OHCA during or after sports was due to long-distance running (21.8%), followed by soccer/futsal (13.3%), basketball (12.2%), and baseball/rubber-ball baseball (11.2%). As for educational level, the greatest frequency of sports-related OHCA occurred during or after swim among elementary school students (52.6%) and long-distance running among junior-high school students (23.0%) and high school/technical college students (22.2%), respectively.

Table 2 shows participants' characteristics and prehospital cares based on the education level. Victims in high school or technical college were more likely to be have OHCA after 5:00 pm and to be witnessed by bystanders, and those in elementary school were more likely to be female and to have the occurrence in April–June. The proportion of VF as the first documented rhythm, bystander CPR, and public-access defibrillation (PAD) was 87.8%, 87.2%, and 63.3% in total, respectively. These proportions were higher among junior-high school students and high school/technical college students than among elementary school students. In addition, the proportion of female students with sports-related OHCA was lower in junior high school and high school/technical college than in elementary school. The proportion of public-access AED application was high, and 97% of bystanders who conducted AED PAD application were school teachers.

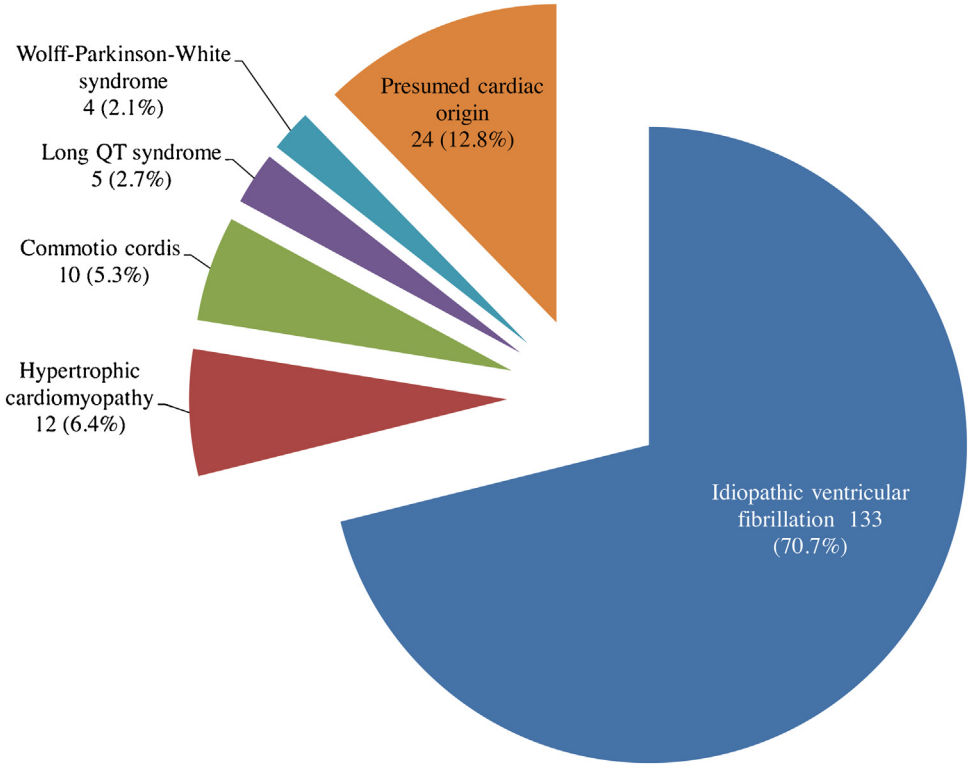

Fig. 2 – Detailed origin of arrest.

Table 1 – Out-of-hospital cardiac arrests occurring during/after sports under school supervision in Japan by type of sports.

