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Socioeconomic factors and outcomes from exercise-related sudden cardiac arrest in high school student-athletes in the USA

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ABSTRACT

Objective Minority student-athletes have a lower survival rate from sudden cardiac arrest (SCA) than non-minority student-athletes. This study examined the relationship between high school indicators of socioeconomic status (SES) and survival in student-athletes with exercise-related SCA.

Methods High school student-athletes in the USA with exercise-related SCA on school campuses were prospectively identified from 1 July 2014 to 30 June 2018 by the National Center for Catastrophic Sports Injury Research. High school indicators of SES included the following: median household and family income, proportion of students on free/reduced lunch and percent minority students. Resuscitation details included witnessed arrest, presence of an athletic trainer, bystander cardiopulmonary resuscitation and use of an on-site automated external defibrillator (AED). The primary outcome was survival to hospital discharge. Differences in survival were analysed using risk ratios (RR) and univariate general log-binomial regression models.

Results Of 111 cases identified (mean age 15.8 years, 88% male, 49% white non-Hispanic), 75 (68%) survived. Minority student-athletes had a lower survival rate compared with white non-Hispanic student-athletes (51.1% vs 75.9%; RR 0.67, 95% CI 0.49 to 0.92). A non-significant monotonic increase in survival was observed with increasing median household or family income and with decreasing percent minority students or proportion on free/reduced lunch. The survival rate was 83% if an athletic trainer was on-site at the time of SCA and 85% if an on-site AED was used.

Conclusions Minority student-athletes with exercise-related SCA on high school campuses have lower survival rates than white non-Hispanic athletes, but this difference is not fully explained by SES markers of the school.

INTRODUCTION

Sudden cardiac arrest (SCA) in a child or adolescent is a tragic event with devastating impact to the family and local community. SCA affects >7000 youth in the USA annually and is the leading cause of exercise-related sudden death in young competitive athletes.[1–4] A proportion of SCA in the young occurs on a school campus, with one systematic review reporting a SCA event in one per 24 –294 primary and secondary schools per year.[5] SCA events in schools present a unique opportunity for targeted interventions through medical emergency response plans that improve outcomes and reduce the occurrence of sudden cardiac death (SCD). Guidelines from the American Heart Association and consensus recommendations on emergency preparedness and management of SCA in high school athletic programmes exist to guide proper emergency responses in schools.[6 7] Current best practice recommendations for high schools recommend access to an automated external defibrillator (AED) within 3 min of collapse.[8] SCA in schools is also more likely to be witnessed and receive bystander intervention.[9] Indeed, recent studies indicate improved outcomes from SCA in middle schools and high schools largely due to wider training in cardiopulmonary resuscitation (CPR) and greater access to publicly available AEDs.[10 11]

In a 2018 study, we reported the overall survival from exercise-related SCA in young athletes was 48% across the USA.[12] Importantly, 83% of athletes survived if an athletic trainer (AT) was on-site and involved in the resucitation, and 89% of athletes survived if an AED was on-site and used.[12] However, racial differences in survival rates were found with 60% of white non-Hispanic athletes surviving SCA compared with 31% survival in minority athletes.[12] We hypothesised that socioeconomic disparities, including reduced access to an AED or AT in schools, may contribute to lower survival rates in low-income communities with a greater proportion of minority students.[12]

The purpose of this study was to (1) define survival outcomes from exercise-related SCA in high school student-athletes, and (2) examine the relationship between SES indicators in high schools and survival from exercise-related SCA occurring in student-athletes on campus. Factors affecting SCA survival such as witnessed arrest, the presence of an AT, bystander CPR and use of an on-site AED were also analysed.

METHODS

This study was conducted in collaboration with the National Center for Catastrophic Sports Injury Research (NCCSIR) and the UW Medicine Center for Sports Cardiology. The study was approved by the institutional review board at the University of North Carolina at Chapel Hill.

Case collection

Cases of SCA and SCD in young athletes participating in organised competitive sports in the USA were prospectively identified from 1 July 2014 to

30 June 2018 through an active surveillance programme led by the NCSSIR. This is an ongoing surveillance programme from which 2 years of survival data were previously reported.[12] This study includes a 4-year dataset which allows a more robust survival analysis and the additional investigation of the relationship of school socioeconomic factors and survival.

Case identification methods included a systematic search of traditional and social media sources; reporting directly to the NCCSIR or UW Medicine Center for Sports Cardiology; direct communication with the National Federation of State High School Associations, state high school associations and National Athletic Trainers' Association; and regular review of cases collected in the Parent Heart Watch database.

Attempts were made to collect additional information via phone interviews with family members, school representatives, ATs and coaches involved in the resuscitation and review of medical records and coroners and medical examiner reports in the event of autopsy. Outreach to family members and school representatives included 4–6 contact attempts by postal mail, email and/or phone over an 8-week period. Autopsy and medical records were gathered from public resources or through next-of-kin consent. All records were examined by a multidisciplinary panel, including experts in cardiovascular pathology, sports medicine and sports cardiology, to determine the underlying cause based on published criteria.[4 12–15] All sources of information were used to classify race and ethnicity. If medical examiner or medical records or a surveillance report from the family or school staff were not available (n=57), media reports and athlete photos were used to determine race and ethnicity.

