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Factors influencing the delivery of automated external defibrillators by lay rescuers to the scene of out-of-hospital cardiac arrests in schools

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Abstract

Aim: Timely use of automated external defibrillators by lay rescuers significantly improves the chances of survival in out-of-hospital cardiac arrest cases. We aimed to identify the factors influencing whether lay rescuers bring automated external defibrillators to the scene of nontraumatic out-of-hospital cardiac arrests in schoolchildren in Japan.

Methods: Data on out-of-hospital cardiac arrests among schoolchildren from April 2008 to December 2021 were obtained from the database of the Stop and Prevent cardIac aRrest, Injury, and Trauma in Schools study. A multivariate Modified Poisson regression analysis was performed to evaluate the factors influencing whether a lay rescuer brought an automated external defibrillator to the scene of out-of-hospital cardiac arrest and the year-by-year changes in automated external defibrillator delivery for each factor were assessed.

Results: Of the 333 nontraumatic out-of-hospital cardiac arrests across the entire study period, lay rescuers brought automated external defibrillators in 85.3% of cases. Female patients and incidents occurring during non-sports activities had lower proportions of automated external defibrillator delivery. Significant year-by-year improvements in automated external defibrillator delivery were observed, with the overall proportion increasing from 73.7% in 2008–2010 to 93.3% in 2020–2021. However, the trend was less pronounced for female students, non-sports activities, and incidents occurring in classrooms/other locations than their counterparts.

Conclusions: AED delivery to the scene of OHCA in schools has improved overall, with the proportion increasing from 73.7% in 2008–2010 to 93.3% in 2020–2021. However, there is still room for improvement, particularly in female patients, and incidents during non-sports activities.

KEYWORDS
automated external defibrillators, out-of-hospital cardiac arrest, schools, students

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INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) requires immediate intervention to prevent fatal outcomes and is a leading cause of death in many industrialized countries, including Japan.[1–3] Timely use of automated external defibrillators (AEDs) by lay rescuers significantly improves the chances of survival in OHCA cases.[4,5] The Japan Resuscitation Council Resuscitation Guidelines 2020 emphasize that when cardiac arrest is suspected, AEDs should be promptly delivered to the scene without hesitation.[6]

Schools are unique environments for AED implementation owing to the high concentration of children and adolescents. Although pediatric OHCA represents a small subset of overall OHCA incidents,[7–9] it has a significant societal impact in terms of lost productive years, healthcare costs for survivors, and emotional burden for families.[7] Despite the increasing use of AEDs by lay rescuers for OHCA of schoolchildren in recent years, there remain some cases in which AEDs are not utilized.[10,11] This highlights the need for continued efforts to improve accessibility and usage of AEDs in school settings.

To ensure that AEDs are delivered more frequently to the OHCA scene in schools, identifying and addressing the factors associated with lay rescuers' AED use is essential. Understanding these factors can inform targeted educational programs and policies for enhancing emergency preparedness in schools. Therefore, this study aimed to identify the factors influencing whether lay rescuers bring AEDs to the scene of nontraumatic OHCAs among schoolchildren in Japan. Specifically, it aimed to explore the time trends in AED delivery by lay rescuers for various factors, identifying which factors showed improvement over time and which did not.

METHODS

Study design

This study was conducted as part of the Stop and Prevent cardIac aRrest, Injury, and Trauma in Schools (SPIRITS) study. The rationale, design, and profile of SPIRITS have been previously described in detail.[12] Briefly, the SPIRITS study integrates data from two large-scale registries: the Injury and Accident Mutual Aid Benefit System of the Japan Sport Council (JSC) and All-Japan Utstein Registry of the Fire and Disaster Management Agency (FDMA). The JSC database includes records of injuries, illnesses, and accidents occurring under school supervision,[13] whereas the FDMA registry documents OHCAs based on the international Utstein format.[14,15] Therefore, SPIRITS covers a comprehensive range of OHCA incidents among Japanese schoolchildren and provides a robust database for analysis.