	Total		Elementary school students		Junior-high school students		High school/technical college students	
	(N = 188)		(N = 19)		(N = 61)		(N = 108)	
Long-distance running, n (%)	41	(21.8)	3	(15.8)	14	(23.0)	24	(22.2)
Soccer/futsal, n (%)	25	(13.3)	0	(0.0)	10	(16.4)	15	(13.9)
Basketball, n (%)	23	(12.2)	0	(0.0)	7	(11.5)	16	(14.8)
Baseball including rubber-ball baseball, n (%)	21	(11.2)	0	(0.0)	4	(6.6)	17	(15.7)
Swim, n (%)	19	(10.1)	10	(52.6)	7	(11.5)	2	(1.9)
Short-distance sprint including hurdling, n (%)	14	(7.4)	2	(10.5)	6	(9.8)	6	(5.6)
Warming-up/stretching, n (%)	12	(6.4)	3	(15.8)	3	(4.9)	6	(5.6)
Tennis including soft tennis, n (%)	6	(3.2)	0	(0.0)	1	(1.6)	5	(4.6)
Volley ball, n (%)	5	(2.7)	0	(0.0)	3	(4.9)	2	(1.9)
Kendo, n (%)	4	(2.1)	0	(0.0)	1	(1.6)	3	(2.8)
Badminton, n (%)	3	(1.6)	0	(0.0)	0	(0.0)	3	(2.8)
Rugby, n (%)	2	(1.1)	0	(0.0)	0	(0.0)	2	(1.9)
Other, n (%)	13	(6.9)	1	(0.1)	5	(8.2)	7	(6.5)

Other includes some sports such as handball, judo, table tennis, boxing, dancing, and mat exercise.

Table 3 shows the association between prehospital factors and one-month survival with favourable neurological outcome after sports-related OHCA. Compared with the non-PAD group, the adjusted OR (95% CI, P-value) of the PAD group was 3.64 (1.78–7.45, $P < 0.001$), and other factors were not significantly associated with improved outcome after sports-related OHCA.

Discussion

Using the SPIRITS database in Japan, the present study demonstrated that 188 schoolchildren had OHCAs of cardiac origin during or after sports activity in the 8-year study period, and clearly depicted their detailed characteristics and outcomes. To our knowledge, this was the first comprehensive epidemiological study to investigate paediatric OHCAs occurring during or after sports activity at schools. These findings provide essential information for developing preventative strategies to inform administrative officials and draw the attention of physicians to understand the mechanism and treatment of sports-related cardiac arrests.

As for the type of sports, paediatric OHCAs of cardiac origin were most common in long-distance running, followed by soccer/futsal, basketball, baseball, and swimming in this study. These sports had a moderate or high dynamic component,[20] and these results suggest that children who play sports that continuously overload the body should be paid more careful attention for the prevention of SCD.

For the purpose of the prevention of sports-related OHCAs, the effects on disease screening even for athletes before participating have been still controversial. Previous studies reported that about 80% of SCDs did not show any abnormalities before participating in sports among various athletes[6] and only 0.4% had, for example, SCD-related diseases detected on pre-participation screening among England adolescent soccer players.[21] On the other hand, Corrado et al. reported that the incidence of sudden cardiovascular death in young competitive athletes has substantially declined in the Veneto region of Italy since the introduction of a nationwide systematic screening.[22] Thus, further studies are needed to assess the screening effects for athletes as well as general population before participating in sports. On the other hand, considering our results, it is important to conduct continuous preventive education on SCD from elementary school onwards, and introduction of CPR training on the assumption that OHCAs can occur at schools,[23–27] because the proportion of idiopathic VF was high among students with sports-related OHCA.

Our study highlighted that the overall proportion of participants with favourable neurological outcome after sports-related OHCAs was >50%, which was considerably higher than the 3.1% of children in the general population reported in a previous study.[3] In this study, the proportion of VF, CPR, and PAD was very high, and the PAD program was effective for paediatric OHCAs during sports activity at school settings in Japan. Indeed, >90% of school students received CPR training, including how to use an AED,[16] and almost 70% of students at junior-high schools and high schools learned basic life support.[16] Conversely, compared with students in junior-high school and high school, the proportion of first documented VF, bystander CPR, AED PAD application, shocks by AEDs, and subsequent favourable neurological outcome tended be lower among students in elementary school. Therefore, further efforts to increase bystander interventions for OHCAs among elementary school students are needed. In addition, most sports-related OHCA occurred during extracurricular activities or after 5:00 pm. In Japan, although club activities after class are not mandatory, many students belong to a club directed by a school and engage in these activities during extracurricular activities or after 5:00 pm. Sports club activities occupy an appreciable amount of time in Japanese students' lives. Therefore, introducing resuscitation training as part of school education would be helpful to improve treatment of OHCAs occurring during sports club activities, especially as bystanders are most likely to be other students.[12]

