ORIGINAL RESEARCH ARTICLE

Outcomes after sudden cardiac arrest in sports centres with and without on-site external defibrillators

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Received 16 September 2017
Revised 21 January 2018
Accepted 23 January 2018

ABSTRACT

Objective Sudden cardiac arrest (SCA) is a rare but tragic event during amateur sports activities. Our aim is to analyse whether availability of automated external defibrillators (AEDs) in amateur sports centres could impact on SCA survival.

Methods This is an observational study. During an 18-year period, data regarding exercise-related SCA in sports centres were prospectively collected. Survival rates and time to response were compared between centres with an AED already available and centres where an AED was not already present.

Results Out of 252 sports facilities, 207 (82%) acquired an AED during follow-up while 45 (18%) did not. From 1999 to 2014, there were 26 SCAs (24 (92%) men, 54±17 years old) with 15 (58%) of them in centres with on-site AED. Neurologically intact survival rates were 93% in centres with on-site AED and 9% in centres without (P<0.001). Presence of on-site AED, presence of shockable rhythm, first assistance by a lay bystander and time to defibrillation were all related to neurological intact survival, but the presence of on-site AED was the only independent predictor in the multivariate analysis. The use of on-site AED resulted in a lower time to first shock when compared with emergency medical system-delivered AED (3.3±1.4min vs 7.3±3.2 min; P=0.001).

Conclusions The presence of on-site AEDs is associated with neurologically intact survival after an exercise-related SCA. Continuous efforts are recommended in order to introduce AEDs in sports and fitness centres, implement educational programmes and increase common awareness about SCA.

INTRODUCTION

Out-of-hospital sudden cardiac arrest (SCA) is a leading cause of death in industrialised countries. The incidence of SCA in Europe is 275 000/year with a 10%–20% survival rate at hospital discharge.[1]

The main cause of SCA is ventricular fibrillation[2] and, in this instance, early defibrillation represents the most effective intervention affecting survival.[3–7] Since one of the major determinants of a good prognosis is the speed of intervention, many protocols have been implemented in several communities with the common goal of improving early defibrillation after out-of-hospital SCA.[8–11]

In addition, physical exercise is a well-known trigger of lethal arrhythmia.[12] Consequently, the incidence of SCA in athletes is high.[13] Since athletes are commonly healthy young individuals and the overall survival rate in this specific population is quite poor, an SCA during sports activity usually results in dramatic consequences for the community. Deployment of on-site automated external defibrillators (AEDs) in sports centres has already been suggested as a potential solution,[13 14] but data are limited.

The aim of the present study is to analyse the impact of on-site AED presence in amateur sports centres in the Piacenza area and compare survival rates and time to response on the basis of AED accessibility.

METHODS

Emergency response system

Piacenza is a mid-sized province in the Emilia-Romagna region of Italy. It has a total population of 291 700 inhabitants over an area of 2586 square kilometres, including both urban and rural communities. Since 1990, an emergency medical system (EMS) is active in coordinating the response to medical emergencies, including out-of-hospital SCA over the entire territory. In addition, in 1999 Piacenza Progetto Vita (PPV) was set up to enable rapid defibrillation. The aim and background of PPV have been previously described.[15] In brief, PPV works mainly through three approaches: (1) By increasing the common awareness on the issue of SCA in the population through educational programmes; (2) By training lay volunteers to perform only early defibrillation through quick AED use. PPV trains policemen, financial and town guards, firemen, lifeguards, personnel working in railway stations, ambulances, post offices, pharmacies and other motivated volunteers; (3) By placing AEDs at fixed and mobile locations. The latter include police and fire brigade vehicles and private assistance ambulances. As part of this programme, PPV encourages and facilitates purchase of AEDs by amateur sports and fitness centres.