Data collection

Data on OHCAs among schoolchildren throughout Japan between April 1, 2008 and December 31, 2021, were obtained from the SPIRITS database. The primary outcome measure was whether lay rescuers brought the AED to the OHCA scene. We did not consider whether the AED pad was actually attached or defibrillated. Secondary outcomes included ventricular fibrillation (VF) as the first documented rhythm and 1-month survival with favorable neurological outcome, defined as the Glasgow-Pittsburg cerebral performance category 1 or 2. Other variables included educational stage, sex, witness status of arrest, origin of arrest, activity at the time of arrest, location of arrest, first documented rhythm, and time of arrest.

Study population

This study included cases of nontraumatic OHCA of schoolchildren from elementary school (age 6–12 years), junior high school (age 12–15 years), high school (age ≥ 15 years), and technical college (age ≥ 15 years). The inclusion criteria were cases where resuscitation was attempted by emergency medical service (EMS) personnel or lay rescuers and the first documented rhythm was recorded. The exclusion criteria were OHCAs due to traumatic causes, arrests occurring outside the school premises, and cases that occurred after the arrival of EMS personnel.

Statistical analyses

A multivariate modified Poisson regression analysis was performed to evaluate the factors influencing lay rescuers' AED delivery to the OHCA scene to estimate risk ratios (RRs) and their 95% confidence intervals (CIs). The analysis included potential factors for lay rescuers' AED delivery, such as sex (male or female), educational level (elementary school, junior high school, or high school/technical college), witness of arrest (witnessed or not witnessed), origin of arrest (cardiac or noncardiac), activity at the time of arrest (sports classes, sports club activities, or non-sports activities), location of arrest (athletic field, gymnasium, swimming pool, classroom/others), and time of arrest (weekdays from 8:00 to 16:00 or all other times, including weekends). Furthermore, Cochran–Armitage tests for trends were applied to assess year-by-year changes in AED delivery for each factor. In addition, the associations between lay rescuers' AED delivery and the secondary outcomes, including VF as the first documented rhythm and 1-month survival with favorable neurological outcome, were evaluated for each factor using the chi-square test. Statistical significance was set at $p < 0.05$. All