Inclusion and exclusion criteria

SCA was defined as an unexpected collapse due to a cardiac cause in which CPR and/or defibrillation was provided regardless of survival outcome.[16] Cases occurring during exercise in which autopsy or medical records could not be obtained were included as cardiac in nature if the event details supported an abrupt collapse requiring cardiac resuscitation. Only exercise-related SCA cases in high school student-athletes that occurred on campus during school hours or during an organised athletic event (ie, practice or competition) were included. Cases of SCA occurring in a non-student or during a non-school-related activity outside of normal school hours were excluded.

School socioeconomic indicators

Demographic statistics and socioeconomic indicators were obtained for each high school with an SCA event. In cases during competition between two schools, the home high school's demographic statistics and SES indicators were used. The school zip codes, school districts and public/private status of the schools were obtained from each school's website. Median household and family incomes for the zip codes of the schools were obtained from the US Census Bureau's American Community Survey 5-Year Estimates (available at census.gov).[17] The years of the median household and family incomes were matched to the calendar year of incident in cases that occurred from 2014 to 2018. For cases that occurred in calendar year 2018, the 2017 incomes were used as this was the most up-to-date data available. Demographic information about the schools, including population, number of students on free/reduced lunch, enrollment by race/ethnicity and locale was acquired through the National Center for Education Statistics' Elementary/Secondary Information System.[18] The demographic and SES information of the schools was matched to the academic year (1 July–30 June) of the incident up to the 2016–2017 academic year. For cases that occurred during the 2017–2018 academic year, the 2016–2017 demographic information was used as this was the most up-to-date data available. The proportion of students on free/reduced lunch was only available for public schools. Details regarding schools' employment of full-time or part-time ATs and the presence of AEDs on school campus were provided by the Korey Stringer Institute and the National Athletic Trainers' Association Athletic Training Locations and Services (ATLAS) project.[19] School AT employment was determined by the data available in ATLAS at the time of inquiry but did not allow matching to the precise year of the event.

Resuscitation details

Resuscitation details including witnessed arrest, presence of an AT, provision of bystander CPR, use of an on-site AED (AED on school campus or brought directly by AT) and use of a defibrillator provided by responding emergency medical services (EMS) were obtained by review of available media reports and phone interviews with school staff, families or survivors.[9 14]

Data analysis and statistics

The primary outcome was survival to hospital discharge following exercise-related SCA. Differences in survival based on minority status and SES indicator percentiles (lower 10th, middle 80th and upper 90th) were analysed using χ^2 tests for the 2×3 tables. For statistically different 2×3 comparisons, post hoc pair-wise comparisons were performed with χ^2 tests with Bonferroni adjustments. In all comparisons where expected cell counts were <1 or when >20% of cell counts were <5, a Fisher's exact test was used instead. Descriptive analyses were used for resuscitation details. A Cochran-Armitage test for trend was performed to analyse the survival proportion over the four academic years included in the study period using a two-sided p value 0.05. The study period was also divided into the initial two academic years (2014/15 and 2015/16) vs the latter 2 years (2016/17 and 2017/18) to assess differences in overall survival and survival by minority status. A p value of<0.05 was considered statistically significant for all analyses.

Survival risk ratios (RR) and 95% CIs for exercise-related SCA survival (yes vs no) were calculated with univariate and multivariate modified Poisson regression with robust standard errors.[19] Independent variables included the following: sex (female vs male), minority status (minority vs white non-Hispanic), academic year (indicator variable: 2015, 2016 and 2017 vs 2014), AT employment (binary variable: part-time or full-time AT vs none), and the four school-based SES indicator variables divided into percentiles (indicator variable: 10th and 90th vs the middle 80th percentiles for median household income, median family income, proportion free/reduced lunch and proportion student minority status). There were missing values for minority status (n=10), AT employment (n=4), proportion of students on free/reduced lunch (n=23), and proportion of student minority status (n=3) and univariate and multivariate models for those variables included only cases with non-missing values. 95% CIs that did not include 1.00 were considered statistically significant. Statistical analyses were performed using RStudio[20] and SAS software.

