

Circulation

JOURNAL OF THE AMERICAN HEART ASSOCIATION



Incidence of Sudden Cardiac Death in National Collegiate Athletic Association Athletes

Kimberly G. Harmon, Irfan M. Asif, David Klossner and Jonathan A. Drezner

Circulation published online Apr 4, 2011;

DOI: 10.1161/CIRCULATIONAHA.110.004622

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 72514

Copyright © 2011 American Heart Association. All rights reserved. Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:

<http://circ.ahajournals.org>

Subscriptions: Information about subscribing to *Circulation* is online at
<http://circ.ahajournals.org/subscriptions/>

Permissions: Permissions & Rights Desk, Lippincott Williams & Wilkins, a division of Wolters Kluwer Health, 351 West Camden Street, Baltimore, MD 21202-2436. Phone: 410-528-4050. Fax: 410-528-8550. E-mail:
journalpermissions@lww.com

Reprints: Information about reprints can be found online at
<http://www.lww.com/reprints>

Incidence of Sudden Cardiac Death in National Collegiate Athletic Association Athletes

Kimberly G. Harmon, MD; Irfan M. Asif, MD; David Klossner, ATC, PhD; Jonathan A. Drezner, MD

Background—The true incidence of sudden cardiac death (SCD) in US athletes is unknown. Current estimates are based largely on case identification through public media reports and estimated participation rates. The purpose of this study was to more precisely estimate the incidence of SCD in National Collegiate Athletic Association (NCAA) student-athletes and assess the accuracy of traditional methods for collecting data on SCD.

Methods and Results—From January 2004 through December 2008, all cases of sudden death in NCAA student-athletes were identified by use of an NCAA database, weekly systematic search of public media reports, and catastrophic insurance claims. During the 5-year period, there were 273 deaths and a total of 1 969 663 athlete participant-years. Of these 273 deaths, 187 (68%) were due to nonmedical or traumatic causes, 80 (29%) to medical causes, and 6 (2%) to unknown causes. Cardiovascular-related sudden death was the leading cause of death in 45 (56%) of 80 medical cases, and represented 75% of sudden deaths during exertion. The incidence of SCD was 1:43 770 participants per year. Among NCAA Division I male basketball players, the rate of SCD was 1:3100 per year. Thirty-nine (87%) of the 45 cardiac cases were identified in the NCAA database, only 25 (56%) by use of public media reports, and 9 (20%) from catastrophic claims data.

Conclusions—SCD is the leading medical cause of death and death during exercise in NCAA student-athletes. Current methods of data collection underestimate the risk of SCD. Accurate assessment of SCD incidence is necessary to shape appropriate health policy decisions and develop effective strategies for prevention. (*Circulation*. 2011;123:1594-1600.)

Key Words: death, sudden ■ exercise ■ sports ■ students ■ athletes

Athletes are seen as one of the healthiest segments of our society. Sudden cardiac death (SCD) in a young athlete is always shocking and profoundly impacts the schools and communities where it occurs. It has been suggested that the prevalence of these events is not as high as it may seem, given the considerable media attention that often accompanies SCD in a young person.^{1,2} The true incidence of SCD in athletes is widely debated and largely unknown in the United States.

Clinical Perspective on p 1600

Prior estimates of SCD in athletes in the United States have varied widely, ranging from 1:23 000 to 1:300 000.¹⁻⁷ A precise numerator (number of deaths per year) and exact denominator (number of athlete participants per year) must be defined to calculate an accurate incidence. Previous studies have relied on media reports, retrospective surveys, voluntary registries, and insurance claims data for case identification (numerator), and some have used imprecise or potentially biased methods for calculation of a denominator. This has led to significant variability in incidence rates. There is no mandatory reporting system for juvenile sudden death in the United States, which makes current assessments of the frequency of SCD in young athletes questionable.

A more precise estimation of athlete SCD is critical, as recommendations for primary (screening) and secondary (emergency response planning) prevention are considered. This study examined the causes of death and the rate of SCD in a highly visible and easily defined population, National Collegiate Athletic Association (NCAA) student-athletes with a known sex and ethnic makeup. The accuracy of various data collection methods previously used to estimate the SCD rate in athletes is also assessed.

Methods

The NCAA consists of a unique group of athletes. In any given year, there are approximately 400 000 student-athletes, ages 17 to 23 years, who compete in 40 sports in 3 different NCAA divisions. Every institution uses a medical staff, which consists at least of a certified athletic trainer, and each institution has a designated media staff. Although there is no mandatory reporting of athlete deaths, deaths in this population are less likely to go unnoticed or unreported than in other populations of athletes, and media searches may be more likely to identify deaths. In addition, the NCAA publishes records of the number of athletes participating each year in each sport, as well as their sex and ethnic makeup.