Since 1999, a total number of 725 AEDs were placed (Heartstart FR semiautomated biphasic defibrillators, Philips Medical Systems, Heartstream Operation, Cardiac Science G5 semiautomated external defibrillators). Of all the AEDs,

To cite: Aschieri D, Penela D, Pelizzoni V, *et al*. *Heart* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/heartjnl-2017-312441

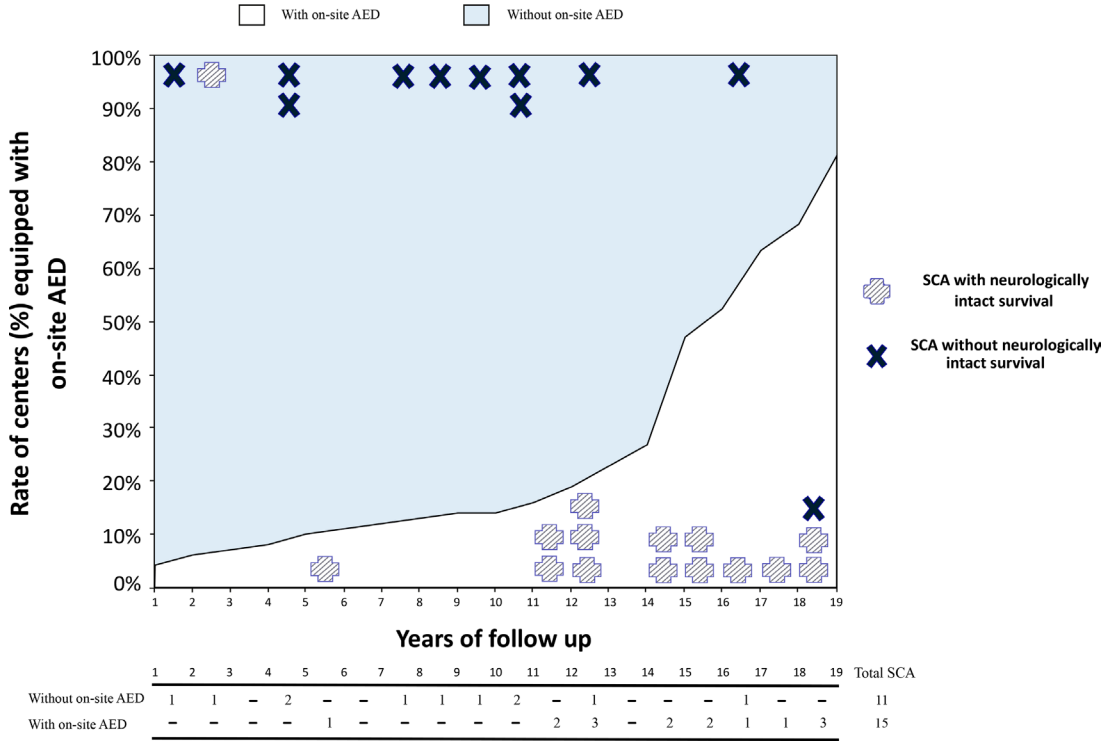

Figure 1 This figure shows the temporal pattern of automated external defibrillation (AED) placed over the study period and its relationship with the probability that a sudden cardiac arrest (SCA) occurs in a centre with or without on-site AED. At the bottom of the figure the outcomes of those SCAs that occurred in centres with an on-site AED are shown, whereas at the top of the figure the outcomes of those SCAs that occurred in centres without on-site AED are shown. Note the relationship between the rate of centres with on-site AED and the probability of neurologically intact survival.

28.5% were placed in 207 amateur sports centres, that is, 82% of the total number of such structures in the whole territory.

Data collection

Since June 1999, out-of-hospital SCA data were recorded on standardised forms and entered in the central database of Piacenza's emergency department. Those include audio recordings, event information and ECG tracings. For the present study, we selected only those cases that, according to the predetermined variable 'location' occurred in a sports centre or facility.

Assessment of neurological outcome in patients that survived was eventually performed by clinical examination at hospital discharge: patients were categorised into four functional levels according to the Cerebral Performance Scale.[7] Time to response were calculated as the difference between the time at which the emergency telephone call was received and the time when the AED was connected to the patient. For this purpose, the internal clocks of the AEDs were synchronised with the EMS central station. Times were then computed and rounded off to the nearest minute.

Continuous AED tracings were then analysed to determine the presenting rhythm and categorised either as shockable (ventricular tachycardia or ventricular fibrillation) or non-shockable (asystole or pulseless electric activity).

The patient's consent acquisition was waived at the time of the acute event due to the obvious inability to comply. All patients who survived signed an informed consent form.

Objectives

The primary objective of the study was to determine survival rates with good neurological outcome at hospital discharge. Other variables of interest included response times, presenting cardiac rhythm and level of neurological recovery in survivors. These variables were subsequently analysed based on the presence of on-site AED.