Based on a statement “Aiming for zero deaths; Prevention of sudden cardiac death in schools” published by the Japan Circulation Society, our final goal will be zero deaths from cardiac events in school settings.[27] Therefore, we should train schoolchildren, students, and staffs to use CPR and AED to allow the PAD program to work more effectively and subsequently improve paediatric OHCA outcomes in schools. Moreover, Japan Sports Center announced guidelines for accident prevention during swimming class, marathon races, and athletic festivals under the supervision of schools.[28] There is at least

Table 2 – Characteristics of out-of-hospital cardiac arrests occurring during/after sports in school settings in Japan.

	Total		Elementary school students		Junior-high school students		High school/ technical college students		P-value
	(n = 188)		(n = 19)		(n = 61)		(n = 108)		
Circumstance, n (%)									0.313
During sports	131	(69.7)	12	(63.2)	39	(63.9)	80	(74.1)	
After sports	57	(30.3)	7	(36.8)	22	(36.1)	28	(25.9)	
Sex, n (%)									<0.001
Boys	150	(79.8)	7	(36.8)	49	(80.3)	94	(87.0)	
Girls	38	(20.2)	12	(63.2)	12	(19.7)	14	(13.0)	
Location, n (%)									<0.001
Schoolyard	93	(49.5)	7	(36.8)	31	(50.8)	55	(50.9)	
Ground out of school	17	(9.0)	0	(0.0)	5	(8.2)	12	(11.1)	
Gymnasium in school	39	(20.7)	1	(5.3)	14	(23.0)	24	(22.2)	
Gymnasium out of school	3	(1.6)	0	(0.0)	1	(1.6)	2	(1.9)	
Pool in school	19	(10.1)	10	(52.6)	7	(11.5)	2	(1.9)	
Street	12	(6.4)	0	(0.0)	3	(4.9)	9	(8.3)	
Other place in school	5	(2.7)	1	(5.3)	0	(0.0)	4	(3.7)	
Activity at the time of arrest, n (%)									0.005
In class	102	(54.3)	17	(89.5)	32	(52.5)	53	(49.1)	
Extracurricular activities	86	(45.7)	2	(10.5)	29	(47.5)	55	(50.9)	
Time of day, n (%)									0.033
9:00 am–4:59 pm	158	(84.0)	19	(100.0)	54	(88.5)	85	(78.7)	
5:00 pm–8:59 am	30	(16.0)	0	(0.0)	7	(11.5)	23	(21.3)	
Season, n (%)									0.041
January–March	42	(22.3)	0	(0.0)	14	(23.0)	28	(25.9)	
April–June	49	(26.1)	10	(52.6)	13	(21.3)	26	(24.1)	
July–September	53	(28.2)	6	(31.6)	21	(34.4)	26	(24.1)	
October–December	44	(23.4)	3	(15.8)	13	(21.3)	28	(25.9)	
Witness of arrest, n (%)									0.020
Bystanders	171	(91.0)	14	(73.7)	56	(91.8)	101	(93.5)	
Not witnessed	17	(9.0)	5	(26.3)	5	(8.2)	7	(6.5)	
Initiation of bystander CPR, n (%)	164	(87.2)	15	(78.9)	53	(86.9)	96	(88.9)	0.486
First documented rhythm, n (%)									0.006
VF	165	(87.8)	12	(63.2)	56	(91.8)	97	(89.8)	
PEA	13	(6.9)	3	(15.8)	2	(3.3)	8	(7.4)	
Asystole	9	(4.8)	4	(21.1)	3	(4.9)	2	(1.9)	
Unknown	1	(0.5)	0	(0.0)	0	(0.0)	1	(0.9)	
Application of public-access AED pads, n (%)	150	(79.8)	10	(52.6)	51	(83.6)	89	(82.4)	0.038
Public-access defibrillation, n (%)	119	(63.3)	6	(31.6)	43	(70.5)	70	(64.8)	0.008
Time from collapse to contact with the patient by EMS personnel, mins, median (IQR)	7.0	(6.0–9.0)	7.0	(5.0–9.0)	7.0	(6.0–9.0)	8.0	(6.0–9.5)	0.189
Time from call to hospital arrival, mins,median (IQR)	29.0	(22.5–35.0)	29.0	(21–35.0)	29.0	(25.0–34.0)	28.5	(21.0–36.0)	0.686