Deaths among NCAA athletes were identified between January 1, 2004, and December 31, 2008, by 2 different means: (1) The development of an NCAA database, compiled by combining the

Received November 22, 2010; accepted February 22, 2011.

From the Department of Family Medicine, University of Washington, Seattle, WA (K.G.H., I.M.A., J.A.D.), and the Director of Health and Safety, National Collegiate Athletic Association, Indianapolis, IN (D.K.).

Correspondence to Kimberly G. Harmon, MD, Box 35440, University of Washington, Seattle, WA 98195. E-mail kharmon@u.washington.edu

© 2011 American Heart Association, Inc.

Circulation is available at <http://circ.ahajournals.org>

DOI: 10.1161/CIRCULATIONAHA.110.004622

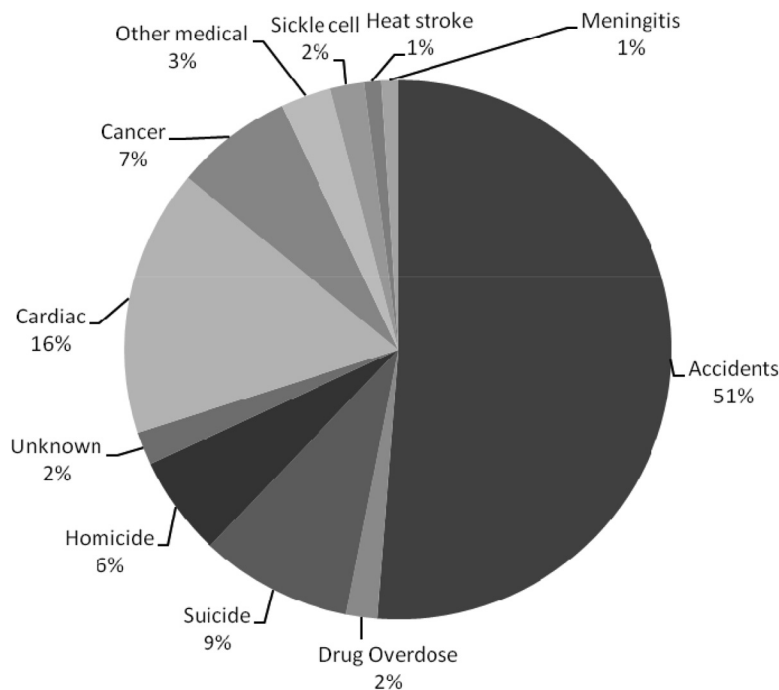


Figure. Causes of sudden death in National Collegiate Athletic Association athletes, 2004 to 2008.

NCAA Memorial Resolutions list and deaths reported to the NCAA, and (2) from the Parent Heart Watch database.

The NCAA Memorial Resolutions list is compiled annually in memory of NCAA student-athletes who have died of any cause. Institutions provide these names voluntarily to the NCAA. There are no causes of death associated with the NCAA Memorial Resolutions list; its primary purpose is to honor the deceased student-athletes. The NCAA Director of Health and Safety keeps track of trends and issues that affect the health and wellness of student-athletes and receives voluntary reports of athletes who have died. Institutions are not required to report student-athlete deaths to the Director of Health and Safety; however, it is not unusual for them to do so. These names were combined with the names from the NCAA Memorial Resolutions list to create an NCAA database of cases of sudden death in student-athletes.

Parent Heart Watch is a not-for-profit group dedicated to the prevention and awareness of sudden cardiac arrest (SCA) in young people. The group maintains an ongoing database of SCD/SCA in young people created from weekly Internet searches (approximately 15 hours per week) using 3 different search engines (Google, Yahoo, and Topix.net) and at least 18 keywords (student, athlete, collapsed, died, heart, cardiac, arrest, attack, football, basketball, baseball, soccer, running, school, unknown, college, defibrillator, and saved). The group has been tracking SCD/SCA in this manner since 2000. The Parent Heart Watch database was reviewed, and deaths among athletes 17 to 24 years of age were selected. Each of these cases was reviewed individually to determine whether the athlete was a member of an NCAA athletic team at the time of his or her death by review of media reports and comparison with NCAA team rosters. If there was a question as to whether the victim was an NCAA athlete or not at the time of his or her death, the institution was contacted.

The NCAA and Parent Heart Watch databases were cross-referenced and combined into a single database, and a retrospective analysis of student-athlete deaths was performed. Missing information regarding deaths was acquired through Internet searches and media reports, reports in the NCAA News, and via e-mails and telephone calls to sports information directors, head athletic trainers, athletic directors, and coroners. When possible, the student-athlete's parents or guardians were interviewed. The study was approved by the University of Washington Division of Human Subjects.

