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Sudden Cardiac Arrest during Participation in Competitive Sports

Cameron H. Landry, M.D., **Katherine S. Allan, Ph.D.**, **Kim A. Connelly, M.B., B.S., Ph.D.**, **Kris Cunningham, M.D., Ph.D.**, **Laurie J. Morrison, M.D.**, **Paul Dorian, M.D.**, and **for the Rescu Investigators***

The Faculty of Medicine (C.H.L., P.D.), Division of Emergency Medicine, Department of Medicine (L.J.M.), the Institute of Health Policy, Management and Evaluation, Faculty of Medicine (L.J.M.), and the Departments of Medicine (P.D.) and Laboratory Medicine and Pathobiology (K.C.), University of Toronto, the Division of Cardiology (K.A.C., P.D.), Rescu (L.J.M.), Li Ka Shing Knowledge Institute (K.A.C., L.J.M.), and the Keenan Research Centre (K.A.C.), St. Michael's Hospital, and the Ontario Forensic Pathology Service (K.C.), Toronto, and the School of Nursing, McMaster University, Hamilton, ON (K.S.A.) — all in Canada

Abstract

BACKGROUND—The incidence of sudden cardiac arrest during participation in sports activities remains unknown. Preparticipation screening programs aimed at preventing sudden cardiac arrest during sports activities are thought to be able to identify at-risk athletes; however, the efficacy of these programs remains controversial. We sought to identify all sudden cardiac arrests that occurred during participation in sports activities within a specific region of Canada and to determine their causes.

METHODS—In this retrospective study, we used the Rescu Epistry cardiac arrest database (which contains records of every cardiac arrest attended by paramedics in the network region) to identify all out-of-hospital cardiac arrests that occurred from 2009 through 2014 in persons 12 to 45 years of age during participation in a sport. Cases were adjudicated as sudden cardiac arrest (i.e., having a cardiac cause) or as an event resulting from a noncardiac cause, on the basis of records from multiple sources, including ambulance call reports, autopsy reports, in-hospital data, and records of direct interviews with patients or family members.

RESULTS—Over the course of 18.5 million person-years of observation, 74 sudden cardiac arrests occurred during participation in a sport; of these, 16 occurred during competitive sports and 58 occurred during noncompetitive sports. The incidence of sudden cardiac arrest during competitive sports was 0.76 cases per 100,000 athlete-years, with 43.8% of the athletes surviving until they were discharged from the hospital. Among the competitive athletes, two deaths were attributed to hypertrophic cardiomyopathy and none to arrhythmogenic right ventricular cardiomyopathy. Three cases of sudden cardiac arrest that occurred during participation in

Address reprint requests to Dr. Dorian at the Division of Cardiology, University of Toronto, St. Michael's Hospital, Toronto, ON M5B 1W8, Canada, or at dorianp@smh.ca.

*A complete list of the Rescu Investigators is provided in the Supplementary Appendix, available at NEJM.org.

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competitive sports were determined to have been potentially identifiable if the athletes had undergone preparticipation screening.

CONCLUSIONS—In our study involving persons who had out-of-hospital cardiac arrest, the incidence of sudden cardiac arrest during participation in competitive sports was 0.76 cases per 100,000 athlete-years. The occurrence of sudden cardiac arrest due to structural heart disease was uncommon during participation in competitive sports. (Funded by the National Heart, Lung, and Blood Institute and others.)

The occurrence of sudden cardiac arrest in young persons during participation in competitive sports is a rare but tragic event. In numerous jurisdictions, preparticipation screening systems have been implemented on the assumption that most cases of sudden cardiac arrest that occur during sports activities can be predicted and prevented by identifying persons at risk, withdrawing them from competitive sports, and in selected cases, applying therapeutic preventive measures.[1,2]

The reported incidence of sudden cardiac death in the young (usually defined as <35 years of age) — with sudden cardiac death referring exclusively to sudden cardiac arrest that results in death — ranges widely, from 1.0 to 6.4 cases per 100,000 patient-years.[3] The instantaneous risk of sudden cardiac arrest in persons who have a predisposition to sudden cardiac arrest is markedly increased during participation in sports, even though most sudden cardiac arrests occur while the person is at rest.[4] The incidence of sudden cardiac death during participation in a sport in the general population has been reported to be approximately 0.46 cases per 100,000 person-years.[5]

The uncertainty regarding the precise incidence of sudden cardiac arrest in the young, particularly during participation in a sport, can be attributed in part to imperfect data collection systems that have been used in previous studies. Almost all the studies have focused on persons who could not be resuscitated (sudden cardiac deaths), and in most of the studies, death certificates, hospital records, autopsy reports, or searches of publicly available records were used to identify cases of sudden cardiac arrest.[3–10] These approaches are limited because systematic methods were not used to identify all persons in a particular community who had sudden cardiac arrest and because survivors were not included.