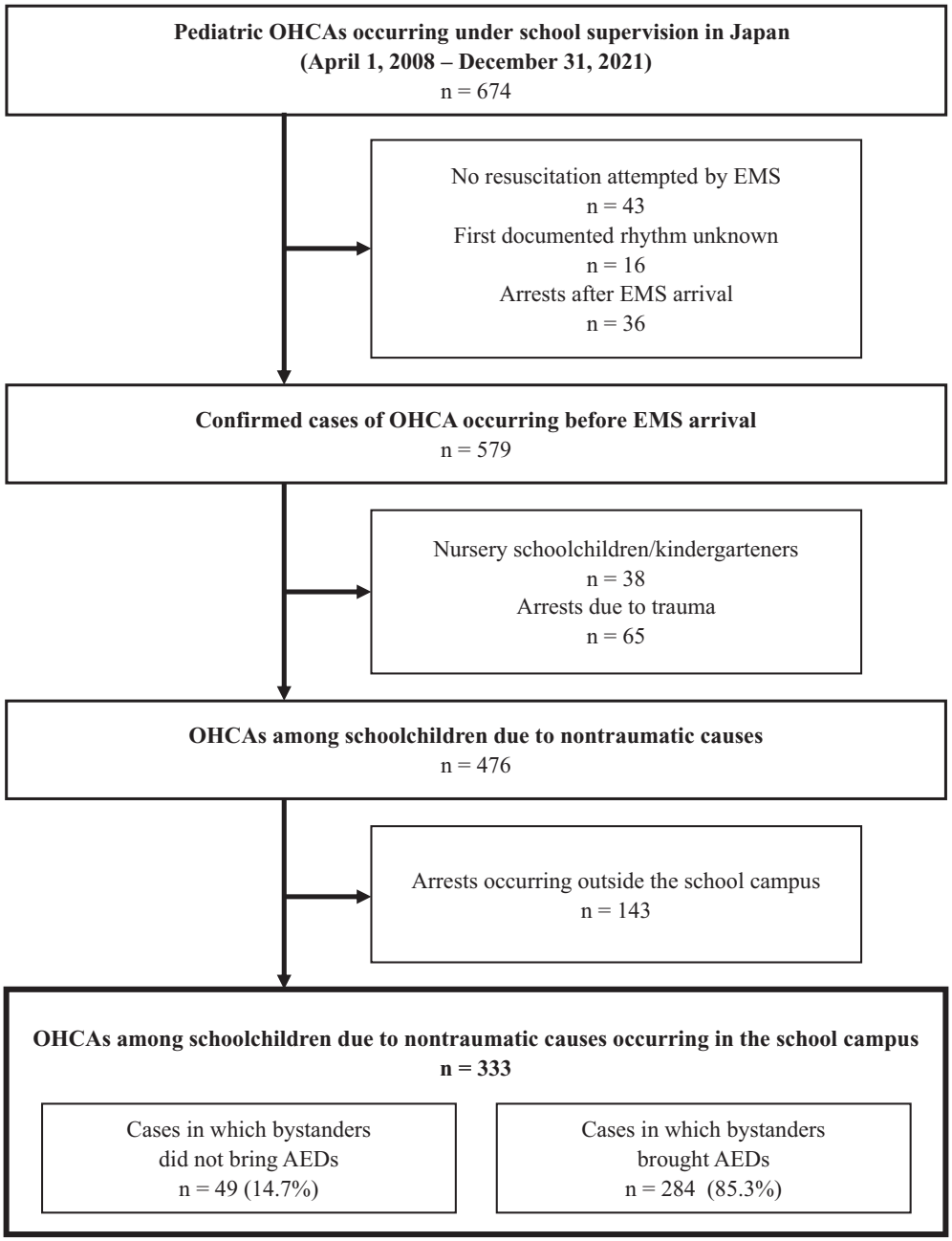

FIGURE 1 Flowchart of the selection process for study participants.

analyses were performed using IBM SPSS Statistics version 27.0 J (IBM Corp., Armonk, NY).

RESULTS

Study population

Figure 1 illustrates the selection process for the study participants. Between April 2008 and December 2021, 476 nontraumatic OHCAs cases among schoolchildren were identified. Of them, 333 cases that occurred on school campuses were included in the analysis. Of the 333 OHCAs cases across the entire study period, lay rescuers brought an AED to the scene in 284 (85.3%) cases. Table 1 shows the characteristics of the study population. The study population comprised 249 (74.8%) male patients. Most OHCAs were witnessed by lay rescuers (294 [88.3%] cases) and were of cardiac origin (297 [89.2%] cases). OHCAs occurred most frequently during physical activity, with 116 (34.8%) cases occurring during sports classes and 149 (44.7%) cases during sports club activities. Most OHCAs occurred in facilities related to physical activity, with 159 (47.7%) in athletic fields, 80 (24.0%) in gymnasiums, and 32 (9.6%) in swimming pools.

TABLE 1 Factors related to bystanders' bringing AEDs to the scene of OHCA throughout the study period (2008–2021).