VF indicates ventricular fibrillation; PEA, pulseless electrical activity; AED, automated external defibrillation; EMS, emergency medical service; IQR, interquartile range.

one AED in all education institutes in Japan,[29] but these guidelines recommend that public-access AEDs should be located in school buildings and school athletic areas, such as the ground, pool, and/or gym,[27–29] so that AED shocks can be delivered within about 5 min, based on Japanese recommendations on the deployment criteria of public-access AEDs.[27,29] In addition to these measures, creating practical emergency action plans together with local EMS agencies and communities would be helpful for achieving zero deaths under the supervision of the schools.[23,30]

There was a gender difference in the occurrence of sports-related OHCA in this study. Although the mechanism of this gender difference was not clear in our study, the difference might be explained partially by the following mechanisms. Some experimental studies showed that oestrogen might have cardioprotective effects for cardiac arrest.[31–33] Another report suggested that oestrogen had a possible neuroprotective effect.[33,34] Thus, these findings suggest the protective effects of endogenous oestrogen against the occurrence of sports-related OHCA among junior high school and high school/technical college female students.[33]

Limitations

Our study has several limitations. First, we did not obtain detailed information on the duration, workload, and skill level of the sports activities. Second, we could not obtain information on several factors

Table 3 – Association between several prehospital factors and one-month survival with favourable neurological outcome after sports-related out-of-hospital cardiac arrest.

	CPC 1 or 2	Crude analysis			Multivariable analysis		
	% (n/N)	OR	95%CI	P-value	OR	95%CI	P-value
Sex							
Boys	53.3 (80/150)	Reference			Reference		
Girls	50.0 (19/38)	0.88	(0.43–1.78)	0.713	1.40	(0.60–3.24)	0.433
Educational level							
Elementary school	36.8 (7/19)	0.54	(0.20–1.48)	0.232	0.72	(0.23–2.28)	0.574
Junior high school	59.0 (36/61)	1.34	(0.71–2.52)	0.370	1.27	(0.64–2.50)	0.490
High school/technical college	51.9 (56/108)	Reference			Reference		
Initiation of bystander CPR							
No	25.0 (6/24)	Reference			Reference		
Yes	56.7 (93/164)	3.93	(1.48–10.41)	0.006	1.90	(0.63–5.70)	0.254
Public-access defibrillation							
No	30.4 (21/69)	Reference			Reference		
Yes	65.5 (78/119)	4.35	(2.30–8.22)	<0.001	3.64	(1.78–7.45)	<0.001

CPC, cerebral performance category.
Multivariable analysis was mutually adjusted for each factor.

that would be associated with the occurrence and outcome of cardiac arrest. This information includes past medical history, such as Kawasaki disease or congenital heart disease, medication, and CPR quality. Third, in the All-Japan Utstein Registry, the aetiology of many cases may have been determined to be of cardiac origin after excluding other possibilities. Autopsy was not performed for all cases of SCD, and the reported autopsy rate was only 2.4% of all death cases in Japan.[35] In addition, this study did not use directly data obtained from echocardiography, ECG, and MRI or medical data such as screening using a heart examination and ECG before the occurrence of cardiac arrest; the diagnosis of eligible patients was confirmed by official medical certificates, including death certificates. Fourth, we obtained information on the first documented VF by an AED in prehospital settings, but it is reported that the AED's sensitivity and specificity for VF is high.[36] On the other hand, the proportion of idiopathic VF in this study was higher than that from other previous study[37,38] and we would overestimate the number of OHCA cases with idiopathic VF. Fifth, as stated previously,[12] input errors may have occurred in the items for data-linkage when developing the SPIRITS database, possibly leading to the underestimation of OHCA cases. Moreover, exclusion of subjects not transported to hospital by EMS personnel could have resulted in the underestimation of OHCA incidence.