Statistical analysis

Continuous variables were presented as the mean value ±SD. Categorical variables were presented as total number and percentages. To compare means of two variables, Student's t-test or Wilcoxon test were used, as appropriate. Proportions were compared using Fisher's exact test. Logistic regression analysis was used to predict survival with favourable neurological outcome. A P value <0.10 was used to screen covariates for inclusion in the multivariate analysis. A backward-stepwise selection algorithm was applied to select covariates for inclusion in the multivariate regression model. At each step, the least significant variable was discarded and OR and 95% CI were calculated. We assessed whether survival with favourable neurological outcome had improved over time using logistic regression analysis, taking the independent variable of year of resuscitation as a continuous variable. This variable was not included in the multivariate model as it showed a strong relationship with the number of AEDs placed, as shown in figure 1. The additional benefit from on-site AED was evaluated on a per year basis taking into consideration the different times at which AEDs were acquired and the increase in survival. The yearly survival rate in sports centres without an on-site AED was considered as the baseline. A P value <0.05 was considered statistically significant. Statistical analysis was performed using R software for Windows V.2.15.0 (R project for statistical computing, Vienna, Austria).

Table 1 Individual baseline characteristics and location information on where the cardiac arrest occurred

	Gender	Age	Amateur/professional	Sport	Location	Town population	On-site AED
Case 1	Woman	22	Amateur	Swimming	Municipal swimming poll	5000–10 000	No
Case 2	Man	60	Amateur	Tennis	Private sports centre	>100 000	No
Case 3	Man	14	Amateur	Football	Municipal football centre	5000–10 000	No
Case 4	Man	48	Amateur	Football	Small football field	<5000	No
Case 5	Man	29	Amateur	Swimming	Municipal swimming poll	5000–10 000	Yes
Case 6	Man	60	Amateur	Tennis	Private sports centre	>100 000	No
Case 7	Man	64	Amateur	Tennis	Private sports centre	<5000	No
Case 8	Man	61	Amateur	Golf	Private sports centre	<5000	No
Case 9	Man	51	Amateur	Football	Small football field	<5000	No
Case 10	Man	58	Amateur	Football	Small football field	>100 000	No
Case 11	Man	65	Amateur	Swimming	Private swimming poll	>100 000	Yes
Case 12	Man	73	Amateur	Dance	Municipal sports centre	>100 000	Yes
Case 13	Man	40	Amateur	Football	Municipal sports centre	>100 000	Yes
Case 14	Man	52	Amateur	Bike	Municipal bike race	5000–10 000	Yes
Case 15	Man	50	Amateur	Swimming	Municipal swimming poll	>100 000	Yes
Case 16	Man	85	Amateur	Bowls	Municipal bowling	10 000–20 000	No
Case 17	Man	45	Amateur	Football	Private sports centre	>100 000	Yes
Case 18	Man	77	Amateur	Witness	Municipal stadium	10 000–20 000	Yes
Case 19	Man	44	Amateur	Running	Municipal sports centre	5000–10 000	Yes
Case 20	Man	47	Amateur	Football	Municipal sports centre	<5 000	Yes
Case 21	Woman	44	Amateur	Dance	Municipal sports centre	5000–10 000	Yes
Case 22	Man	65	Amateur	Running	Municipal sports centre	10 000–20 000	No
Case 23	Man	71	Amateur	Motocross	Motocross circuit	<5000	Yes
Case 24	Man	65	Amateur	Tennis	Private sports centre	>100 000	Yes
Case 25	Man	65	Amateur	Tennis	Private sports centre	>100 000	Yes
Case 26	Man	70	Amateur	Swimming	Municipal swimming poll	>100 000	Yes

AED, automated external defibrillator.

RESULTS

Twenty-six SCAs occurred in the 252 amateur sports centres. Sixteen (62%) of them occurred in urban sports centres, whereas 10 (38%) occurred in rural areas. The most practised sports during SCA were football (seven patients (27%)), tennis (five patients (19%)) and swimming (five patients (19%)). All SCAs occurred during sports practice, except for a single one that occurred in a viewer. See table 1 for details. An on-site AED was present in 15 cases (58%). Eleven (42%) patients had previously diagnosed ischaemic heart disease; in four (15%) the SCA occurs during an acute coronary syndrome; one (4%) patient was finally diagnosed with arrythmogenic right ventricular cardiomyopathy and one (4%) patient was diagnosed with idiopathic ventricular fibrillation after SCA. The aetiology of the remaining nine (35%) remains unknown. Baseline characteristics are summarised in table 2. Twenty-four patients were male (92%) and mean age at presentation was 54±17 years.