		Total	Bringing AEDs to the scene of OHCA by bystanders		Univariate analysis			Multivariate analysis		
		N	*n*	(%)	RR	(95% CI)	*p*-value	RR	(95% CI)	*p*-value
Sex	Male	249	224	(90.0%)	Reference			Reference		
	Female	84	60	(71.4%)	0.794	(0.689–0.915)	0.001	0.849	(0.738–0.977)	0.022
Educational stage	Elementary school	67	47	(70.1%)	0.790	(0.669–0.932)	0.005	0.839	(0.700–1.004)	0.056
	Junior high school	105	94	(89.5%)	1.008	(0.925–1.098)	0.856	0.995	(0.916–1.080)	0.898
	High school/technical college	161	143	(88.8%)	Reference			Reference		
Witness of arrest	Witnessed	294	255	(86.7%)	1.166	(0.965–1.410)	0.112	1.062	(0.869–1.296)	0.558
	Not witnessed	39	29	(74.4%)	Reference			Reference		
Origin of arrest	Cardiac	297	254	(85.5%)	1.026	(0.880–1.196)	0.740	0.860	(0.721–1.026)	0.095
	Noncardiac	36	30	(83.3%)	Reference			Reference		
Activity at the time of arrest	Sports classes	127	116	(91.3%)	Reference			Reference		
	Sports club activities	138	118	(85.5%)	0.936	(0.858–1.021)	0.138	0.927	(0.834–1.030)	0.160
	Non-sports activities	68	50	(73.5%)	0.805	(0.691–0.937)	0.005	0.764	(0.587–0.996)	0.046
Location of arrest	Athletic field	159	139	(87.4%)	Reference			Reference		
	Gymnasium	80	72	(90.0%)	1.029	(0.937–1.131)	0.544	1.031	(0.945–1.125)	0.488
	Swimming pool	32	25	(78.1%)	0.894	(0.737–1.083)	0.253	0.927	(0.761–1.129)	0.450
	Classroom/other places	62	48	(77.4%)	0.886	(0.765–1.026)	0.105	1.065	(0.833–1.361)	0.614
Time of arrest	Weekdays from 8:00 to 16:00	232	199	(85.8%)	1.019	(0.923–1.126)	0.708	1.074	(0.956–1.205)	0.229
	All other times, including weekends	101	85	(84.2%)	Reference			Reference		
Total		333	284	(85.3%)						

Abbreviations: AED, automated external defibrillator; CI, confidence interval; OHCA, out-of-hospital cardiac arrest; RR, risk ratio.

Factors of AED delivery by lay rescuers

Table 1 also shows the proportion of lay rescuers bringing AEDs to the OHCA scene for each potential factor and the results of the modified Poisson regression analyses across the entire study period. The multivariate analysis revealed that female patients had a lower likelihood of AED delivery than male patients (RR, 0.849; 95% CI, 0.738–0.977). Similarly, cases occurring during non-sports activities were less likely to receive AED intervention compared with those occurring during sports classes (RR, 0.764; 95% CI, 0.587–0.996).

Year-by-year trends of AED delivery by lay rescuers

Table 2 shows the year-by-year trend in the proportion of lay rescuer AED delivery from 2008 to 2021 according to each subgroup. Overall, the proportion of AED deliveries by lay rescuers significantly increased over the study period, from 73.7% in 2008–2010 to 93.3% in 2020–2021 ($p < 0.001$). A significant improvement in the proportion of AED deliveries was also observed between 2008 and 2021 in most subgroups. Nevertheless, the improvements were less pronounced for female students ($p = 0.113$), non-sports activities ($p = 0.343$), and cases occurring in classrooms/other locations ($p = 0.872$) than their counterparts.

Outcomes after OHCA according to lay rescuer AED delivery to the scene

Table 3 shows the outcomes after OHCA based on whether lay rescuers brought AEDs to the scene. Overall, VF as the first documented rhythm was observed in 82.0% of cases where an AED was brought, compared to 49.0% when an AED was not brought ($p < 0.001$). One-month survival with favorable neurological outcome was 55.6% in the AED group, compared to 24.5% in the non-AED group ($p < 0.001$). In most subgroups, cases where an AED was brought to the scene showed better outcomes, with a higher proportion of VF and improved 1-month survival with favorable neurological outcome, compared to cases where an AED was not brought.

DISCUSSION

This study assessed the factors influencing whether lay rescuers bring AEDs to the scene of nontraumatic OHCAs among schoolchildren in Japan and investigated the 14-year

TABLE 2 Year-by-year trend in the proportion of lay rescuer AED delivery from 2008 to 2021 according to each subgroup.