Patient and public involvement

Patient and public involvement was not sought for design of this study, choice of outcome measures or dissemination of the results. The public could report an incident of catastrophic injury

Table 1 Demographic information for student-athletes with exercise-related sudden cardiac

	Sudden cardiac arrest with survival n (%)	Sudden cardiac death n (%)	Total n (%)
Sex			
Male	68 (91)	30 (83)	98 (88)
Female	7 (9)	6 (17)	13 (12)
Mean age, years (range)	15 (14–18)	16 (13–18)	16 (13–18)
Race			
White non-Hispanic	41 (55)	13 (36)	54 (49)
Black/African American	18 (24)	16 (44)	34 (31)
Asian	1 (1)	1 (3)	2 (2)
White Hispanic	5 (7)	6 (17)	11 (10)
Unknown	10 (13)	0 (0)	10 (9)
Activity at time of arrest			
During organised practice	36 (48)	26 (72)	62 (56)
During competition	28 (37)	5 (14)	33 (30)
During strength and conditioning	1 (1)	1 (3)	2 (2)
Physical education class	5 (7)	3 (8)	8 (7)
Pick-up game (not team sanctioned)	2 (3)	0 (0)	2 (2)
Exercise/conditioning (not team sanctioned)	0 (0)	1 (3)	1 (1)
Other recreational activity	3 (4)	0 (0)	3 (3)
Total	75	36	111

in an athlete through a public portal to the NCCSIR. Patient survivors and/or next-of-kin could provide additional information about a case via phone interview.

RESULTS

Case demographics

A total of 215 SCA cases among high school student-athletes were captured over the 4-year study period. Of the 215 total cases, 168 were exercise-related, and of the exercise-related cases, 111 (66%) occurred on a school campus during normal school hours or during practice or competition (table 1). The mean student-athlete age was 15.8 years (range 13–18) with 88% of cases occurring in males. Fifty-four (49%) athletes were white non-Hispanic, 34 (31%) black/African American, 11 (10%) white Hispanic and 2 (2%) Asian. Race could not be determined in 10 athletes.

Sixty-two (56%) cases occurred during practice and 33 (30%) occurred during competition. Cases occurring during a competition were more likely to survive (28/33; 85%) than cases occurring at practice (36/62; 58%) (χ^2 7.03, p=0.008). Additional cases in student-athletes included eight (7%) cases during physical education class, three (3%) cases during recreational activities on campus during school hours, two (2%) cases during team-sanctioned strength and conditioning, two (2%) cases during a pick-up game and one (1%) case during an exercise/conditioning activity not sanctioned by the team.

Survival outcomes and school demographics

The overall survival was 68% (75 survivors, 36 deaths). Higher survival was observed in the latter two academic years of the study period compared with the earlier 2 years but the trend was not statistically significant (figure 1). Across the 4-year study period, minority athletes had a lower likelihood of surviving

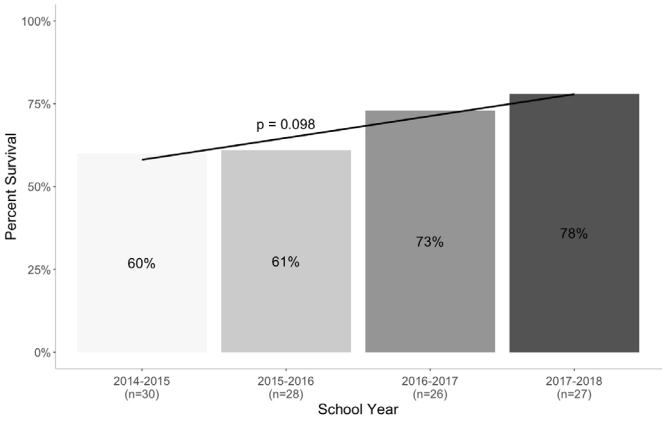

Figure 1 Survival for exercise-related sudden cardiac arrest in student-athletes on high school campuses by academic year: 1 July 2014 to 30 June 2018 (n=111).

exercise-related SCA than white non-Hispanic athletes (24/47 (51%) vs 41/54 (76%); χ^2 6.77, p=0.009; RR 0.67, 95% CI 0.49 to 0.92) (figure 2). When adjusting for covariates, while not statistically significant the effect size still suggests a meaningful difference (RR 0.76, 95% CI 0.52 to 1.13) (online supplemental table 1).

The demographics of high schools where exercise-related SCA events occurred are shown in table 2. Eighty-nine (80%) cases occurred at public schools and 22 (20%) occurred at private schools. Survival was similar between cases that occurred at public (67%; 60/89) versus private (68%; 15/22) schools. Twenty-nine (26%) of the cases occurred in a city, 48 (43%) in a suburb, 15 (13%) in a town and 18 (16%) in a rural locale. There was no difference in survival based on the location of the school: city (69%), suburb (68.8%), town (66.7%) and rural (66.7%). Sixty-eight (61%) schools employed a full-time AT, 27 (24%) employed a part-time AT and 12 (11%) did not employ an AT. Cases occurring in schools that employed an AT (full-time or part-time) had a higher survival rate (71%; 67/95) than at schools that did not employ an AT (50%; 6/12), but the difference was not statistically significant (χ^2 2.07, p=0.150) or when adjusting for covariates (RR 1.64, 95% CI 0.65 to 4.10) (online supplemental table 1).