Data Analysis

Data were analyzed for overall death rate, as well as death rate according to sex, ethnicity, sport, and NCAA division. Each indi-

vidual database was compared against the aggregate database to assess the accuracy of different data collection methods. In addition, the aggregate database was compared with NCAA catastrophic insurance claims data because insurance claims data have been used previously to estimate SCD incidence.

A capture-recapture analysis was performed to estimate the number of deaths that may have been missed and to compare the capture rate between divisions. Capture-recapture analyses can be performed when data are obtained from 2 different databases to estimate the total number in a population.⁸⁻¹⁰ In epidemiology, they represent attempts to estimate or adjust for the incomplete ascertainment with information from overlapping lists of cases from distinct sources.¹⁰ The number of deaths included in the aggregate database was compared with the number estimated by the capture-recapture analysis and stratified by NCAA division to estimate potential case identification bias between divisions. Because of the smaller numbers of deaths in Divisions II and III, the data for these divisions were combined.

The deaths were categorized broadly as accident, homicide, suicide, drug overdose, or medical. The medical causes were further broken down on the basis of the available details from all sources into cardiac, cancer, heat stroke with or without sickle cell trait, meningitis, and other medical causes (Figure). In addition, when possible, medical deaths were categorized as exertional or not. Deaths during exertion were defined as a sudden death that occurred during or within 1 hour after exercise, training, or competition. If the cause of death could not be reasonably identified, it was recorded as "unknown."

Demographic data in NCAA athletes were obtained from the *NCAA Sports Sponsorship and Participation Rates Report*¹¹ and the *NCAA Student-Athlete Ethnicity Report*.¹² The sex and ethnic information is provided by institutions to the NCAA annually, and these reports are compiled periodically by the NCAA Department of Research. The ethnic breakdown for the academic year 2004 was not recorded, so an average from the other 4 years was used.

Results

During the 5-year period from 2004 to 2008, there were a total of 1 969 663 athlete participation-years. There were 843 106 female athlete participation-years and 1 126 557 male athlete participation-years. A total of 300 835 athlete

Table 1. Incidence of SCD in NCAA Athletes According to Sex, Ethnicity, and Division, 2004–2008

	No. of Athlete-Years	No. of Deaths	Death Rate (per Year)
NCAA athletes	1 969 663	45	1:43 770
Sex			
Male	1 126 557	34	1:33 134
Female	843 106	11	1:76 646
Ethnicity			
Black	300 835	17	1:17 696
White	1 583 635	27	1:58 653
By division			
Division I	788 023	27	1:29 186
Division II	424 572	10	1:42 457
Division III	760 258	8	1:95 032

SCD indicates sudden cardiac death; NCAA, National Collegiate Athletic Association.

participation-years were among black athletes and 1 583 635 were among white athletes.

There were 273 deaths (Figure). The majority of deaths occurred off the playing field and were nonmedical (187 of 273, or 68%); these included accidents (140, 51%), suicide (25, 9%), homicide (18, 6%), and drug overdoses (5, 2%). A cause of death could not be attributed in 2% (6) of the 273 cases. Medical causes of death represented 29% of cases (n=80). The leading medical cause of death was cardiac (45 of 273 deaths, or 16%), and this cause was responsible for roughly the same amount of deaths as homicide and suicide combined. Cardiac deaths accounted for the majority of medical deaths (45 of 80, or 56%). The incidence of SCD in an NCAA student-athlete was 1:43 770 per year.

Risk of SCD was examined by sex, division of play, and ethnicity (Table 1). There were 34 cardiac deaths in male athletes, with an incidence of SCD of 1:33 134 per year. There were 11 cardiac deaths in female athletes, with an incidence of SCD of 1:76 646 per year. There were 26 deaths in Division I athletes, 10 in Division II, and 9 in Division III. The annual risk of SCD stratified by division was 1:30 301 in Division I, 1:42 457 in Division II, and 1:84 473 in Division III. Risk of SCD was also stratified by ethnicity. There were

44 cases in which ethnicity was identified as either black or white; the ethnicity of the remaining case was unknown, and was not included in calculations. There were 27 deaths in whites, with an SCD rate of 1:58 653 athletes per year. There were 17 deaths in black athletes, with a risk of SCD of 1:17 696 per year. Broken down further, the risk of SCD in black male athletes was 1:12 990.

Risk varied considerably by sport (Table 2). Basketball was by far the highest-risk sport, with an overall annual death rate of 1:11 394. The risk for SCD was 1:5743 in black basketball athletes and 1:21 824 for whites per year. The highest-risk group of athletes regardless of ethnicity were Division I male basketball athletes, with a risk of SCD of 1:3126. There was a >3-fold increase in risk of SCD for black male basketball athletes compared to white male basketball athletes when looking at all divisions (black 1:3947 versus white 1:1281). The sports with the next highest overall risk were swimming (1:23 488) and lacrosse (1:23 357), (1:23 488), followed by football (1:38 497) and cross-country (1:41 695). The risk in Division I football was 1:25 297, but unlike basketball, the risk varied considerably by ethnicity.