After SCA, the first intervention was performed by PPV trained volunteers in 10 cases (38%), by the EMS in 7 cases (27%) and by lay bystanders in 9 cases (35%). The first rhythm was a shockable rhythm in 21 cases (81%) and a non-shockable rhythm in 5 cases (19%).

On average, the defibrillator connection time was 5.1±3.0 min. There were substantial differences in response times according to the type of response. Mean defibrillator connection time was 2.9±1.3 min for lay bystanders, 5.4±2.5 min for trained volunteers and 9.5±2.4 min for EMS (P=0.002). In these cases in which a lay bystander connected the AED, the mean difference between the AED connection time and the EMS arrival was 4.5±3 min, as shown in table 3.

Table 2 Baseline characteristics and assistance response characteristics based on the presence of on-site AED

	Total n=26	On-site AEDs n=15	No AEDs n=11	P value
Gender (male)	24 (92%)	14 (93%)	10 (91%)	0.9
Age (years)	54±17	53±20	55.6±14	0.7
Urban centre	10 (38%)	7 (47%)	3 (27%)	0.27
Shockable rhythm	21 (81%)	14 (93%)	7 (64%)	0.03*
AED connection time, min	5.1±3.0	3.3±1.4	7.3±3.3	0.001*
First responder				0.04*
Lay bystander	9 (35%)	8 (53%)	1 (9%)	
Volunteers	10 (38%)	5 (33%)	5 (45%)	
EMS	7 (27%)	2 (14%)	5 (45%)	

AED, automated external defibrillator; EMS, emergency medical system
*p<0.05.

SCA occurred in centres with on-site AED

Fifteen SCAs (58%) occurred in amateur sports centres equipped with an on-site AED. Table 2 shows the baseline characteristics based on the presence or not of on-site AED at the time of the SCA. There were no differences in age or gender between groups. Seven SCAs (47%) occurred in urban facilities with on-site AED compared with three (27%) urban facilities without (P=0.27). On average, the defibrillator connection time was significantly lower in on-site AED centres (3.3±1.4 min vs 7.3±3.3 min, respectively; P=0.001). The first rhythm was shockable in 14 patients (93%) in centres with on-site AED versus 7 patients

Table 3 AED connection time and the time of the emergency medical system (EMS) arrival, in the eight cases in which a lay bystander connected the on-site AED

	Time from call to AED connection	First rhythm	Time from call to EMS arrival	Rhythm at the EMS arrival
Case 1	2	VF	7	Sinus rhythm
Case 2	3	VF	5	Sinus rhythm
Case 3	2	VF	5	VT
Case 4	2	VF	4	Sinus rhythm
Case 5	3	VF	13	Sinus rhythm
Case 6	4	VF	7	Sinus rhythm
Case 7	4	VF	8	Sinus rhythm
Case 8	1	VF	7	Sinus rhythm

AED, automated external defibrillator; EMS, emergency medical system; VF, ventricular fibrillation; VT, ventricular tachycardia.

(64%) in centres without (P=0.03). The first operator to connect the AED to the patient was a lay bystander in eight (53%) of the SCAs that occurred in on-site AED facilities. In these cases, the defibrillator connection time was 2.6+1.0 min compared with the 4.7±0.9 min needed when the responder was a trained volunteer or the EMS (P=0.007).

Survival rates

Overall, the rate of survival with favourable neurological outcome was 57.7% (15 patients). Six patients (23%) survived but with severe impaired neurological status (Cerebral Performance Scale=4, five (83%) of them in centres without on-site AED) and five patients (19%) died.

Having an AED already on-site was associated to increased survival with favourable neurological outcome (93% in on-site AED facilities versus 9% in non-equipped facilities, P<0.001).

Other variables related to survival with favourable neurological outcome were: presence of shockable rhythm (survival rate of 66% in patients with shockable rhythm vs 20% in patients with non-shockable rhythm; P=0.03); lay bystander as the first operator to connect the AED (survival rate of 100% vs 50% in case of trained volunteers and 14% in case of EMS; P=0.002); and defibrillator connection time (3.5+1.4 min for neurologically intact survivals versus 7.6+3.4 min for patients with permanent neurological impairment or patients that died; P=0.001).