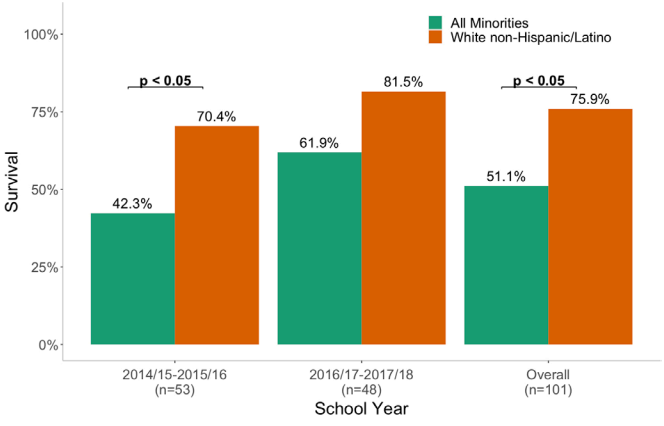

Figure 2 Survival for exercise-related sudden cardiac arrest in student-athletes on high school campuses by race: 1 July 2014 to 30 June 2018 (n=101). All comparisons not shown were non-significant.

Table 2 Demographics of high schools with a case of exercise-related sudden cardiac arrest and death, 1 July 2014 to 30 June 2018

	Sudden cardiac arrest with survival n (%)	Sudden cardiac death n (%)	Total n (%)
Public vs private school			
Public	60 (80)	29 (81)	89 (80)
Private	15 (20)	7 (19)	22 (20)
Locale			
City	20 (27)	9 (25)	29 (26)
Suburb	33 (44)	15 (42)	48 (43)
Town	10 (13)	5 (14)	15 (14)
Rural	12 (16)	6 (17)	18 (16)
Unknown	0 (0)	1 (3)	1 (1)
Athletic trainer employment			
Full-time	48 (64)	20 (56)	68 (61)
Part-time	19 (25)	8 (22)	27 (24)
None	6 (8)	6 (17)	12 (11)
Unknown	2 (3)	2 (6)	4 (4)
Total	75	36	111

*Data obtained between 1 July 2014 and 30 June 2018. Data provided as n (%).

Survival by SES indicators

Survival according to minority status and SES indicator percentiles (lower 10th, middle 80th and upper 90th) are shown in figures 3–5.

A summary of the univariate and multivariate analysis is shown in online supplemental table 1. A monotonic increase in survival was observed in univariate analyses with increasing median household or family income, but this trend attenuated when adjusting for covariates. A monotonic decrease in survival was observed in univariate analyses with increasing percent minority population or proportion of students on free/reduced lunch, but this trend also attenuated when adjusting for covariates.

Resuscitation details

Resuscitation and defibrillation details are shown in online supplemental table 2. The SCA event was witnessed in 107 (96%) cases. The administration of bystander CPR was confirmed in 88 (79%) cases and unknown in 23 (21%) cases.

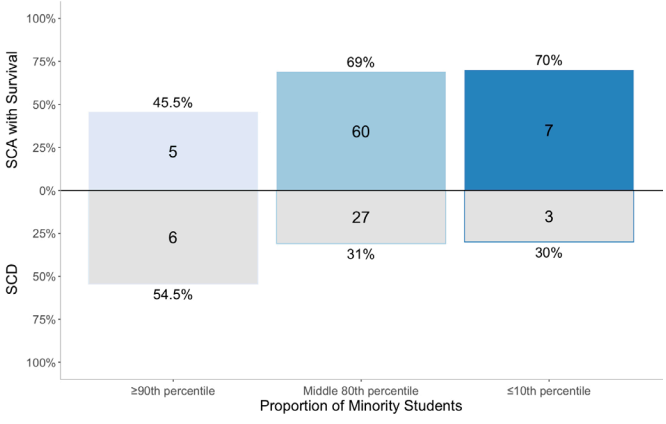

Figure 3 Survival for exercise-related sudden cardiac arrest in student-athletes on high school campuses based on the proportion of minority students. High proportion: ≥90th percentile of minority students; mid-proportion: middle 80th percentile of minority students; low proportion: ≤10th percentile of minority students. SCA, sudden cardiac arrest; SCD, sudden cardiac death.

In cases where bystander CPR was performed, 80% (70/88) of athletes survived. An AT was on-site at the time of SCA in 46 (41%) cases, not on-site in 5 (5%) cases, and the presence of an AT on-site was unknown in 60 (54%) cases. In cases where an AT was confirmed on-site at the time of SCA, 83% (38/46) of athletes survived.

An on-site AED was available at 65 (59%) schools where the SCA event occurred and used in 61 (55%) of the total cases. If an on-site AED was used in the resuscitation, 85% (52/61) of cases survived. Information on defibrillator use by the responding EMS was difficult to obtain. Defibrillator use by EMS was confirmed in 14 cases with 9/14 (64%) surviving, not used in 29 cases in which an on-site AED was already used and the athlete survived, and unknown in 68 cases.

