Survival trends in the United States following exercise-related sudden cardiac arrest in the youth: 2000–2006

Jonathan A. Drezner, MD, Jordan S.D.Y. Chun, MD, Kimberly G. Harmon, MD, Linette Derminer

From the Department of Family Medicine, University of Washington, Seattle, Washington and Parent Heart Watch, Geneva, Ohio.

BACKGROUND Sudden cardiac arrest is the leading cause of death in young athletes. However, limited studies have examined survival rates after exercise-related sudden cardiac arrest in the youth.

OBJECTIVE The Purpose of this study was to monitor exercise-related sudden death in the United States and to assess survival trends following exercise-related sudden cardiac arrest in the youth.

METHODS From January 1, 2000, through December 31, 2006, exercise-related sudden death events in young individuals were identified through a systematic search of public media reports. Media reports were reviewed to clarify case circumstances and relation to exercise, cause of death, outcome, and use of a defibrillator. The study used an observational cohort design with weekly searches and updates to the database.

RESULTS During the 7-year period from 2000–2006, 486 total cases of exercise-related sudden cardiac arrest were identified in elementary school (age 5–11 years), middle school (age 11–14 years), high school (age 14–18 years), and college (age 18–22 years) individuals in the United States, with an average of 69 cases per year (range 48–96 years). Eighty-three percent (405/486) of victims were male and 17% (81/486) were female, with a male-to-female ratio of 5:1. Overall survival during this time period was 11% (55/486), with a range of 4% to 21% survival per year. There was a statistically significant trend toward improved survival in recent years ($P = .035$). Females were more likely to survive sudden cardiac arrest than were males (21% vs 9%, $P = .001$).

CONCLUSION Survival following exercise-related sudden cardiac arrest in the youth has been universally poor over the last 7 years in the United States, despite a recent trend toward improved survival. Improved reporting systems are needed to accurately monitor these events, and strategies to improve outcomes from exercise-related sudden cardiac arrest in the youth, such as improved emergency response planning and public access defibrillation programs, should be considered.

KEYWORDS Sudden cardiac death; Sudden cardiac arrest; Survival; Athlete; Sports; Defibrillator

(Heart Rhythm 2008;5:794–799)

Introduction

Exercise-related sudden death in young individuals is a catastrophic event with far-reaching emotional and social impact on communities.[1–3] The vast majority of these sudden deaths are due to a variety of structural cardiovascular abnormalities (i.e., cardiomyopathies) and primary electrical diseases (i.e., channelopathies) that go undetected in otherwise healthy appearing athletes.[1–9] Although such cardiac events are reported to be uncommon, the true incidence of exercise-related sudden cardiac arrest (SCA) is unknown.[2,10,11] In the United States, evaluation of SCA in young athletes is limited by the lack of a mandatory reporting system for juvenile sudden death. Studies to date have relied on survey or nonmandatory reporting systems that likely underestimate the true incidence of SCA in athletes.[2,3,7] Available studies have estimated the annual incidence of sudden cardiac death in high school-aged athletes to be 1:100,000 to 1:300,000 and 1:65,000 to 1:69,000 in college-aged athletes.[2,4,10–12] More recently, intensive search of public media reports and other electronic databases has identified a larger number of cases of SCA in athletes than previously established. The Sudden Death in Young Athletes Registry in the United States has identified approximately 115 cases of SCA per year in young competitive athletes, or about one case of sudden death every 3 days in the United States in organized youth sports.[13] Thus, with approximately five million competitive high school athletes and 500,000 competitive collegiate athletes, a more accurate estimate of the annual incidence of SCA in young athletes is approximately 1:50,000 athletes.

Dr. Drezner is on the Medical Advisory Board for Parent Heart Watch, the Medical and Scientific Advisory Board for the Sudden Cardiac Arrest Association, and the Scientific Advisory Board for Heart Screen America, for which he also is a partial stockholder. Dr. Drezner is the Director of the National Registry for AED Use in Sports and has received grant funding from the National Operating Committee on Standards for Athletic Equipment to study emergency planning and sudden cardiac arrest in the athletic setting. Mrs. Derminer is the Executive Director of Parent Heart Watch.