Conclusions

In Japan, 188 schoolchildren experienced OHCAs of cardiac origin occurring during or after sports activity at schools between 2008 and 2015, and the OHCAs occurred during a wide variety of sports activities. Increasing PAD is essential to enhance better neurological outcome after sports-related OHCA among students.

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Conflict of interest

None declared.

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Appendix A. Supplementary data

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REFERENCES

1. Atkins DL, Everson-Stewart S, Sears GK, et al. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. Circulation 2009;119:1484–91.
2. Bardai A, Berdowski J, van der Werf C, et al. Incidence, causes, and outcomes of out-of-hospital cardiac arrest in children. A comprehensive, prospective, population-based study in the Netherlands. J Am Coll Cardiol 2011;57:1822–8.
3. Nitta M, Iwami T, Kitamura T, et al. Age-specific differences in outcomes after out-of-hospital cardiac arrests. Pediatrics 2011;128:e812–20.
4. Atkins DL, Berger S. Improving outcomes from out-of-hospital cardiac arrest in young children and adolescents. Pediatr Cardiol 2012;33:474–83.
5. Risgaard B, Winkel BG, Jabbari R, et al. Sports-related sudden cardiac death in a competitive and a noncompetitive athlete population aged 12 to 49 years: data from an unselected nationwide study in Denmark. Heart Rhythm 2014;11:1673–81.