There were 36 medical deaths that could be identified as having occurred with exertion. The others either occurred at rest or could not be classified. Of the exertional deaths, 27 (75%) of 36 were related to cardiac causes, with the remaining exertional deaths related to heat stroke. Five of the 10 heat stroke deaths were associated with sickle cell trait. The aggregate database identified and confirmed 45 total cases of SCD in NCAA athletes. The NCAA database identified 39 (87%), the Parent Heart Watch database (media) identified only 25 (56%), and the insurance claims database identified 9 (20%).

The total number of cases of SCD identified in the aggregate database was 45. Capture-recapture analysis estimated that the number of deaths was 49.1 (95% confidence interval [CI], 45.4 to 50.5), which would result in an incidence of SCD of 1:39 711 student-athletes per year. In Division I, the aggregate database identified 27 deaths. Capture-recapture analysis estimated 28.4 deaths would have occurred in that period (95% CI, 27.4 to 32.1). In Division II/III, 18 deaths were identified, with capture-recapture anal-

Table 2. Incidence of NCAA SCD by Sport, 2004–2008

Sport	Number of Deaths	Overall Incidence*	Incidence in Males	Incidence in Females	Incidence in African Americans	Incidence in Caucasians
Basketball	14	1:11,394	1:6,993	1:37,799	1:5,743	1:21,824
Division I	9	1:5,451	1:3,126	1:23,901	1:5,284	1:6,135
Division II	3	1:12,631	1:11,330	1:15,232	1:9,503	1:20,822
Division III	2	1:24,681	1:13,646	†	1:6,952	†
Swimming	4	1:21,293	1:34,552	1:16,457	†	1:20,981
Lacrosse	3	1:23,357	1:19,770	1:30,531	†	1:23,357
Football	8	1:38,497	1:38,497	†	1:59,814	1:14,401
Cross-country	3	1:41,695	1:59,484	1:32,801	1:12,043	1:51,033

NCAA indicates National Collegiate Athletic Association; SCD, sudden cardiac death.

*SCD incidence is expressed as number of athletes per year.

†No deaths for incidence calculation.

Table 3. Capture-Recapture Analysis

	No. of Deaths in Aggregate Database	Cap-Recap Estimate of No. of Deaths	95% Confidence Interval	No. of Athletes	Aggregate Database Incidence*	Cap-Recap Incidence Estimate
Total	45	49.6	45.4–50.4	1 969 663	1:43 770	1:39 711
Division I	27	28.4	27.4–32.5	788 023	1:29 186	1:29 186
Division II/III	18	22.4	18.8–43.1	1 184 830	1:65 824	1:52 894

Cap-Recap indicates capture-recapture.

*SCD incidence rates are expressed in number of athletes per year.

ysis estimating 22.4 deaths expected (95% CI, 18.8 to 43.1; Table 3).

Discussion

This study demonstrates that the incidence of SCD in NCAA athletes is significantly higher than frequently cited estimates, with an overall rate of approximately 1:43 000 student-athletes per year. Previous studies on the rate of SCD in athletes have produced widely varying estimates ranging from 1:23 000 to 1:300 000, largely because of differing methodology.^{1,6,13,14} Studies examining similar aged physically active populations have yielded rates as low as 1:9000.¹⁵ An accurate calculation of SCD incidence requires reliable identification of the numerator (number of deaths) and an exact denominator (number of athletes participating), common definitions of the events included (exertional versus all deaths), and universal definitions of athlete and of the population studied (competitive athletes versus all young people).

Van Camp et al⁶ first studied the rate of SCD in high school and college athletes from 1983 to 1993. They relied on case identification from media reports, at the time primarily from a newspaper clipping service. In all, 100 deaths due to cardiac causes were identified during the 10-year period, 92 in male athletes and 8 in female athletes. Deaths were more common in high-profile sports, such as football and men's basketball, and were less common in women's sports and high schools. The denominator was obtained from participation rates from high school and college athletic associations in the 17 common sports, divided by a factor to account for athletes who played multiple sports. This resulted in an overall SCD rate of 1:300 000. The estimated rate of SCD was 1:212 000 for male athletes and 1:1 300 000 for female athletes. The difference between these estimates and those of the present study are likely accounted for by collection bias, incomplete identification of all cases, and an imprecise denominator.