Address reprint requests and correspondence: Dr. Jonathan A. Drezner, Department of Family Medicine, University of Washington, Box 354775, Seattle, Washington 98015. E-mail address: jdrezner@fammed.washington.edu. (Received October 20, 2007; accepted March 1, 2008.)

1547-5271/$ -see front matter doi:10.1016/j.hrthm.2008.03.001

Prior studies of sudden cardiac death in athletes have focused mostly on determining the etiology and incidence. Limited studies have examined survival rates after SCA in young athletes. These reports have found rather dismal survival rates despite the otherwise good health and conditioning of the young athletes with SCA. In a small series of collegiate athletes, the survival rate was 11% despite timely resuscitation in most cases.[14] In the U.S. Commotio Cordis Registry, the overall survival rate was found to be 16%.[15]

The purpose of this study was to monitor exercise-related sudden death in the United States and to assess survival trends following exercise-related SCA in the youth.

Methods

From 2000–2006, exercise-related sudden death events in young individuals were identified through a systematic search of public media reports. The search was conducted by members of Parent Heart Watch, a national organization and support network of parents and families of children affected by SCA dedicated to preventing sudden cardiac death in the youth. During this 7-year period, approximately 15 hours per week was spent performing Internet-based searches using three search engines (Google, Yahoo, and Topix.net) and the following search terms: student, athlete, collapsed, died, heart, cardiac, arrest, attack, football, basketball, baseball, soccer, running, school, unknown, college, defibrillator, saved. Search terms were chosen to identify all cases of SCA, including both deaths and survivors. Accordingly, the study used an observational cohort design, with cases determined longitudinally through weekly updates.

All cases of apparent exercise-related sudden death in elementary school, middle school, high school, and college-aged individuals were reviewed. Both recreational athletes and competitive athletes participating in organized sports were included. A case was defined as exercise related if it occurred during exercise or within 1 hour of completing exercise. Cases not thought to be exercise related were excluded.

One of the study authors (JC) reviewed all of the available Internet-based media reports for the purposes of clarification of case circumstances and relation to exercise, cause of death, outcome, and use of a defibrillator. Cases that were noncardiac in origin were excluded. The remaining cases were classified as confirmed SCA or suspected SCA based on details of the media report. Suspected SCA included cases with a witnessed collapse of unknown cause but in whom SCA was probable based on the available information.

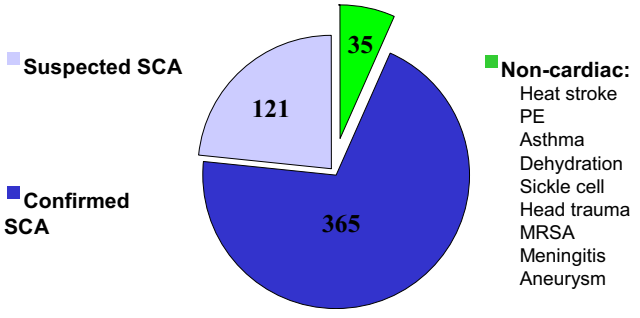

Figure 1 Exercise-related sudden cardiac arrest (SCA) in the youth from 2000–2006 in the United States. MRSA = methicillin-resistant *Staphylococcus aureus;* PE = pulmonary embolism.

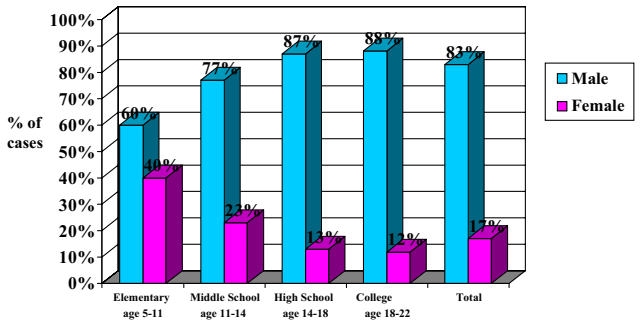

Figure 2 Gender differences in exercise-related sudden cardiac arrest.

Statistical analysis was conducted with SPSS 11.5 (SPSS, Inc., Chicago, IL, USA), using the Pearson Chi-square statistic to assess significance for comparisons of proportions and the linear-by linear association for test for trend.[16] The study was approved by the Human Subjects Division at the University of Washington.