		Year					
		2008–2010	2011–2013	2014–2016	2017–2019	2020–2021	P-for-trend
Sex	Male	84.0%	81.4%	93.2%	96.7%	100.0%	0.001
	Female	53.8%	81.8%	77.8%	77.8%	77.8%	0.113
Educational stage	Elementary school	37.5%	66.7%	80.0%	94.4%	80.0%	0.001
	Junior high school	80.0%	92.0%	95.2%	88.5%	100.0%	0.168
	High school/technical college	85.7%	81.6%	91.9%	94.1%	94.1%	0.100
Witness of arrest	Witnessed	76.5%	84.3%	91.9%	92.6%	92.3%	0.003
	Not witnessed	50.0%	63.6%	83.3%	90.0%	100.0%	0.015
Origin of arrest	Cardiac	74.3%	81.2%	91.7%	92.9%	92.9%	<0.001
	Noncardiac	66.7%	83.3%	87.5%	87.5%	100.0%	0.245
Activity at the time of arrest	Sports classes	74.1%	93.9%	90.5%	100.0%	100.0%	0.001
	Sports club activities	77.4%	75.9%	94.4%	87.1%	100.0%	0.027
	Non-sports activities	66.7%	68.4%	81.8%	84.6%	71.4%	0.343
Location of arrest	Athletic field	69.7%	90.9%	88.9%	94.3%	100.0%	0.003
	Gymnasium	81.3%	78.6%	95.0%	95.2%	100.0%	0.036
	Swimming pool	60.0%	57.1%	100.0%	100.0%	100.0%	0.012
	Classroom/other places	82.4%	68.8%	87.5%	76.9%	75.0%	0.872
Time of arrest	Weekdays from 8:00 to 16:00	70.2%	83.9%	92.3%	96.7%	90.0%	<0.001
	All other times, including weekends	84.2%	76.0%	89.7%	77.8%	100.0%	0.371
Total		73.7%	81.5%	91.2%	92.3%	93.3%	<0.001

trends in AED delivery. A unique feature of this study is its focus on whether lay rescuers brought an AED to the scene, rather than whether the AED was actually used. This approach provides a clear measure of lay rescuer intervention and highlights the crucial first step in the chain of survival by ensuring that an AED is promptly available at the scene. Previous studies have mostly concentrated on AED use and effectiveness,[4,5] but the actual usage of AEDs depends on the specific circumstances and conditions of the patient. By focusing on the act of bringing the AED, this study highlights a key aspect of lay rescuer response that is essential for improving overall emergency preparedness and outcomes. The insights gained from this research can guide improvements in emergency response protocols and lay rescuer education within school environments, supporting broader efforts in acute medicine to optimize prehospital care and enhance the effectiveness of early interventions in critical situations. Additionally, these findings could serve as valuable evidence for consideration in future updates to resuscitation guidelines, particularly in emphasizing the role of AED availability and timely intervention in prehospital settings. Our findings will inform targeted interventions and strategies to enhance AED accessibility and usage in school settings, ultimately improving survival outcomes in schoolchildren experiencing OHCA.

Our results indicate a significant year-by-year improvement in the proportion of AED deliveries by lay rescuers. This remarkable progress indicates the successful implementation of AED and resuscitation education programs in Japanese schools. Several factors contribute to this positive trend. First, the widespread distribution of AEDs in schools has likely played a significant role. In 2017, almost all public elementary, junior high, and high schools in Japan had at least one AED installed.[16] Second, many teachers, staff members, and students have been equipped with the knowledge and skills to respond effectively to cardiac emergencies. As of 2017, approximately 95% of schools in Japan have conducted basic life support (BLS) training sessions for some or all staff members, and 74% have held training sessions for all staff members annually.[16] BLS training for students has been provided during health and physical education classes, as stipulated by the curriculum guidelines for junior high[17] and high schools.[18] The proportions of schools providing hands-on training in health and physical education classes were as follows: 11.4% in elementary schools, 58.9%, junior high schools; and 66.0%, high schools. Third, the dissemination of the "ASUKA Model[19]" in schools across Japan has likely contributed to this positive trend. The ASUKA Model[19] was developed in 2012 as a guideline for accident response in schools in response to a fatal accident that occurred at an elementary school in Saitama Prefecture in 2011. Schools nationwide have been implementing this model to enhance their emergency preparedness and response capabilities. Continued efforts to enhance these initiatives can serve as a model for other public places and contribute to further improvements in emergency response and survival rates for OHCAs.