6. Landry CH, Allan KS, Connelly KA, Cunningham K, Morrison LJ, Dorian P. Sudden cardiac arrest during participation in competitive sports. N Engl J Med 2017;377:1943–53.
7. Marijon E, Tafflet M, Celermajer DS, et al. Sports-related sudden death in the general population. Circulation 2011;124:672–81.
8. Van Camp SP, Bloor CM, Mueller FO, Cantu RC, Olson HG. Nontraumatic sports death in high school and college athletes. Med Sci Sports Exerc 1995;27:641–7.
9. Harmon KG, Asif IM, Maleszewski JJ, Owens DS, Prutkin JM, Salerno JC, et al. Incidence, cause, and comparative frequency of sudden cardiac death in national collegiate athletic association athletes: a decade in review. Lippincott Williams & Wilkins, WK Health; 2015 p. 10.
10. Berdowski J, de Beus MF, Blom M, et al. Exercise-related out-of-hospital cardiac arrest in the general population: incidence and prognosis. Eur Heart J 2013;34:3616–23.
11. Kiyohara K, Nishiyama C, Kiguchi T, et al. Exercise-related out-of-hospital cardiac arrest among the general population in the era of public-access defibrillation: a population-based observation in Japan. J Am Heart Assoc 20176:.
12. Kiyohara K, Sado J, Kitamura T, et al. Epidemiology of pediatric out-of-hospital cardiac arrest at school—an investigation of a nationwide registry in Japan. Circ J 2018;82:1026–32.
13. Japan Sports Council. School Safety Department, 2018. (Accessed 26 September 2018, at https://www.jpnsport.go.jp/corp/english/activities/tabid/395/Default.aspx).
14. Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). Circulation 2004;110:3385–97.
15. Hazinski MF, Nolan JP, Aickin R, et al. Part 1: Executive summary: 2015 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Circulation 2015;132:S2–S39.
16. Ministry of Education Culture Sports Science and Technology, Elementary and Secondary Education Bureau Elementary and Secondary, Education Planning Division. Current investigation about promoting plan of the school safety in Japan (2015). 2018 (Accessed 26 September 2018, at http://www.mext.go.jp/component/a_menu/education/detail/__icsFiles/afieldfile/2017/03/24/1289307_12.pdf).
17. Maron BJ, Doerer JJ, Haas TS, Tierney DM, Mueller FO. Sudden deaths in young competitive athletes: analysis of 1866 deaths in the United States, 1980-2006. Circulation 2009;119:1085–92.
18. Fishman GI, Chugh SS, Dimarco JP, et al. Sudden cardiac death prediction and prevention: report from a National Heart, Lung, and Blood Institute and Heart Rhythm Society Workshop. Circulation 2010;122:2335–48.
19. D'Ascenzi F, Zorzi A, Alvino F, Bonifazi M, Corrado D, Mondillo S. The prevalence and clinical significance of premature ventricular beats in the athlete. Scand J Med Sci Sports 2017;27:140–51.
20. Mirabelli MH, Devine MJ, Mendoza M, Singh J. The preparticipation sports evaluation. Am Fam Physician 2015;92:371–6.
21. Malhotra A, Dhutia H, Finocchiaro G, et al. Outcomes of cardiac screening in adolescent soccer players. N Engl J Med 2018;379:524–34.
22. Corrado D, Basso C, Pavei A, Michieli P, Schiavon M, Thiene G. Trends in sudden cardiovascular death in young competitive athletes after implementation of a preparticipation screening program. JAMA 2006;1593.
23. Drezner JA, O'Connor FG, Harmon KG, et al. AMSSM Position Statement on Cardiovascular Preparticipation Screening in Athletes: current evidence, knowledge gaps, recommendations and future directions. Br J Sports Med 2017;51:153–67.
24. Cave DM, Aufderheide TP, Beeson J, et al. Importance and implementation of training in cardiopulmonary resuscitation and automated external defibrillation in schools: a science advisory from the American Heart Association. Circulation 2011;123:691–706.
25. Lorem T, Palm A, Wik L. Impact of a self-instruction CPR kit on 7th graders' and adults' skills and CPR performance. Resuscitation 2008;79:103–8.
26. Japan AED Project. Japan AED Project (in Japanese), 2015. (Accessed 1 October 2018, at http://aed-project.jp/).
27. Mitamura H, Iwami T, Mitani Y, Takeda S, Takatsuki S. Aiming for zero deaths: prevention of sudden cardiac death in schools—statement from the AED committee of the Japanese circulation society. Circ J 2015;79:1398–401.
28. Japan Sports Council. The project for promoting the preventive provision of accidents during physical education activity in Japanese schools (2017). 2018 [Accessed 30 September 2018, at https://www.jpnsport.go.jp/anzen/anzen_school/bousi_kenkyu/tabid/1861/Default.aspx].
29. Committee on dissemination of public-access AEDs of the Japanese Circulation Society, Committee on dissemination of public-access AEDs of the Japanese Circulation Society. Recommendations on deployment criteria of public-access AEDs. 2012 [Accessed 2 October 2018, at http://www.jhf.or.jp/aed/images/44-4shinzo.pdf].
30. Toresdahl B, Courson R, Borjesson M, Sharma S, Drezner J. Emergency cardiac care in the athletic setting: from schools to the Olympics. Br J Sports Med 2012;46 Suppl 1:i85–9.
31. Niemann JT, Rosborough JP, Youngquist S. Is the tumour necrosis factor-alpha response following resuscitation gender dependent in the swine model? Resuscitation 2008;77:258–63.
32. Kuhar P, Lunder M, Drevensek G. The role of gender and sex hormones in ischemic-reperfusion injury in isolated rat hearts. Eur J Pharmacol 2007;561:151–9.
33. Kitamura T, Iwami T, Kawamura T, et al. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. Lancet 2010;375:1347–54.
34. McCullough LD, Hurn PD. Estrogen and ischemic neuroprotection: an integrated view. Trends Endocrinol Metab 2003;14:228–35.
35. Ministry of Health, Labour and Welfare. Vital statistics of Japan, (Accessed 18 Decemeber 2018, at http://www.e-stat.go.jp/SG1/estat/List.do?lid=000001138000).
36. Macdonald RD, Swanson JM, Mottley JL, Weinstein C. Performance and error analysis of automated external defibrillator use in the out-of-hospital setting. Ann Emerg Med 2001;38:262–7.
37. Conte G, Caputo ML, Regoli F, et al. True idiopathic ventricular fibrillation in out-of-hospital cardiac arrest survivors in the Swiss Canton Ticino: prevalence, clinical features, and long-term follow-up. Europace 2017;19:259–66.
38. Visser M, van der Heijden JF, Doevendans PA, Loh P, Wilde AA, Hassink RJ. Idiopathic ventricular fibrillation: the struggle for definition, diagnosis, and follow-up. Circ Arrhythm Electrophysiol 20169:.