More recently, Maron et al¹ used similar strategies to examine SCD over 27 years. In contrast to the study by Van Camp et al,⁶ death in any competitive athlete up to age 39 years, not just those on a high school or college team, was examined, and all deaths thought to be related to cardiac causes, not just exertional deaths, were included. The denominator used to arrive at this death rate included participation information from high school and college athletic associations, minor league and professional sports, and "a number of participants in public competitive sport including marathons, triathlons, cycling, skiing, and soccer." The SCD rate was calculated for the years 2001 to 2006, and was reported as

1:164 000. The use of Internet search strategies may have increased case identification compared with previous studies; however, even modern search strategies identified only 56% of cases in the present study. Although estimation of a denominator in such a broad population of athletes is the only way to calculate an incidence rate, this represents a significant weakness of the study by Maron et al,¹ which was highly dependent on the inclusion or exclusion of different sports and prone to high variability.

Drezner³ used a retrospective survey of Division I head athletic trainers with a 75% response rate to assess the prevalence of automated external defibrillators (AEDs) and their use. A rate of SCD in Division I NCAA athletes of 1:67 000 was calculated, which is closer to the rate found in the present study. This survey had improved methodology because it did not rely on media reports for case identification and the population survey was well defined, which yielded an accurate denominator.

A cross-sectional study⁴ was conducted among high school athletes. During the study period, there were 14 SCAs in student-athletes, with 9 of the 14 surviving.⁴ This was the first study to examine the rate of SCA (not death), and it found a rate of 1:23 000. The rate of SCD in this same population was 1:63 000. Schools that had an AED or that had a student-athlete who experienced an SCA may have been more likely to respond to these surveys, thus falsely increasing the rates of SCA/SCD reported.

The examination of insurance claims data has also been used as a way to calculate the SCD incidence rate.⁵ In Minnesota, all high school athletes are covered by catastrophic injury insurance that will provide a benefit in the case of death that occurs during or immediately related to participation in a sanctioned event. The NCAA has a similar policy for all athletes at member institutions. In Minnesota, the number of claims paid out over 12 years was used to calculate a numerator and thus captured only exertional deaths that occurred during a sports season. The denominator used was participation information provided by the Minnesota State High School League and adjusted for multiple-sports participants on the basis of a figure calculated from a sample year. During the study period, there were 3 claims paid for deaths related to cardiovascular causes, all in male athletes, for a rate of 1:217 000. Data from the present study suggest that catastrophic claims only identified 20% of the deaths due to cardiovascular causes. Thus, although the study by Maron et al¹ provides an accurate denominator, the numerator likely underestimates the true number of cases.

Corrado et al¹³ reported an SCD incidence of 1:28 000 for young competitive athletes before implementation of a na-

tional screening program that used ECGs. The study was prospective; the cases of SCD were all recorded in a mandatory registry for juvenile SCD; the causes of death were confirmed by autopsy; and the exact number of athletes was known, all of which supports the reliability of these results.¹³ Likewise, Eckart et al¹⁵ reviewed deaths among military recruits over a 25-year period. Although military recruits are generally not considered athletes, they undertake regular vigorous exercise and are of a similar age group (18 to 35 years of age) as NCAA athletes, and there is mandatory reporting of all deaths. An SCD rate of 1:9000 recruit-years with autopsy confirmation of cause of death was found.¹⁵ These studies both had a highly reliable numerator and denominator.

The prevalence of cardiovascular abnormalities that predispose young athletes to SCD is approximately 0.3% (3 in 1000).^{13,16–21} Exercise is a trigger for SCA, and therefore, athletes are thought to be at greater risk than nonathletes for SCD.²² However, population-based data from the Centers for Disease Control and Prevention show that the cardiac-related death rate in the general population 15 to 24 years of age is 2.5 per 100 000 (or 1:40 000),²³ which suggests that SCD rates in the general population may be similar to those calculated among NCAA athletes.

A prospective population-based study conducted at 11 US and Canadian cities and utilizing rigorous methodology, with all cases of SCA collected through the emergency medical services system, reported an incidence of SCA due to cardiovascular disease of 1:27 000 in children and young adults (age 14 to 24 years).²⁴ Another US population-based study found the incidence of SCA in children age 10 to 14 years to be 1:58 000.²⁵ Although the present study did not examine all cases of SCA (only deaths), the incidence of SCD in NCAA athletes we found compares favorably with these studies.

The present study is the first estimate of SCD incidence in which the precise sex and ethnic makeup of athletes were known. SCD in the present study population was 2.3 times more common in male athletes than in female athletes; however, the overall rate in female athletes (1:77 000) was much higher than reported previously. Rates for female athletes have been estimated from 0 to 1:1 300 000.^{5,6} Other studies have not reported on sex, or reported only the overall percentage of SCD in female athletes as being low (11%).¹ Likewise, although the percentage of total deaths in blacks is reported as being higher than expected in other studies, no actual rate can be calculated.^{26,27} The present study shows an alarmingly high rate of SCD in blacks at 1:18 000 and a rate of 1:11 000 in Division I black male athletes.