DISCUSSION

We report a 68% survival rate in high school student-athletes with exercise-related SCA occurring on a school campus. Nationwide survival for EMS-treated children that suffer out-of-hospital

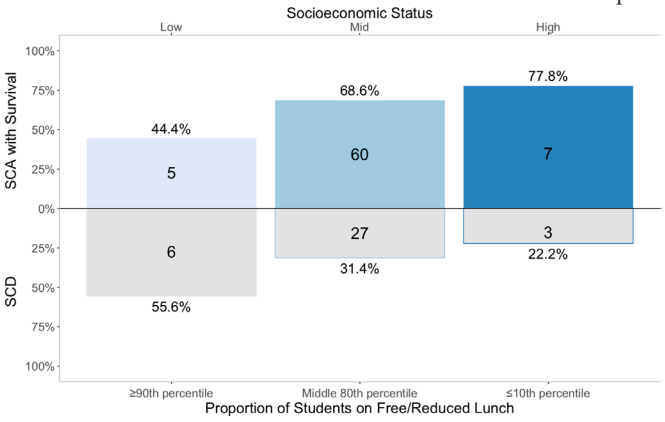

Figure 4 Survival for exercise-related sudden cardiac arrest in student-athletes on high school campuses based on the proportion of students on free/reduced lunch. Low SES: ≥90th percentile of students on free/reduced lunch; mid-SES: middle 80th percentile of students on free/reduced lunch; high SES: ≤10th percentile of students on free/reduced lunch. SCA, sudden cardiac arrest; SCD, sudden cardiac death; SES, socioeconomic status.

cardiac arrest is approximately 8%.[3 21] The higher survival rate found in this study is likely linked to the high proportion of cases that were witnessed and received prompt resuscitation. In a 2013 study of 2149 high schools in which 87% had a school-based AED programme, survival was 89% (16/18) in student-athletes with SCA during exercise.[22] The larger sample size (n=111) in this study of exercise-related SCA and inclusion of all schools independent of their emergency preparedness provides more generalisable and encouraging results.

This is the first study to analyse the relationship between school SES indicators and survival outcomes from exercise-related SCA on US high school campuses. Our findings suggest an association between SES indicators of high schools and SCA survival that attenuated when adjusting for all covariates. Low SES communities and those with a higher minority population may be disproportionately affected by SCA and death.[23–27] Across all age groups, studies report SCA rates are higher, but survival to hospital discharge is lower, in communities with a lower SES.[23–27] For example, in New York City, black patients

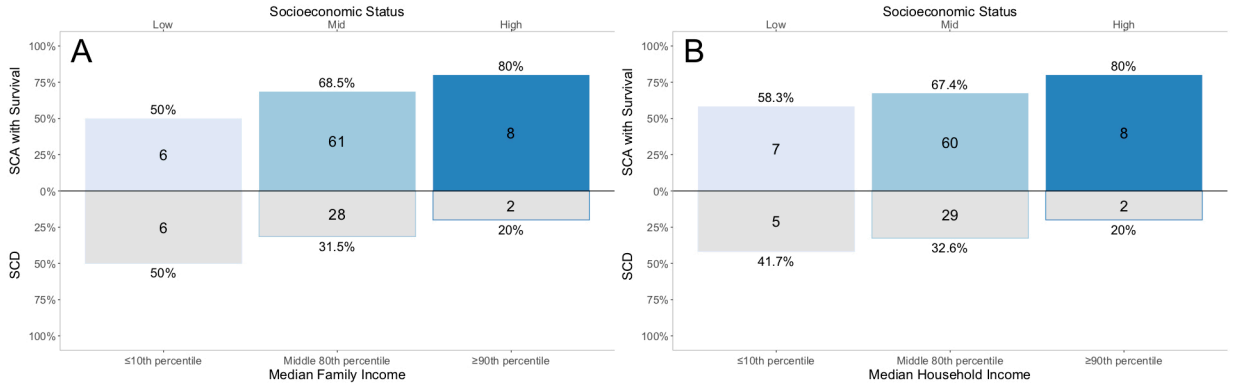

Figure 5 Survival for exercise-related sudden cardiac arrest in student-athletes on high school campuses based on median family or household income. (A) Survival based on median family income and (B) survival based on median household income. Low SES: ≤10th percentile of median family/household income; mid-SES: middle 80th percentile of median family/household income; high SES: ≥90th percentile of median family/household income. SCA, sudden cardiac arrest; SCD, sudden cardiac death; SES, socioeconomic status.

had twice the age-adjusted incidence of out-of-hospital cardiac arrest and nearly half the rate of age-adjusted survival of white patients, consistent with earlier research in Seattle and Chicago.[28 29 30] When looking specifically at SCA in youth, counties with lower SES were shown to have a higher incidence of sudden death in the young.[31] In 2018, a previous study using 2 years of the NCCSIR surveillance data reported lower survival from SCA in minority compared with white non-Hispanic athletes of all ages.[12] In this study with a longer study period and a focus only on high school athletes, minority athletes also had lower survival from exercise-related SCA than white non-Hispanic athletes. Since SES factors did not fully account for these differences in survival, future studies should explore more details of school emergency response training as well as intrinsic factors such as the specific etiologies of SCA.