Results

During the 7-year period from 2000–2006, 521 total cases of exercise-related sudden death were identified in the United States in elementary school, middle school, high school, and college-aged individuals. The age range for cases based on school level was 5–11 years for elementary school, 11–14 years for middle school, 14–18 years for high school, and 18–22 years for college. Of these 521 cases, 35 were excluded from further analysis after the cause of death was determined to be noncardiac (Figure 1). Three-hundred sixty-five cases were confirmed SCA, and 121 cases were suspected SCA based on the available information in the media report.

Over 7 years, 486 total cases of exercise-related SCA were identified in U.S. youth, with an average of 69 cases per year (range 48–96). Overall, 83% (405/486) of victims were male and 17% (81/486) were female, with a male-to-female ratio of 5:1 (Figure 2). Males represented 60%, 77%, 87%, and 88% of cases in the elementary school, middle school, high school, and college populations, respectively.

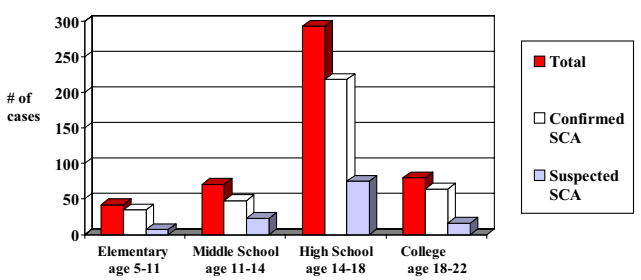

Figure 3 Exercise-related sudden cardiac arrest (SCA) by school level.

Table 1 Exercise-related sudden cardiac arrest in the youth

	2000			2001			2002		
	Deaths	Survivors	Total SCA	Deaths	Survivors	Total SCA	Deaths	Survivors	Total SCA
Elementary (age 5–11), Male									
Confirmed	0	0	0	0	0	0	2	0	2
Suspected	1	0	1	0	0	0	1	0	1
Total	1	0	1	0	0	0	3	0	3
Elementary (age 5–11), Female									
Confirmed	0	0	0	3	0	3	0	0	0
Suspected	0	0	0	0	0	0	0	0	0
Total	0	0	0	3	0	3	0	0	0
Elementary, Total	1	0	1	3	0	3	3	0	3
Middle School (age 11–14), Male									
Confirmed	1	0	1	8	2	10	3	1	4
Suspected	0	0	0	1	0	1	2	0	2
Total	1	0	1	9	2	11	5	1	6
Middle School (age 11–14), Female									
Confirmed	1	0	1	2	1	3	0	0	0
Suspected	0	0	0	0	0	0	0	0	0
Total	1	0	1	2	1	3	0	0	0
Middle School, Total	2	0	2	11	3	14	5	1	6
High School (age 14–18), Male									
Confirmed	24	3	27	17	2	19	21	1	22
Suspected	6	0	6	13	0	13	11	0	11
Total	30	3	33	30	2	32	32	1	33
High School (age 14–18), Female									
Confirmed	6	1	7	1	0	1	6	1	7
Suspected	0	0	0	0	0	0	0	0	0
Total	6	1	7	1	0	1	6	1	7
High School, Total	36	4	40	31	2	33	38	2	40
College (age 18–22), Male									
Confirmed	4	0	4	10	0	10	9	1	10
Suspected	0	0	0	2	0	2	1	0	1
Total	4	0	4	12	0	12	10	1	11
College (age 18–22), Female									
Confirmed	0	1	1	0	0	0	0	0	0
Suspected	0	0	0	0	0	0	1	0	1
Total	0	1	1	0	0	0	1	0	1
College, Total	4	1	5	12	0	12	11	1	12
Grand Total	43	5	48	57	5	62	57	4	61

All ages are given in years.
SCA = sudden cardiac death.

The majority of cases of SCA occurred in the high school-aged population (Figure 3). Table 1 lists the number of deaths and survivors based on the year and school level.