Rescu Epistry is a prospective, comprehensive registry of all persons who had out-of-hospital cardiac arrest and whose event was attended by emergency medical services (EMS) personnel in a defined region of the province of Ontario, Canada. This validated registry allows an opportunity to systematically examine the circumstances and causes of out-of-hospital cardiac arrest to quantify how many of the events are truly sudden and how many are truly cardiac in origin.[11] We used this registry to ascertain the incidence of sudden cardiac arrest during participation in competitive and noncompetitive sports activities among young persons and to determine the underlying causes. Currently, no widespread systematic programs to screen persons before participation in a sport are in place in Canada[12]; the current analysis allowed us to estimate the potential efficacy of systematic pre-participation screening.

METHODS

STUDY DESIGN

In this retrospective study, we identified out-of-hospital cardiac arrests using the population-based Rescu Epistry cardiac arrest database, which is based on data definitions from the Cardiac Arrest Registry of the Resuscitation Outcomes Consortium[13] database and the Strategies for Post Arrest Resuscitation Care Network[11] database. In brief, the Rescu Epistry database is a prospective, population-based registry of consecutive out-of-hospital cardiac arrests attended by EMS personnel who were responding to 911 calls in a specific area of Ontario, including both urban and rural regions, that has a combined population of 6.6 million (see Fig. S1 in the Supplementary Appendix, available with the full text of this article at NEJM.org). Data are collected from a network of seven land-based EMS agencies, local fire departments, the provincial air ambulance service, and 44 participating destination hospitals. Trained personnel enter epidemiologic data from standardized pre-hospital call reports and in-hospital records into secured databases. Potential out-of-hospital cardiac arrests that are missed by Rescu Epistry are assumed to be expected deaths for which an advance directive is in place or for which the treating physician arranges for body removal services without involving EMS. Such deaths must meet legislated criteria that define obvious death.

The St. Michael's Hospital research ethics board provided ethics approval for the study. The study was supported by the National Heart, Lung, and Blood Institute, the Canadian Institutes of Health Research, and others. None of the organizations that funded the study had any role in the design or conduct of the study; in the collection, management, analysis, or interpretation of the data; or in the preparation, review, or approval of the manuscript for submission. All the authors vouch for the completeness and accuracy of the data and the analyses.

KEY DEFINITIONS

We defined out-of-hospital cardiac arrest as an event that did not occur in a hospital, was attended by EMS personnel, may or may not have been witnessed, was associated with an abrupt loss of vital signs, and resulted either in death or in successful resuscitation.[14] We defined sudden cardiac arrest as an unexpected out-of-hospital cardiac arrest that occurred abruptly in a seemingly healthy person, may or may not have been witnessed, and was attributed to a cardiac cause after adjudication (as described in the Supplementary Appendix). Our definition of sudden cardiac arrest included persons who did not survive (defined previously as sudden cardiac death) as well as persons who were successfully resuscitated.

We defined a competitive sport as any organized or sanctioned sporting event that had been certified by an official, recognized sports association; persons who participated in a competitive sport could have been either professional or amateur athletes. We defined a noncompetitive sport as any form of a sport or recreational physical activity that was not formally organized or sanctioned. Out-of-hospital cardiac arrest was considered to be associated with a sport if the person was estimated to have exerted more than 3 metabolic

equivalents (METs) during the activity in question and if the cardiac arrest occurred either during the activity or within 1 hour after the activity, during either competition or training.[15,16]

STUDY POPULATION

All cases of out-of-hospital cardiac arrest of presumed cardiac cause (according to the standardized Utstein criteria[17–19]), as well as cases that could have been the result of a sudden cardiac arrest event (e.g., drownings), that occurred among persons 12 to 45 years of age, that were attended by paramedics, that were treated or untreated (according to criteria specified by the medical directives of the EMS that define the presence or absence of signs of obvious death), and that resulted in death or in resuscitation were identified from the Rescu Epistry database from the beginning of 2009 to the end of 2014. The lower age limit for the study was chosen to include athletes who were potentially eligible for screening. The upper age limit was chosen to maximize the inclusion of persons who had heritable cardiac syndromes and to reduce overlap with out-of-hospital cardiac arrest due to atherosclerotic coronary artery disease.

The estimated total number of competitive athletes in the region served by the participating EMS agencies (Fig. S1 in the Supplementary Appendix) who were 12 to 45 years of age was calculated on the basis of the total number of competitive athletes who had registered with a sporting organization in Ontario during 2012 (information was obtained through direct correspondence with the Ontario Ministry of Tourism, Culture, and Sport) and was prorated according to the age-matched population in the geographic area covered by the study with the use of the 2011 Canadian Census. Athletes who were registered in racing events were recorded separately from those who participated in other sports, according to region and age group.[20] It was assumed that the number of athletes did not vary significantly from year to year within the study period.[21]

CASE IDENTIFICATION

Cases of out-of-hospital cardiac arrest that were related to competitive or noncompetitive sports were defined as cases that occurred during, or within 1 hour after, exertion of more than 3 METs during the activity. We identified such cases by manually sorting through all ambulance call reports and records from the emergency department or hospital for reports of persons who had a cardiac arrest at a recreational facility, university or college, sports field, stadium or arena, athletic facility, golf course, water area, hotel, condominium or apartment, park, or street.