TABLE 3 Outcomes after OHCA according to bystanders' bringing AEDs to the scene.

		Bringing AEDs to the scene of OHCA by bystanders	Total	VF			CPC 1 or 2		
			N	*n*	(%)	*p*-value	*n*	(%)	*p*-value
Sex	Male	Yes	224	188	(83.9%)	<0.001	129	(57.6%)	0.005
		No	25	13	(52.0%)		7	(28.0%)	
	Female	Yes	60	45	(75.0%)	0.010	29	(48.3%)	0.020
		No	24	11	(45.8%)		5	(20.8%)	
Educational stage	Elementary school	Yes	47	25	(53.2%)	0.173	19	(40.4%)	0.043
		No	20	7	(35.0%)		3	(15.0%)	
	Junior high school	Yes	94	82	(87.2%)	0.005	56	(59.6%)	0.369
		No	11	6	(54.5%)		5	(45.5%)	
	High school/ technical college	Yes	143	126	(88.1%)	0.002	83	(58.0%)	0.004
		No	18	11	(61.1%)		4	(22.2%)	
Witness of arrest	Witnessed	Yes	255	215	(84.3%)	<0.001	145	(56.9%)	<0.001
		No	39	20	(51.3%)		11	(28.2%)	
	Not witnessed	Yes	29	18	(62.1%)	0.225	13	(44.8%)	0.048
		No	10	4	(40.0%)		1	(10.0%)	
Origin of arrest	Cardiac	Yes	254	229	(90.2%)	<0.001	156	(61.4%)	<0.001
		No	43	23	(53.5%)		11	(25.6%)	
	Noncardiac	Yes	30	4	(13.3%)	0.829	2	(6.7%)	0.418
		No	6	1	(16.7%)		1	(16.7%)	
Activity at the time of arrest	Sports classes	Yes	116	106	(91.4%)	0.005	86	(74.1%)	0.452
		No	11	7	(63.6%)		7	(63.6%)	
	Sports club activities	Yes	118	106	(89.8%)	<0.001	67	(56.8%)	<0.001
		No	20	12	(60.0%)		3	(15.0%)	
	Non-sports activities	Yes	50	21	(42.0%)	0.287	5	(10.0%)	0.894
		No	18	5	(27.8%)		2	(11.1%)	
Location of arrest	Athletic field	Yes	139	127	(91.4%)	<0.001	87	(62.6%)	0.001
		No	20	13	(65.0%)		5	(25.0%)	
	Gymnasium	Yes	72	63	(87.5%)	0.006	44	(61.1%)	0.543
		No	8	4	(50.0%)		4	(50.0%)	
	Swimming pool	Yes	25	22	(88.0%)	0.286	20	(80.0%)	0.053
		No	7	5	(71.4%)		3	(42.9%)	
	Classroom/other places	Yes	48	21	(43.8%)	0.045	7	(14.6%)	0.129
		No	14	2	(14.3%)		0	(0.0%)	
Time of arrest	Weekdays from 8:00 to 16:00	Yes	199	155	(77.9%)	<0.001	111	(55.8%)	0.002
		No	33	15	(45.5%)		9	(27.3%)	
	All other times, including weekends	Yes	85	78	(91.8%)	<0.001	47	(55.3%)	0.007
		No	16	9	(56.3%)		3	(18.8%)	
Total		Yes	284	233	(82.0%)	<0.001	158	(55.6%)	<0.001
		No	49	24	(49.0%)		12	(24.5%)	

Abbreviations: AED, automated external defibrillator; CPC, cerebral performance category; VF, ventricular fibrillation.