Cardiac deaths were most common in basketball (14), football (8), swimming (4), lacrosse (3), and cross-country (3); however, incidence rates were strikingly different. The overall rate of SCD in basketball was 1:11 394. When stratified by sex, the rate was approximately 5 1/2 times higher in male basketball athletes (1:7000) than in female basketball athletes (1:38 000). The rate for white male basketball athletes overall (1:13 000) was concerning; however, the rate of SCD in black male basketball athletes was even more alarming (1:4000). More notable, however, is the rate of SCD in Division I male basketball athletes, which was

approximately 1:3000 for both blacks and whites. Van Camp et al⁶ also noted a comparatively high rate of SCD in male collegiate basketball players (1:28 000). Although the absolute number of SCDs in football was high, the rate in football was 1:38 000, which is near the average rate for an NCAA athlete.

Although the SCD rate determined in the present study is high, there is some evidence that high school athletes are at increased risk compared with collegiate athletes,^{1,14,28} and because there are more high school athletes (7 million), more total deaths occur in this age group. Deaths in high school athletes may be even less likely to be identified by media reports as opposed to higher-profile NCAA athletes. The present study tracked only deaths, not all cardiac arrests. With the increasing attention paid to emergency preparedness and use of AEDs, the SCD rate may be as much as 2.7 times lower than the SCA rate.⁴

The present study has profound implications for both primary and secondary prevention strategies. ECG screening is effective in detecting 66% to 100% of silent cardiovascular diseases in athletes,^{17–21} with a false-positive rate of 2% to 5% when contemporary standards for ECG interpretation are used.^{21,29} Cost-effectiveness calculations for the inclusion of an ECG in the preparticipation screening of athletes will differ significantly depending on the incidence rate used.^{28,30} The present study demonstrates a much higher incidence of SCD than previously estimated in college athletes, in female athletes, in black athletes, and in basketball athletes. The European Society of Cardiology and the International Olympic Committee recommend an ECG as part of a preparticipation examination, whereas the American Heart Association has recommended only a history and physical examination, predominantly on the basis of concerns regarding cost-effectiveness and infrastructure.^{16,31,32} A history and physical examination without an ECG are of questionable value and have been shown not to be cost-effective because of their poor sensitivity and specificity.^{30,33} Targeting high-risk groups may prove a reasonable starting point to begin ECG screening programs in the United States.

Basketball, football, cross-country, swimming, and lacrosse were the NCAA sports in which athletes were most likely to experience an SCD. In the preparation of an emergency plan, consideration should be given to placing AEDs in venues where these sports occur. Student nonathletes, spectators, and coaches may also benefit from AEDs in these locations.^{3,4} Preparing for an SCA in distance runners is challenging. Runners should be encouraged to train with a partner and to carry cell phones. Organizers of cross-country meets should consider having AEDs accessible via carts or bikes, and spotters on the course should have a communication system with access to the medical team.

Study Limitations

A limitation of the present study was that cause of death was not confirmed by autopsy in most cases; therefore, the specific cause of death (hypertrophic cardiomyopathy, anomalous coronaries, etc) could not be reported. Instead, only the overall incidence rate of SCD was reported. In addition, data on the deaths were collected in a retrospective manner.

Although several different methods were used to collect student-athlete death information, some deaths may have been missed. Thus, 1:43 770 represents a minimum rate, and the rate may actually be higher. Capture-recapture analysis indicates that the overall study death rate estimate was fairly close, with a calculated incidence of 1:39 711 athlete participation-years (95% CI, 1:43 385 to 1:39 081). Deaths also may have been identified more readily in divisions and sports that typically have increased media coverage. Capture-recapture analysis suggests an increased incidence of SCD in Division I (1:27 141) versus Division II/III (1:52 894); however, the 95% CI incidence rate is much wider in the Division II/III calculations (CI 1:63 023 to 1:27 490) than for Division I (CI 1:28 760 to 1:24 247).

Additional research is needed to define SCD risk in other age groups, as well as in nonathletes. The effect of screening and participation modification on mortality and overall health of athletes needs to be considered. More studies should be undertaken to understand whether there is a higher incidence of potentially lethal cardiovascular disease in basketball players or whether it is the demands of the sport that substantially increases the risk for those with underlying disease. This may ultimately influence not only primary and secondary preventative strategies but activity recommendations for those with cardiovascular disorders.