Overall survival during this time period was poor, with an average survival rate of 11% (55/486) and a range of 4% to 21% survival per year (Figure 4). When cases of confirmed SCA were considered alone, survival was similarly poor at 11% (40/365). Survival in cases of suspected SCA was 12% (15/121), suggesting the two groups were similar ($P = .665$). There was a statistically significant trend toward improved survival in more recent years. A linear-by-linear association test for trend showed that overall survival for all cases of SCA improved in recent years ($P = .035$) as well as when only those cases of confirmed SCA were considered ($P = .018$). There was no difference in survival between age groups or school level. Females were more likely to survive SCA than were males (21% vs 9%, $P = .001$; Figure 5).

Of the 55 cases of survival, the details of resuscitation were reported by the media in 40 cases. Of these 40 cases, 93% (37/40) received defibrillation: 35% (14/40) through use of an automated external defibrillator (AED) by a nontraditional first responder and 58% (23/40) through defibrillation by emergency medical services (EMS) personnel (Figure 6). It appeared there may be a trend toward increased AED use by nontraditional first responders in recent years; however, the number of cases was too small to perform a trend analysis. The details of the resuscitation and method of defibrillation were provided in only 12 (<3%) of 431 media reports of nonsurvivors; thus, further analysis on the details of defibrillation in this group was not possible.

Table 1 continued

2003			2004			2005			2006			2000–2006		
Deaths	Survivors	Total SCA	Deaths	Survivors	Total SCA	Deaths	Survivors	Total SCA	Deaths	Survivors	Total SCA	Deaths	Survivors	Total SCA
3	0	3	5	3	8	6	0	6	1	0	1	17	3	20
0	0	0	2	0	2	0	0	0	1	0	1	5	0	5
3	0	3	7	3	10	6	0	6	2	0	2	22	3	25
2	0	2	2	0	2	5	1	6	2	0	2	14	1	15
0	0	0	0	0	0	2	0	2	0	0	0	2	0	2
2	0	2	2	0	2	7	1	8	2	0	2	16	1	17
5	0	5	9	3	12	13	1	14	4	0	4	38	4	42
6	0	6	2	0	2	6	1	7	5	3	8	31	7	38
3	0	3	1	0	1	4	0	4	6	0	6	17	0	17
9	0	9	3	0	3	10	1	11	11	3	14	48	7	55
1	0	1	1	0	1	0	0	0	2	1	3	7	2	9
0	0	0	1	1	2	3	0	3	2	0	2	6	1	7
1	0	1	2	1	3	3	0	3	4	1	5	13	3	16
10	0	10	5	1	6	13	1	14	15	4	19	61	10	71
26	0	26	20	3	23	32	5	37	30	5	35	170	19	189
8	1	9	7	1	8	9	1	10	8	1	9	62	4	66
34	1	35	27	4	31	41	6	47	38	6	44	232	23	255
4	0	4	1	1	2	3	2	5	1	1	2	22	6	28
2	1	3	2	0	2	1	2	3	2	0	2	7	3	10
6	1	7	3	1	4	4	4	8	3	1	4	29	9	38
40	2	42	30	5	35	45	10	55	41	7	48	261	32	293
9	1	10	5	0	5	7	1	8	7	2	9	51	5	56
5	0	5	2	0	2	3	0	3	1	0	1	14	0	14
14	1	15	7	0	7	10	1	11	8	2	10	65	5	70
0	1	1	1	1	2	1	0	1	2	1	3	4	4	8
0	0	0	0	0	0	1	0	1	0	0	0	2	0	2
0	1	1	1	1	2	2	0	2	2	1	3	6	4	10
14	2	16	8	1	9	12	1	13	10	3	13	71	9	80
69	4	73	52	10	62	83	13	96	70	14	84	431	55	486

Discussion

To our knowledge, this is the largest study assessing survival following exercise-related SCA in young individuals in the United States. Although this study was not designed to calculate the true incidence rate of exercise-related SCA, an average of one to two cases per week were identified in the United States over the last 7 years. It also is likely that not all cases were identified due to underreporting and limitations in the search process.

This study identified a higher proportion of female victims of SCA than has been previously reported. Past studies found a male-to-female ratio of 9:1 versus the 5:1 ratio found in this study.[2,3,5,11] One potential factor contributing to the higher proportion of female SCA victims in this study is the inclusion of recreational athletes and all exercise-related SCA. Past studies focused primarily on competitive athletes involved in organized athletics. Thus, although exercise-related SCA may be more common in females than previously suspected, the differences in study populations may account for this finding.