Disparities also exist in communities with low SES or a higher minority population in regard to emergency preparedness to respond to SCA. Among laypeople in the USA, there is a strong correlation between SES factors and the likelihood a layperson has received CPR training.[32] A 2012 systematic review and meta-analysis identified that black patients were less likely to have a witnessed cardiac arrest, receive bystander CPR, and survive out-of-hospital cardiac arrest in the USA than white patients.[33] A 2016 study identified that black and Asian patients were less likely to suffer a witnessed arrest or receive bystander CPR than white patients.[34] In addition, patients that suffer out-of-hospital cardiac arrest in predominantly black neighbourhoods have lower rates of bystander CPR, AED use and survival than those in predominantly white neighbourhoods.[35 36] When looking specifically at schools, disparities also exist in emergency preparedness. In Michigan, schools with more students eligible for free/reduced lunch or in lower SES counties were less likely to have cardiac emergency response plans in place and the number of AEDs per student varied inversely with the size of the minority student population.[31 37] Although not directly investigated in this study, systemic or structural inequities in resources, training and emergency preparedness may exist in schools with a higher proportion of minority students and may explain in part the lower survival rate observed in minority student-athletes in this cohort. Further research is needed to understand racial/ethnic differences in outcomes from SCA in student-athletes.

Schools are in a unique position to implement targeted interventions that improve outcomes from SCA. In Japan, a nationwide survey determined that students that suffered out-of-hospital cardiac arrest in a school were more likely to be defibrillated by bystanders and had better overall outcomes than in other locations.[9] In this study, 96% of exercise-related SCA events that occurred on high school campuses were witnessed, providing a critical opportunity for a prompt emergency response.

Current emergency health and safety best practice policy recommendations for high schools advise that all schools implement and practice an emergency action plan for SCA, provide CPR and AED education for anticipated responders, employ an AT that is available for practices/competitive events, and have well-maintained AEDs accessible within 3 min of collapse.[6–8] Additionally, guidelines from the American Heart Association advise that high schools provide formal CPR education to all freshman and junior students.[6] The cost for schools to purchase an AED, institute a medical emergency response plan, educate students in CPR, and institute a lay rescuer AED programme is estimated at US$7965 per school in the first year, with an annual cost of US$3065 in subsequent years.[6] Although these costs may be difficult in schools with limited resources, implementation of these policies undoubtedly provides a foundation to improve survival from out-of-hospital cardiac arrest. Our study found that when bystander CPR was performed, 80% of student-athletes survived; when an on-site AED was used in the resuscitation, 85% of student-athletes survived; and when an AT was on-site and involved in the resuscitation, 83% of student-athletes survived.

Our study demonstrated a trend towards improved SCA survival in the latter 2 years of the study. When comparing the first 2 years to the final 2 years of the study, overall survival improved by 15%. Additionally, the minority status disparities in survival also appear to narrow in the latter 2 years of the study. Whereas there was a 28% difference in survival between white non-Hispanic athletes and minority athletes in the 2014/15–2015/16 academic years, this difference decreased to 20% in the 2016/17–2017/18 academic years. Although this narrowing of the survival gap between white non-Hispanic and minority students in more recent years is encouraging, there is undoubtedly still work to be done.

One avenue to close SES and racial disparities in SCA survival is through broader legislation and funding to ensure all high schools meet best practice recommendations for SCA preparedness. In the USA, the majority of states do not mandate the placement of AEDs in schools and even fewer provide adequate funding to cover the associated costs.[38] In Washington, 82%

of high schools without AEDs identified financial resources as either the first or second obstacle to acquiring an AED, with 60% of all schools with AEDs relying on donations to implement an AED programme.[39] These findings present an opportunity for advocacy and increased legislation to improve SCA preparedness in schools. A 2017 study identified that state legislation in Connecticut led to an increase in AED prevalence among local high schools.[40] In Oregon, high schools with an AT were both more likely to have an AED available and to implement venue-specific emergency action plans.[41] high schools with AED programmes also are more likely to establish a comprehensive emergency action plan.[42]

Limitations

This study has limitations that should be acknowledged in the interpretation of results. First, there is no mandatory reporting system for SCA in high school student-athletes which may result in missing SCA cases in this study. However, this study used a national ongoing surveillance system for capture of SCA cases and the details about each event, as well as application of a rigorous, expert-informed adjudication process to evaluate all SCA cases. Second, acquisition of case details, medical records and autopsy reports is difficult and resulted in missing data regarding race and ethnicity and the details of the resuscitation. In cases where more explicit records were unavailable, media reports and athlete photos were used to determine race and ethnicity which may have been inaccurate. Although this study had a process in place to contact families and schools involved, in many cases family or school staff would not respond or were hesitant to provide information regarding the case. Third, with only 111 cases, power for some analyses were limited, and a longer study period is needed to better understand the relationship between school SES indicators and survival. Fourth, while AT employment information is continually updated in the ATLAS database, a potential mismatch in AT services and AED presence at the time of the SCA may have occurred as we were unable to match the ATLAS data to the precise year of the event. Fifth, Bonferroni is a conservative method for assessing differences and may miss significant differences. Similarly, using 95% CIs of the RR that exclude 1.00 (null value) to determine statistically significant differences may be overly conservative (ie, fail to reject the null when it should have been rejected).[43] Finally, although the median household and family incomes and proportion of students on free/reduced lunch are useful indicators to estimate a school's SES, they are not exact measurements of school resources. Investigation of other markers of SES and school resources such as the Area Deprivation Index, the Center for Disease Control's Social Vulnerability Index, educational attainment, and the proportion of residents living below the poverty line should be considered in future studies.