Table 4 shows the multivariate models for predicting survival with favourable neurological outcome: on-site AED proved to be the only independent predictor of survival with preserved neurological profile (OR 142 (7.7–2520), P=0.001).

There was a non-relevant increase over time in survival with favourable neurological outcome (OR 1.19 (0.98–1.46), P=0.07). As shown in figure 1, the number of AEDs placed progressively increased over the duration of the study. In the first half of the study period (1999–2007), only 35 AEDs had been placed and only one (12%) SCA occurred in a centre already equipped with an on-site AED, as shown in table 5. On the other hand, in the second half of the study (2008–2016) the remaining 172 AEDs were placed. In this period, 14 SCAs (77%) occurred in centres equipped with on-site AEDs. Survival rate in these last 9 years was significantly higher compared with the first 9 years of the study (72% survival rate vs 25% survival with favourable neurological outcome rate, respectively; P=0.03).

According to our data, we estimate that it is necessary to provide 79 sports centres with an on-site AEDs in order to save one additional life per year, taking into consideration a baseline survival rate of 9%.

Table 4 Univariate/multivariate models for predicting survival with favourable neurological outcome

	Univariate		Multivariate	
	OR (95% CI)	P value	OR (95% CI)	P value
Sex (male)	0.7 (0.04 to 12.8)	0.81		
Age	1.01 (0.96 to 1.06)	0.78		
Urban centre	2.3 (0.44 to 12.4)	0.3		
On-site AEDs	140 (7.8 to 2514)	0.001*	142 (7.7 to 2520)	0.001
Non-shockable rhythm	0.12 (0.12 to 1.34)	0.08*		
AED connection time (min)	0.5 (0.29 to 0.88)	0.016*		

*Variables included in the model.
AED, automated external defibrillator.

DISCUSSION

This study describes the impact of on-site AEDs on improving the outcome after exercise-related SCA in sports facilities and fitness centres. The presence of on-site AED significantly reduced time to response and was an independent predictor of survival with favourable neurological outcome. The results of the present study stress out the key role of the education of the general population in the use of AEDs in the early defibrillation programmes, since the highest survival rates were observed when lay bystanders performed the first intervention.

Survival improvement with AED background

SCA is a leading case of death in athletes.[16] It was suggested that there is a three times higher incidence of SCDs in athletes (estimated at 2.3 per 100 000 individuals) than in non-athletes (0.9 per 100 000 individuals).[17] It is also relevant that the incidence of SCD is similar in competitive and recreational sports.[18] In recent years, there has been an increased interest in recreational sports,[19] due in part to heightened public awareness of the health benefit of regular physical exercise. Consequently, the absolute number of sport-related SCAs in amateur sports activities is increasing. To face this growing problem, some countries have developed protocols of preparticipation evaluation (PPE). These programmes can significantly decrease SCA-related mortality by identification and disqualification of athletes with an underlying and unsuspected cardiomyopathy.[20] However, ever if PPE had showed efficacy, the problem of sport-related SCA is still far from being resolved.[21] Placing AED in sports centres was already suggested as a potential solution.[13 14] We report an excellent rate of survival with favourable neurological outcome after SCA in sports centres equipped with on-site

Table 5 Change in assistance response characteristics over time. At the end of the first period of the study (1999–2007) 36 AEDs were placed. The remaining 171 AEDs were placed over the second period of the study (2008–2016)

	From 1999 to 2007	From 2008 to 2016	P value
SCA occurred in on-site AEDs centres	1 (12%)	14 (77%)	0.003
Shockable rhythm	5 (62%)	16 (88%)	0.28
AED connection time (min)	7.3+4	3.8+2	0.007
Survival rate	25%	72%	0.03
First response by a lay bystander	1 (12%)	8 (44%)	0.13

AED, automated external defibrillator; SCA, sudden cardiac arrest.