Survival following exercise-related SCA in young individuals was universally poor and consistent with rates reported in earlier smaller studies.[14,15] Historically, survival following out-of-hospital SCA in the general population has been low when relying solely on conventional EMS response.[17,18] Public access defibrillation programs with use of an AED by nontraditional responders or bystanders have greatly improved survival from out-of-hospital cardiac arrest, with survival rates from 41% to 74% if bystander CPR is provided and defibrillation occurs within 3 to 5 minutes of collapse.[12,19–27] The poor survival found in this study in young individuals is in many ways counterintuitive given their otherwise good health and youth. Factors responsible in part for the low survival rates in young athletes have been

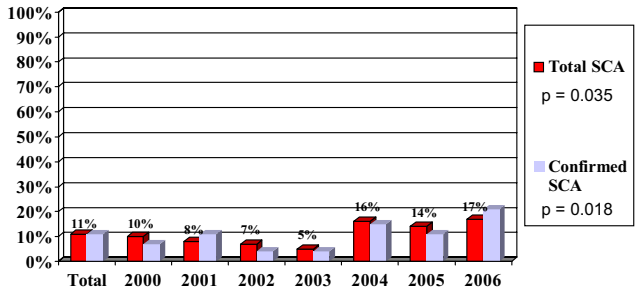

Figure 4 Survival Rates after exercise-related sudden cardiac arrest (SCA). P values indicate trend toward improved survival in recent years.

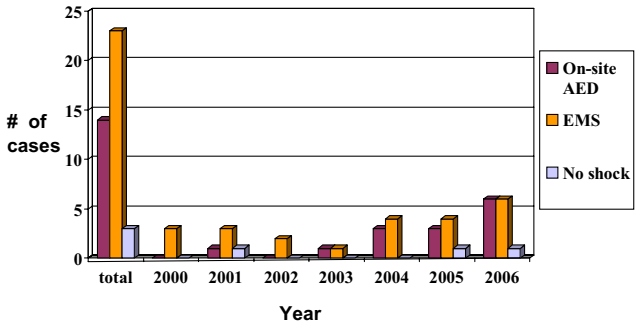

Figure 6 Method of resuscitation in survivors of exercise-related sudden cardiac arrest. AED = automatic external defibrillator; EMS = emergency medical services.

suggested and include poor rescuer recognition of SCA, inaccurate rescuer assessment of pulse or respirations, delayed access to AEDs and early defibrillation, and the presence of intrinsic structural cardiac abnormalities, such as hypertrophic cardiomyopathy, which may become more resistant to defibrillation with delays in resuscitation.[14]

A trend toward improved survival was identified in recent years. The reasons for this trend are not immediately clear, although it could be due to improved recognition of SCA and the increasing presence of on-site AED programs in high school and college athletic programs.[12,28] It also is possible that an increased reporting bias toward survivors of SCA in recent years accounts for this trend. In this study, it appears there may be a trend toward increased AED use in recent years that would correlate with the statistically significant trend toward improved survival. However, the number of cases was too small to run a statistical analysis. We speculate that, over the next few years, the close link between on-site AED programs in schools and improved survival following SCA in young athletes will be clearly demonstrated.

This study found a higher survival rate in females than in males. More research is needed to elucidate the etiologies and other factors that may influence this survival difference in young individuals with SCA.

In this study, 93% of SCA survivors received defibrillation. Although study limitations do not allow determination of the overall efficacy of AEDs in cases of SCA in young individuals, this study does highlight the necessity of appropriate emergency planning for SCA, with consideration for a readily accessible AED to provide prompt and timely access to defibrillation during resuscitation. In 2007, an interassociation task force provided consensus recommendations for emergency preparedness and management of SCA in high school and college athletic programs.[7] Access to early defibrillation is essential, and a target goal of less than 3 to 5 minutes from collapse to first shock is strongly recommended.[7] The poor sensitivity of current preparticipation screening practices in the United States in identifying potentially lethal cardiac abnormalities in young athletes underscores the importance of appropriate emergency preparedness and access to early defibrillation as a means of secondary prevention of sudden death.[7]