CONCLUSION

This study demonstrates that exercise-related SCA in a student-athlete on a high school campus is largely a survivable event with prompt on-site resuscitation. However, minority student-athletes with exercise-related SCA have a lower survival rate than white non-Hispanic student-athletes, and this difference is not fully explained by markers of SES in the high schools. All SES indicators suggest a possible relationship between higher SES in schools and greater SCA survival. Wider advocacy, legislation, and funding aimed to increase emergency preparedness, the presence of AEDs, and AT employment in high schools may help narrow the disparities in SCA survival based on minority status and school SES factors.

What are the new findings?

- From July 2014 to June 2018, the overall survival rate in US high school student-athletes with exercise-related sudden cardiac arrest (SCA) was 68%; survival rates were >80% if an athletic trainer was present or an on-site automated external defibrillator (AED) was used in the resuscitation.
- Minority student-athletes with exercise-related SCA on high school campuses have lower survival rates than white non-Hispanic athletes (51.1% vs 75.9%; RR 0.67, 95% CI 0.49 to 0.92); this difference is not fully explained by socioeconomic factors of the schools.

How might it impact on clinical practice in the future?

- Universal emergency preparedness for SCA with trained responders and access to an AED are strongly encouraged at all schools and athletic venues hosting competitive sport.
- Wider advocacy, legislation and funding aimed to increase the presence of emergency action plans, AEDs and athletic trainer employment in high schools may help narrow disparities in SCA survival based on minority status or school socioeconomic factors.