AED compared with those without (93% vs 9%, respectively, P<0.001). This high rate of survival in centres already equipped with an on-site AED is in line with the data reported by Drezner *et al*, who reported a 71% survival rate among SCA occurred in US high schools with AED programmes.[14] Moreover, our study shows difference in survival as well in the time to response over time, as long as AEDs were progressively placed in a significant proportion of the sports centres. In this regard, the EMS protocol for responding to the out-of-hospital SCA remained unmodified during the entire study period, as previously reported.[11] Authors attribute the higher rate of SCA during the second half of the study (from 2008 to 2016) to the increased interest in amateur sports in the last decade in developed countries.[19 22]

Finally, even if a cost-effective analysis was not the aim of the present study, the number of on-site AEDs needed to avoid a fatal event (79 per life saved per year) seems to justify the spreading of programmes to introduce AEDs in sports and fitness centres.

Relevance of education programmes in early defibrillation

The excellent rate of survival with favourable neurological outcome in centres equipped with an on-site AED was associated with a significant reduction in the defibrillator connection time. This reduction is justified for the high ratio of AEDs connected by a lay bystander. In our study more than half (53%) of the first shocks in on-site AED centres was delivered by a non-trained citizen who, autonomously or guided on phone by EMS, connected the AEDs. This finding underlines the knowledge of the citizens of Piacenza about the importance of an early defibrillation. As we claimed in the methods section, one of the PPV activities is to increase common awareness on the issue of sudden death in the general population through educational programmes. The high rate of AEDs used by non-trained individuals showed in this study highlights the relevance of the general population education programmes. Finally, a detailed map by the EMS, showing where the AEDs are placed, is critical to adequately guide the first responder.

PPV promotes early defibrillation as the cornerstone of SCA response. Therefore, all volunteers are instructed to access and turn on a nearby AED, relegating cardiopulmonary resuscitation to a secondary role. The rationale of this approach is that it vastly simplifies the response, focusing on the single item most likely to save a life, that is, shockable ventricular fibrillation.[15] Although overlooking chest compressions in the resuscitation process is controversial, the results of this study provide further evidence that early defibrillation can achieve an excellent rate of survival after SCA, even when non-medical responders perform it.

Limitations

First, our analyses are based on observational data and consequently, we cannot prove causality. Second, since postmortems were not systematically performed, the cause of fatal SCA was not established in a majority of the cases. Although we do acknowledge the importance of inhospital postresuscitation care, the focus of our study was mainly on prehospital parameters. Therefore, we are unable to provide more detailed information about inhospital postresuscitation care. Moreover, even if the protocol for responding to the out-of-hospital SCA was not modified during the study period, we cannot exclude modifications into inhospital care over time. Cases were selected only if the cardiac arrest occurred in a sports centre or facility. As a consequence, exercise-related SCAs occurring during the study period but outside of a sports centre were not included. Time between the collapse and the emergency phone call was not prospectively collected. However, all SCAs were witnessed and no call to EMS was performed prior to the collapse. Therefore, there are no reasons to suppose that this time could differ between groups. Lastly, the final decision over acquiring an AED or not, and the time of acquiring it was made by each sports centre administration. We cannot deny that it could introduce a bias, as those centres that acquired an AED earlier could be more motivated in their response to SCA.

CONCLUSIONS

Presence of on-site AEDs in sports facilities reduces the defibrillator connection time and is an independent predictor of survival with favourable neurological outcome. The presence of on-site AEDs definitely provides an excellent neurologically intact survival rate within the context of exercise-related SCA. In the light of these results, we strongly recommend continuous efforts to introduce AEDs in sports and fitness centres as well as to implement educational programmes aimed at increasing common awareness about the issue of sudden death and providing basic knowledge for AED use.

Key messages

What is already known on this subject?
Data regarding the effectiveness of automated external defibrillator (AED) programmes in treating sport-related sudden cardiac arrest (SCA) are limited.

What might this study add?
Presence of on-site AEDs in sports facilities reduces the defibrillator connection time, is associated with a high rate of shockable rhythm and provides an excellent neurologically intact survival rate within the context of exercise-related SCA.

How might this impact on clinical practice?
The results of the present study highlight the need to place AEDs in sports and fitness centres as well as to implement educational programmes aimed at increasing common awareness about the issue of sudden death and to provide basic knowledge for AED use.

Contributors DA, DP and FG wrote the manuscript. DA, GQV and AC planned the study. FG performed the statistical analysis. VP, VAC, LR, TL and GL collected data. DA is responsible for the overall content as guarantor.

Competing interests None declared.

Patient consent Obtained.