Conclusions

The present study has several important findings. SCD is the leading medical cause of death in NCAA athletes, is the leading cause of death during sport and exercise, and occurs at a much higher rate than previously accepted. The SCD rate in female athletes is also much higher than demonstrated in the past. This study demonstrates that relying solely on media reports or insurance claims for case identification is inaccurate. Both methods are unlikely to assess all cases of SCD, and when used as the sole source of data, they may be unreliable for scientific purposes. Better methods of case identification, such as mandatory reporting, should be developed.

This is the first study to develop a race-specific incidence rate, which suggests that SCD is >3 times more likely in blacks than in whites. Additionally, basketball is a high-risk sport for SCD in both male and female athletes, with the incidence being particularly high in Division I male basketball athletes. Improved strategies for identification of those at risk for SCA and prevention of SCD must be considered. ECG screening should be considered for the highest-risk groups.

Acknowledgments

The authors acknowledge the receipt of technical assistance with capture-recapture analysis from Stephen Marshall, PhD, and the Datalys Center.

Disclosures

None.

References

1. Maron BJ, Doerfer JJ, Haas TS, Tierney DM, Mueller FO. Sudden deaths in young competitive athletes: analysis of 1866 deaths in the United States, 1980–2006. *Circulation*. 2009;119:1085–1092.
2. Maron BJ. Sudden death in young athletes. *N Engl J Med*. 2003;349:1064–1075.
3. Drezner JA. Practical guidelines for automated external defibrillators in the athletic setting. *Clin J Sport Med*. 2005;15:367–369.
4. Drezner JA. Preparing for sudden cardiac arrest: the essential role of automated external defibrillators in athletic medicine: a critical review. *Br J Sports Med*. 2009;43:702–707.
5. 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.
6. Van Camp SP, Bloor CM, Mueller FO, Cantu RC, Olson HG. Non-traumatic sports death in high school and college athletes. *Med Sci Sports Exerc*. 1995;27:641–647.
7. Maron BJ. Hypertrophic cardiomyopathy and other causes of sudden cardiac death in young competitive athletes, with considerations for preparticipation screening and criteria for disqualification. *Cardiol Clin*. 2007;25:399–414, vi.
8. Hook EB, Regal RR. Internal validity analysis: a method for adjusting capture-recapture estimates of prevalence. *Am J Epidemiol*. 1995;142:S48–S52.
9. Hook EB, Regal RR. Capture-recapture estimation. *Epidemiology*. 1995;6:569–570.
10. Hook EB, Regal RR. Capture-recapture methods in epidemiology: methods and limitations. *Epidemiol Rev*. 1995;17:243–264.
11. DeHass DM. 1981-82-2007-2008 NCAA Sports Sponsorship and Participation Rates Report. Indianapolis, IN: NCAA; 2009.
12. Zgonc E. 1999-2000-2008-2009 NCAA Student-Athlete Ethnicity Report. Indianapolis, IN: NCAA; 2010.
13. Corrado D, Basso C, Pavei A, Michieli P, Schiavon M, Thiene G. Trends in sudden cardiovascular death in young competitive athletes after implementation of a preparticipation screening program. *JAMA*. 2006;296:1593–1601.
14. Drezner JA, Chun JS, Harmon KG, Derminer L. Survival trends in the United States following exercise-related sudden cardiac arrest in the youth: 2000–2006. *Heart Rhythm*. 2008;5:794–799.
15. Eckart RE, Scoville SL, Campbell CL, Shry EA, Stajduhar KC, Potter RN, Pearce LA, Virmani R. Sudden death in young adults: a 25-year review of autopsies in military recruits. *Ann Intern Med*. 2004;141:829–834.
16. Maron BJ, Thompson PD, Ackerman MJ, Balady G, Berger S, Cohen D, Dimeff R, Douglas PS, Glover DW, Hutter AM Jr, Krauss MD, Maron MS, Mitten MJ, Roberts WO, Puffer JC. 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;115:1643–1455.
17. Baggish AL, Hutter AM Jr, Wang F, Yared K, Weiner RB, Kupperman E, Picard MH, Wood MJ. Cardiovascular screening in college athletes with and without electrocardiography: a cross-sectional study. *Ann Intern Med*. 2010;152:269–275.
18. Bessem B, Groot FP, Nieuwland W. The Lausanne recommendations: a Dutch experience. *Br J Sports Med*. 2009;43:708–715.
19. Fuller CM, McNulty CM, Spring DA, Arger KM, Bruce SS, Chryssos BE, Drummer EM, Kelley FP, Newmark MJ, Whipple GH. Prospective screening of 5,615 high school athletes for risk of sudden cardiac death. *Med Sci Sports Exerc*. 1997;29:1131–1138.
20. Hevia AC, Fernandez MM, Palacio JM, Martin EH, Castro MG, Reguero JJ. ECG as a part of the preparticipation screening programme: an old and still present international dilemma. *Br J Sports Med*. Published online before print July 15, 2010. doi:10.1136/bjism.2009.063958. <http://bjism.bmj.com/content/early/2010/07/15/bjism.2009.063958.abstract>. Accessed September 9, 2010.
21. Wilson MG, Basavarajaiah S, Whyte GP, Cox S, Loosemore M, Sharma S. Efficacy of personal symptom and family history questionnaires when screening for inherited cardiac pathologies: the role of electrocardiography. *Br J Sports Med*. 2008;42:207–211.
22. Corrado D, Basso C, Rizzoli G, Schiavon M, Thiene G. Does sports activity enhance the risk of sudden death in adolescents and young adults? *J Am Coll Cardiol*. 2003;42:1959–1963.
23. Heron M, Hoyert D, Murphy S, Xy J, Kochanek K, Tejada-Vera B. Deaths: final data for 2006. *Natl Vital Stat Rep*. 2009;57:1–134.
24. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR, Berg RA. Epidemiology and outcomes from out-of-hospital cardiac