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REFERENCES

1 Maron BJ, Doerer JJ, Haas TS, *et al*. Sudden deaths in young competitive athletes. *Circulation* 2009;119:1085–92.
2 Endres BD, Kerr ZY, Stearns RL, *et al*. Epidemiology of sudden death in organized youth sports in the United States, 2007-2015. *J Athl Train* 2019;54:349–55.
3 Benjamin EJ, Virani SS, Callaway CW, *et al*. Heart disease and stroke Statistics-2018 update: a report from the American heart association. *Circulation* 2018;137:e67–492.
4 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.
5 Smith CM, Colquhoun MC. Out-Of-Hospital cardiac arrest in schools: a systematic review. *Resuscitation* 2015;96:296–302.
6 Hazinski MF, Markenson D, Neish S, *et al*. Response to cardiac arrest and selected life-threatening medical emergencies: the medical emergency response plan for schools--a statement for healthcare providers, policymakers, school administrators, and community leaders. *Ann Emerg Med* 2004;43:83–99.
7 Drezner JA, Courson RW, Roberts WO, *et al*. Inter-association Task force recommendations on emergency preparedness and management of sudden cardiac arrest in high school and College athletic programs: a consensus statement. *J Athl Train* 2007;42:143–58.
8 Casa DJ, Almquist J, Anderson SA, *et al*. The inter-association Task force for preventing sudden death in secondary school athletics programs: best-practices recommendations. *J Athl Train* 2013;48:546–53.
9 Mitani Y, Ohta K, Ichida F, *et al*. Circumstances and outcomes of out-of-hospital cardiac arrest in elementary and middle school students in the era of public-access defibrillation. *Circ J* 2014;78:701–7.
10 Atkins DL, Berger S. Improving outcomes from out-of-hospital cardiac arrest in young children and adolescents. *Pediatr Cardiol* 2012;33:474–83.
11 Berger S, Stuart B. Survival from out-of-hospital cardiac arrest: are we beginning to see progress? *J Am Heart Assoc* 2017;6:e007469.
12 Drezner JA, Peterson DF, Siebert DM, *et al*. Survival after Exercise-Related sudden cardiac arrest in young athletes: can we do better? *Sports Health* 2019;11:8.
13 Harmon KG, Asif IM, Maleszewski JJ, *et al*. Incidence and etiology of sudden cardiac arrest and death in high school athletes in the United States. *Mayo Clin Proc* 2016;91:1493–502.
14 Harmon KG, Drezner JA, Maleszewski JJ, Harmon Kimberly G, Drezner Jonathan A, *et al*. Pathogeneses of sudden cardiac death in national collegiate athletic association athletes. *Circ Arrhythm Electrophysiol* 2014;7:198–204.
15 Peterson DF, Kucera K, Thomas LC, *et al*. Aetiology and incidence of sudden cardiac arrest and death in young competitive athletes in the USA: a 4-year prospective study. *Br J Sports Med* 2021;55:1196-1203.
16 Peterson DF, Siebert DM, Kucera KL, *et al*. Etiology of sudden cardiac arrest and death in US competitive athletes: a 2-year prospective surveillance study. *Clin J Sport Med* 2020;30:305-314.
17 Bureau UC. American community survey (ACS). the United States census bureau. Available: https://www.census.gov/programs-surveys/acs [Accessed 23 Feb 2020].
18 ELSI - Elementary and Secondary Information System. Available: https://nces.ed.gov/ccd/elsi/tableGenerator.aspx [Accessed 16 July 2019].
19 How can I estimate relative risk in SAS using proC genmod for common outcomes in cohort studies? | SAS FAQ. Available: https://stats.idre.ucla.edu/sas/faq/how-can-i-estimate-relative-risk-in-sas-using-proc-genmod-for-common-outcomes-in-cohort-studies/ [Accessed 27 Aug 2021].
20 R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, 2019. Available: https://www.R-project.org/
21 Committee on the treatment of cardiac arrest: current status and future directions, board on health sciences policy, Institute of medicine. strategies to improve cardiac arrest survival: a time to act. (Graham R, McCoy MA, Schultz am, eds.). National academies press (US), 2015. Available: http://www.ncbi.nlm.nih.gov/books/NBK305685/ [Accessed 20 Jun 2019].
22 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.
23 Chugh SS, Reinier K, Teodorescu C, *et al*. Epidemiology of sudden cardiac death: clinical and research implications. *Prog Cardiovasc Dis* 2008;51:213–28.
24 Reinier K, Thomas E, Andrusiek DL, *et al*. Socioeconomic status and incidence of sudden cardiac arrest. *Can Med Assoc J* 2011;183:1705–12.
25 Reinier K, Stecker EC, Vickers C, *et al*. Incidence of sudden cardiac arrest is higher in areas of low socioeconomic status: a prospective two year study in a large United States community. *Resuscitation* 2006;70:186–92.
26 Feero S, Hedges JR, Stevens P. Demographics of cardiac arrest: association with residence in a low-income area. *Acad Emerg Med* 1995;2:11–16.
27 Jonsson M, Härkönen J, Ljungman P, *et al*. Survival after out-of-hospital cardiac arrest is associated with area-level socioeconomic status. *Heart* 2019;105:632–8.
28 Galea S, Blaney S, Nandi A, *et al*. Explaining racial disparities in incidence of and survival from out-of-hospital cardiac arrest. *Am J Epidemiol* 2007;166:534–43.
29 Becker LB, Han BH, Meyer PM, *et al*. Racial differences in the incidence of cardiac arrest and subsequent survival. The CPR Chicago project. *N Engl J Med* 1993;329:600–6.
30 Cowie MR, Fahrenbruch CE, Cobb LA, *et al*. Out-Of-Hospital cardiac arrest: racial differences in outcome in Seattle. *Am J Public Health* 1993;83:955–9.
31 White MJ, Loccoh EC, Goble MM, *et al*. High school cardiac emergency response plans and sudden cardiac death in the young. *Prehosp Disaster Med* 2017;32:269–72.
32 Abdulhay NM, Totolos K, McGovern S, *et al*. Socioeconomic disparities in layperson CPR training within a large U.S. City. *Resuscitation* 2019;141:13–18.
33 Shah KSV, Shah ASV, Bhopal R. Systematic review and meta-analysis of out-of-hospital cardiac arrest and race or ethnicity: black us populations fare worse. *Eur J Prev Cardiol* 2014;21:619–38.
34 Ghobrial J, Heckbert SR, Bartz TM, *et al*. Ethnic differences in sudden cardiac arrest resuscitation. *Heart* 2016;102:1363–70.
35 Starks MA, Schmicker RH, Peterson ED, *et al*. Association of neighborhood demographics with out-of-hospital cardiac arrest treatment and outcomes: where you live may matter. *JAMA Cardiol* 2017;2:1110–8.
36 Sasson C, Magid DJ, Chan P, *et al*. Association of neighborhood characteristics with bystander-initiated CPR. *N Engl J Med* 2012;367:1607–15.
37 White MJ, Loccoh EC, Goble MM, *et al*. Availability of automated external defibrillators in public high schools. *J Pediatr* 2016;172:142–6.
38 Sherrid MV, Aagaard P, Serrato S, *et al*. State requirements for automated external defibrillators in American schools: framing the debate about legislative action. *J Am Coll Cardiol* 2017;69:1735–43.
39 Rothmier JD, Drezner JA, Harmon KG. Automated external defibrillators in Washington state high schools. *Br J Sports Med* 2007;41:301–5.
40 Thornton MD, Cicero MX, McCabe ME, *et al*. Automated external defibrillators in high schools: disparities persist despite legislation. *Pediatr Emerg Care* 2020;36:419–23.
41 Johnson ST, Norcross MF, Bovbjerg VE, *et al*. Sports-Related emergency preparedness in Oregon high schools. *Sports Health* 2017;9:181–4.
42 Toresdahl BG, Harmon KG, Drezner JA. High school automated external defibrillator programs as markers of emergency preparedness for sudden cardiac arrest. *J Athl Train* 2013;48:242–7.
43 Schenker N, Gentleman JF. On judging the significance of differences by examining the overlap between confidence intervals. *Am Stat* 2001;55:182–6.