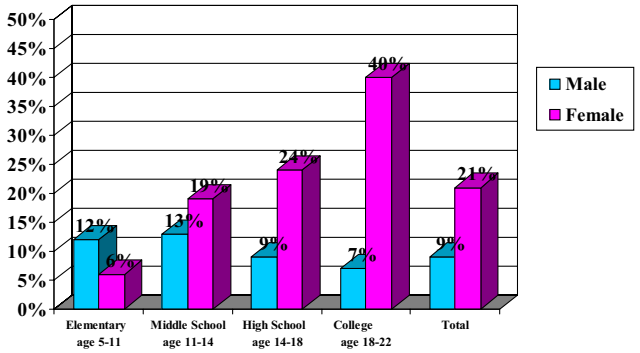

Figure 5 Survival rates in males vs females after exercise-related sudden cardiac arrest.

Study limitations

The limitations of this study should be considered when interpreting the results. The reliance of this study on media reporting to identify cases of exercise-related SCA may result in some selection bias. Media reports may be more likely to identify deaths in athletes participating in highly visible team sports and possibly bias the results toward poor outcomes. It also is likely that, due to underreporting or limitations in the search process, not all cases of exercise-related SCA were identified. Information from media reports on the etiology of the SCA was limited. An attempt was made to categorize cases as confirmed or suspected SCA based on the details of the case available. Although it is possible that not all of the cases in the suspected SCA group were cardiac in origin, the comparable survival rates with the confirmed SCA group suggest the groups are similar. Lastly, because the details of resuscitation efforts frequently were not reported in cases that ultimately resulted in death, the overall efficacy of AEDs in cases of SCA could not be determined in this study. Further research that more closely examines the details of resuscitation, emergency planning, and timing and method of defibrillation in exercise-related SCA in the youth is ongoing.

This study and its limitations highlight the need for a mandatory reporting system for juvenile sudden death in the United States. Without an improved reporting system, reliance on media reports is one of the only means of identi-

fying cases of exercise-related SCA. Closer follow-up and review of each case would be valuable, but further investigation should not preclude recognition that current survival rates following SCA in exercising youth are dismally low. The impact of sudden death in a young athlete is disproportionately large, and the low survival rate should compel the medical community to support methods for better investigation, prevention, and secondary management of these events should they occur. A mandatory reporting system would enhance the study of the true incidence and etiology of exercise-related sudden death of all causes for both organized and recreational athletes and would advance our knowledge, which could aid in the identification of athletes at risk. The value of a mandatory reporting system in determining the impact of a standardized preparticipation screening program has been demonstrated in Italy.[29]

Conclusion

Survival following exercise-related SCA in young individuals has been poor over the last 7 years in the United States. Despite the poor survival rate, there is a statistically significant trend toward improved survival in recent years, and there may be a concurrent trend toward increased AED use. Females were found to have a higher survival rate than males, and this finding requires further research to identify contributing factors. This study highlights the need for improved reporting systems for juvenile sudden death in the United States. Improved emergency response planning, enhanced recognition of SCA, and access to early defibrillation through on-site AED programs are the likely means to improving survival from exercise-related SCA.

Acknowledgements

We are grateful to the Parent Heart Watch organization for their collaboration and tireless efforts in searching for cases of exercise-related sudden cardiac arrest in the youth. We thank Carol Fahrenbruch, MSPH, for statistical support and analysis.