This study also revealed that female students with OHCAs had a lower likelihood of receiving AED interventions than male students. Moreover, the improvement in AED delivery over time was less pronounced in females than in males, with no significant trend observed. Such sex disparities in lay rescuer interventions have been noted in various studies over the years.[20–23] The persistent sex disparity despite the overall improvements in AED delivery suggests that deeply ingrained social and psychological factors influence lay rescuer behavior.[24] A previous questionnaire survey indicated that female respondents feared inappropriate contact, whereas male respondents feared accusations of sexual assault or harassment,[25] both of

which would be factors that inhibited the administration of lay rescuer interventions for women. Targeted interventions are essential to address these disparities. Educational campaigns should emphasize that legal protections for lay rescuers who provide emergency assistance apply equally, regardless of the patient's sex. Furthermore, training programs should include scenarios involving female patients to help normalize AED use in these situations. Featuring female rescuers and patients in training videos and campaigns can normalize AED use for women, reducing sex biases.

We also found that the proportion of AED deliveries was lower during non-sports activities compared with OHCAs occurring during sports classes. Additionally, the improvement in AED delivery over time was less pronounced in non-sports settings. One reason for this disparity can be the strategic placement of AEDs, predominantly near areas where physical activities are conducted. The most common locations for AED placement in schools were staff/visitor entrances and gymnasiums.[16] Considering that most schools in Japan have only one or two AEDs,[16] this placement strategy, while logical for high-risk sports events, may insufficiently cover all areas where OHCAs can occur. Furthermore, the visibility and perceived urgency of OHCAs during sports activities are relatively high, prompting a quicker and more decisive response from lay rescuers. Sports activities are often closely supervised, and the physical exertion involved increases the risk of cardiac events. By contrast, non-sports activities may not have the same level of supervision or immediate recognition of cardiac emergencies, leading to delayed responses. BLS training that simulates OHCAs in various locations can also improve lay rescuer readiness and response times, regardless of the activity or location. Enhancing awareness of the importance of AED accessibility in all areas of schools can help create a more comprehensive emergency preparedness strategy, ultimately improving the outcomes for all students. Furthermore, increasing education and training for students, who are often the bystanders present during emergencies, is also essential to improve overall emergency response readiness and outcomes in schools.

Limitations

This study has some limitations. First, a significant limitation is the lack of detailed information about lay rescuers. Our data did not include key characteristics or whether lay rescuers had received resuscitation training. The absence of detailed lay rescuer information limits the depth of analysis of the factors that influence AED delivery. Second, we did not consider the potential effects of individual school policies or emergency preparedness programs on AED delivery. Variations in training programs, AED accessibility, and school-specific response protocols can influence the likelihood of lay rescuer AED use. However, these factors were not measured or controlled for in this study. Third, as noted in a previous study,[12] the SPIRITS database may underreport OHCA cases to some extent. This underreporting can be due to input errors in the data linkage items used to develop the database and because cases not transported to the hospital by EMS were not registered. Fourth, unmeasured and/or unknown factors might have influenced the proportion of lay rescuer AED deliveries. Further studies are required to identify and investigate additional factors that may affect AED delivery in school settings.

CONCLUSION

The present study investigated the factors affecting lay rescuer AED delivery in the context of nontraumatic OHCAs among schoolchildren in Japan. The proportion of AED deliveries by lay rescuers significantly increased from 73.7% in 2008–2010 to 93.3% in 2020–2021. However, there is still room for improvement, particularly in female patients and incidents during non-sports activities. Addressing these gaps requires further efforts to fulfill the stated aim of the AED Committee of the Japanese Circulation Society to achieve "zero sudden cardiac deaths in schools."[26]

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data not shared.

ETHICS STATEMENT

Approval of the research protocol: The study protocol was approved by the Ethics Committees of Otsuma Women's University and Osaka University.
Informed consent: Personal identifiers were removed from the database, and the requirement for informed consent was waived.
Registry and registration no. of the study/trial: This study was not registered.
Animal studies: N/A.

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