- arrest in children: the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. *Circulation*. 2009;119:1484–1491.
25. Chugh SS, Reinier K, Balaji S, Uy-Evanado A, Vickers C, Mariani R, Gunson K, Jui J. Population-based analysis of sudden death in children: the Oregon Sudden Unexpected Death Study. *Heart Rhythm*. 2009;6:1618–1622.
 26. Maron BJ, Carney KP, Lever HM, Lewis JF, Barac I, Casey SA, Sherrid MV. Relationship of race to sudden cardiac death in competitive athletes with hypertrophic cardiomyopathy. *J Am Coll Cardiol*. 2003;41:974–980.
 27. Burke A, Farb A, Virmani R, Goodin J, Smialek J. Sports-related and non-sports-related sudden cardiac death in young adults. *Am Heart J*. 1991;121:568–575.
 28. Drezner JA. Contemporary approaches to the identification of athletes at risk for sudden cardiac death. *Curr Opin Cardiol*. 2008;23:494–501.
 29. Nora M, Zimmerman F, Ow P, Fenner P, Marek J. Abstract 3718: preliminary findings of ECG screening in 9,125 young adults. *Circulation*. 2007;116:845.
 30. Wheeler MT, Heidenreich PA, Froelicher VF, Hlatky MA, Ashley EA. Cost-effectiveness of preparticipation screening for prevention of sudden cardiac death in young athletes. *Ann Intern Med*. 2010;152:276–286.
 31. Corrado D, Pelliccia A, Bjornstad HH, Vanhees L, Biffi A, Borjesson M, Panhuyzen-Goedkoop N, Deligiannis A, Solberg E, Dugmore D, Mellwig KP, Assanelli D, Delise P, van-Buuren F, Anastasakis A, Heidbuchel H, Hoffmann E, Fagard R, Priori SG, Basso C, Arbustini E, Blomstrom-Lundqvist C, McKenna WJ, Thiene G. Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: proposal for a common European protocol: consensus statement of the Study Group of Sport Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology. *Eur Heart J*. 2005;26:516–524.
 32. *Sudden Cardiovascular Death in Sport: Lausanne Recommendations: Under the Umbrella IOC Medical Commission*. Lausanne, Switzerland; IOC Medical Commission; 2004.
 33. Drezner J, Corrado D. Is there evidence for recommending electrocardiogram as part of the pre-participation examination? *Clin J Sport Med*. 2011;21:18–24.

CLINICAL PERSPECTIVE

This report more accurately estimates the incidence of sudden cardiac death (SCD) in athletes using improved methodology compared with previous studies. It demonstrates an overall rate of SCD of 1:43 000, with some subpopulations showing a risk of SCD as high as 1:3000. The rate of SCD has been commonly cited as 1:200 000. From a clinical perspective, this is critically important information. The preparticipation examination, or sports physical, is a core part of the practice of sports medicine and primary care physicians alike. The purpose of the preparticipation examination, according to the latest AHA scientific statement, is to identify conditions that may lead to SCD. The current recommendation of the AHA is that this is best done, in the United States, by the use of a directed history and physical exam. There is increasing evidence that this strategy is neither effective nor cost-effective. In other countries, an ECG is a routine part of a sports physical, or in some cases a well-child visit. The information presented in this report will inform the ongoing discussion about SCD in young people and how best to prevent it. There may be subpopulations of athletes or young people in which screening with an ECG by use of modern interpretation criteria would be highly cost-effective, and others in which it would not. This report will have significant ramifications for clinical practice as we strive to understand how to best use our resources, fulfill the primary objective of the sports physical, prepare for sudden cardiac arrest, and ultimately prevent SCD.

Fighting Heart Disease and Stroke

Circulation
 JOURNAL OF THE AMERICAN HEART ASSOCIATION