Ethics approval The present observational study complies with the Declaration of Helsinki and was approved by the local regulatory authorities.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1 Atwood C, Eisenberg MS, Herlitz J, *et al*. Incidence of EMS-treated out-of-hospital cardiac arrest in Europe. *Resuscitation* 2005;67:75–80.
2 Nichol G, Sayre MR, Guerra F, *et al*. Defibrillation for ventricular fibrillation. A shocking update. *J Am Coll Cardiol* 2017;70:1496–509.
3 Bayés de Luna A, Coumel P, Leclercq JF. Ambulatory sudden cardiac death: mechanisms of production of fatal arrhythmia on the basis of data from 157 cases. *Am Heart J* 1989;117:151–9.
4 Eisenberg MS, Bergner L, Hallstrom A. Cardiac resuscitation in the community. Importance of rapid provision and implications for program planning. *JAMA* 1979;241:1905–7.

5 Page RL, Joglar JA, Kowal RC, *et al*. Use of automated external defibrillators by a US airline. *N Engl J Med* 2000;26343:1210–6.
6 Valenzuela TD, Roe DJ, Nichol G, *et al*. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. *N Engl J Med* 2000;343:1206–9.
7 Cobb LA, Fahrenbruch CE, Walsh TR, *et al*. Influence of cardiopulmonary resuscitation prior to defibrillation in patients with out-of-hospital ventricular fibrillation. *JAMA* 1999;281:1182–8.
8 Berdowski J, Blom MT, Bardai A, *et al*. Impact of onsite or dispatched automated external defibrillator use on survival after out-of-hospital cardiac arrest. *Circulation* 2011;124:2225–32.
9 Kitamura T, Kiyohara K, Sakai T, *et al*. Public-access defibrillation and out-of-hospital cardiac arrest in Japan. *N Engl J Med* 2016;375:1649–59.
10 Hallstrom AP, Ornato JP, Weisfeldt M, *et al*. Public-access defibrillation and survival after out-of-hospital cardiac arrest. *N Engl J Med* 2004;351:637–46.
11 Capucci A, Aschieri D, Piepoli MF, *et al*. Tripling survival from sudden cardiac arrest via early defibrillation without traditional education in cardiopulmonary resuscitation. *Circulation* 2002;106:1065–70.
12 Sutherland GR. Sudden cardiac death: the pro-arrhythmic interaction of an acute loading with an underlying substrate. *Eur Heart J* 2017;38:2986–94.
13 Harmon KG, Asif IM, Maleszewski JJ, *et al*. Incidence, cause, and comparative frequency of sudden cardiac death in national collegiate athletic association athletes: a decade in review. *Circulation* 2015;132:10–19.
14 Drezner JA, Toresdahl BG, Rao AL, *et al*. Outcomes from sudden cardiac arrest in US high schools: a 2-year prospective study from the National Registry for AED use in sports. *Br J Sports Med* 2013;47:1179–83.
15 Capucci A, Aschieri D, Guerra F, *et al*. Community-based AED only resuscitation for out of hospital cardiac arrest victims. *American Heart Journal* 2016;172:192–200.
16 Harmon KG, Asif IM, Klossner D, *et al*. Incidence of sudden cardiac death in National Collegiate Athletic Association athletes. *Circulation* 2011;123:1594–600.
17 Corrado D, Basso C, Rizzoli G, *et al*. Does sports activity enhance the risk of sudden death in adolescents and young adults? *J Am Coll Cardiol* 2003;42:1959–63.
18 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.
19 Kim JH, Malhotra R, Chiampas G, *et al*. Cardiac arrest during long-distance running races. *N Engl J Med* 2012;366:130–40.
20 Mont L, Pelliccia A, Sharma S, *et al*. Pre-participation cardiovascular evaluation for athletic participants to prevent sudden death: Position paper from the EHRA and the EACPR, branches of the ESC. Endorsed by APHRS, HRS, and SOLAECE. *Europace* 2017;19:139–63.
21 Maron BJ, Haas TS, Doerer JJ, *et al*. Comparison of U.S. and Italian experiences with sudden cardiac deaths in young competitive athletes and implications for preparticipation screening strategies. *Am J Cardiol* 2009;104:276–80.
22 Sallis JF, Bull F, Guthold R, *et al*. Progress in physical activity over the Olympic quadrennium. *The Lancet* 2016;388:1325–36.