References

1. Maron BJ. Sudden death in young athletes. N Engl J Med 2003;349:1064–1075.
2. Maron BJ, Shirani J, Poliac LC, et al. Sudden death in young competitive athletes. Clinical, demographic, and pathological profiles. JAMA 1996;276: 199–204.
3. Maron BJ, Thompson PD, Ackerman MJ, et al. Recommendations and considerations related to preparticipation screening for cardiovascular abnormalities in competitive athletes: 2007 update: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism: endorsed by the American College of Cardiology Foundation. Circulation 2007; 115:1643–1655.
4. Maron BJ, Thompson PD, Puffer JC, et al. Cardiovascular preparticipation screening of competitive athletes. A statement for health professionals from the Sudden Death Committee (clinical cardiology) and Congenital Cardiac Defects Committee (cardiovascular disease in the young), American Heart Association. Circulation 1996;94:850–856.
5. Maron BJ, Carney KP, Lever HM, et al. Relationship of race to sudden cardiac death in competitive athletes with hypertrophic cardiomyopathy. J Am Coll Cardiol 2003;41:974–980.
6. Corrado D, Basso C, Thiene G, et al. Spectrum of clinicopathologic manifestations of arrhythmogenic right ventricular cardiomyopathy/dysplasia: a multicenter study. J Am Coll Cardiol 1997;30:1512–1520.
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. Heart Rhythm 2007;4:549–565.
8. Doolan A, Langlois N, Semsarian C. Causes of sudden cardiac death in young Australians. Med J Aust 2004;180:110–112.
9. Puranik R, Chow CK, Duflou JA, et al. Sudden death in the young. Heart Rhythm 2005;2:1277–1282.
10. Maron BJ, Gohman TE, Aeppli D. Prevalence of sudden cardiac death during competitive sports activities in Minnesota high school athletes. J Am Coll Cardiol 1998;32:1881–1884.
11. Van Camp SP, Bloor CM, Mueller FO, et al. Nontraumatic sports death in high school and college athletes. Med Sci Sports Exerc 1995;27:641–647.
12. Drezner JA, Rogers KJ, Zimmer RR, et al. Use of automated external defibrillators at NCAA division I universities. Med Sci Sports Exerc 2005;37:1487–1492.
13. Maron BJ, Doerer JJ, Haas TS, et al. Profile and frequency of sudden death in 1463 young competitive athletes: From a 25 year U.S. national registry: 1980–2005. Circulation 2006;114:11(18):830.
14. Drezner JA, Rogers KJ. Sudden cardiac arrest in intercollegiate athletes: detailed analysis and outcomes of resuscitation in nine cases. Heart Rhythm 2006;3:755–759.
15. Maron BJ, Gohman TE, Kyle SB, et al. Clinical profile and spectrum of commotio cordis. JAMA 2002;287:1142–1146.
16. SPSS for Windows. SPSS, Inc., Chicago, Illinois, 2001.
17. Becker LB, Ostrander MP, Barrett J, et al. Outcome of CPR in a large metropolitan area–where are the survivors? Ann Emerg Med 1991;20:355–561.
18. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary resuscitation and survival following out-of-hospital cardiac arrest. JAMA 1995;274:1922–1925.
19. Caffrey SL, Willoughby PJ, Pepe PE, et al. Public use of automated external defibrillators. N Engl J Med 2002;347:1242–1247.
20. Hallstrom AP, Ornato JP, Weisfeldt M, et al. Public-access defibrillation and survival after out-of-hospital cardiac arrest. N Engl J Med 2004;351:637–646.
21. Page RL, Joglar JA, Kowal RC, et al. Use of automated external defibrillators by a U.S. airline. N Engl J Med 2000;343:1210–1216.
22. 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;343:1206–1209.
23. Weaver WD, Hill D, Fahrenbruch CE, et al. Use of the automatic external defibrillator in the management of out-of-hospital cardiac arrest. N Engl J Med S 1988;319:661–666.
24. White RD, Asplin BR, Bugliosi TF, et al. High discharge survival rate after out-of-hospital ventricular fibrillation with rapid defibrillation by police and paramedics. Ann Emerg Med 1996;28:480–485.
25. Myerburg RJ, Fenster J, Velez M, et al. Impact of community-wide police car deployment of automated external defibrillators on survival from out-of-hospital cardiac arrest. Circulation 2002;106:1058–1064.
26. White RD, Bunch TJ, Hankins DG. Evolution of a community-wide early defibrillation programme experience over 13 years using police/fire personnel and paramedics as responders. Resuscitation 2005;65:279–283.
27. Mosesso VN Jr, Davis EA, Auble TE, et al. Use of automated external defibrillators by police officers for treatment of out-of-hospital cardiac arrest. Ann Emerg Med 1998;32:200–207.
28. Rothmier JR, Drezner JA, Harmon KG. Automated external defibrillators in Washington State high schools. Br J Sports Med 2007;41:301–305.
29. Corrado D, Basso C, Pavei A, et al. Trends in sudden cardiovascular death in young competitive athletes after implementation of a preparticipation screening program. JAMA 2006;296:1593–1601.