Cases were cross-referenced by comparison with additional data sources to obtain a clinical and pathological assessment that was as complete as possible. The data sources that were used included ambulance call reports, fire call reports, in-hospital data (abstracted from emergency department reports, in-hospital medical notes, discharge summaries, consultations, clinical tests, and medical certificates of death), medical records from family physicians, coroner investigative statements, autopsy reports, toxicology reports, and records of direct interviews with patients or family members. All out-of-hospital cardiac arrests were

classified as either sudden cardiac arrest or cardiac arrest from other causes, as defined above and described previously.[22]

AUTOPSY AND MOLECULAR AUTOPSY

Autopsies were performed at the Provincial Forensic Pathology Unit of Ontario, which conducts approximately 6000 autopsies annually (Statistics Canada 2014, www.mcscs.jus.gov.on.ca/english/DeathInvestigations/Pathology/pathology_main.html), and were conducted either by forensic pathologists or by cardiovascular pathologists according to a standardized protocol in which all organs are examined both macroscopically and microscopically.[4] Criteria for identifying specific cardiac pathologies have been described previously[23]; additional details are provided in the Supplementary Appendix. Molecular autopsies, if performed, were done by analysis (GeneDx, Familion, or CTGT Connective Tissue Gene Tests) of DNA samples obtained from whole blood at the time of the autopsy.

STATISTICAL ANALYSIS

Descriptive statistics were used to assess the distribution of variables; continuous variables were summarized as mean values with standard deviations, and categorical variables were summarized as counts and percentages. Incidence rates per 100,000 person-years were calculated in the total population of competitive athletes over a 6-year period. All calculations and analyses were performed with the use of SPSS software, version 23.0 (IBM).

RESULTS

STUDY PARTICIPANTS AND DETAILS OF CARDIAC ARRESTS

The population of persons 12 to 45 years of age in the region served by the participating EMS agencies (Fig. S1 in the Supplementary Appendix) was estimated to be 3,085,240 in 2011. The estimated total follow-up time was 18.5 million person-years between the beginning of 2009 and the end of 2014. There were an estimated 352,499 registered competitive athletes in the study region in 2012 (which represented 11.4% of the population in the study region), resulting in an estimated total follow-up time of 2.1 million athlete-years. A total of 3825 out-of-hospital cardiac arrests among persons 12 to 45 years of age occurred during the study period, of which 2144 occurred in a public place. We reviewed the ambulance call reports for all 2144 cases, as well as the associated in-hospital records, coroner's records, and records of direct interviews with patients or family members, as appropriate. Of the cardiac arrests that occurred in a public place, 74 were determined to be sudden cardiac arrests that occurred during competitive sports (16 cases) or noncompetitive sports (58 cases) (Fig. 1).

Details of prehospital events and causes and outcomes of sudden cardiac arrest are provided in Table 1 for the 16 cases that occurred during competitive sports and in Table S1 in the Supplementary Appendix for the 58 cases that occurred during noncompetitive sports. Data sufficient to ascertain the cause of the sudden cardiac arrest among persons participating in competitive sports were obtained in 10 of the 16 cases. In 2 cases of nonsurvivors in which autopsies did not identify a cause of death, the cause of the sudden cardiac arrest was

considered to be primary arrhythmia. In 4 cases of survivors in which no cause was identified after a detailed investigation, the cause of the cardiac arrest was also considered to be primary arrhythmia. In all 6 cases, either the cardiac structure was normal at autopsy or the results of the cardiac investigations, such as echocardiography or cardiac catheterization, were normal in the survivors.

RATES AND CAUSES OF SUDDEN CARDIAC ARREST

The sports associated with the greatest number of cases of sudden cardiac arrest among competitive athletes were race events and soccer (4 events each) (Table 2) and among noncompetitive athletes were gym workouts (12 events) and running (9 events) (Table S2 in the Supplementary Appendix). Assuming that all registered athletes are competitive athletes, the incidence of sudden cardiac arrest, including both survivors and nonsurvivors, during competition or training was 0.76 cases per 100,000 athlete-years (Table 3). Survival rates among competitive and noncompetitive athletes who had sudden cardiac arrest were similar (43.8% and 44.8%, respectively) (Table 4).

There were no significant differences in the distribution of causes of sudden cardiac arrest between survivors and nonsurvivors. The predominant cause of sudden cardiac arrest varied according to age group; among competitive and noncompetitive athletes younger than 35 years of age, structural and primary arrhythmic causes were the most common causes, whereas among persons 35 to 45 years of age, coronary artery disease was the most common cause (Table 4). Hypertrophic cardiomyopathy and arrhythmogenic right ventricular cardiomyopathy were uncommon causes of sudden cardiac arrest. Hypertrophic cardiomyopathy was reported as the cause of sudden cardiac arrest in 12.5% of competitive athletes and in 6.9% of noncompetitive athletes, and arrhythmogenic right ventricular cardiomyopathy was identified as the cause of sudden cardiac arrests in none of the competitive athletes and in 6.9% of noncompetitive athletes (Table 1, and Table S1 in the Supplementary Appendix).

With respect to abnormalities that could potentially have been identified during preparticipation screening of competitive athletes, two athletes had a structural abnormality (i.e., hypertrophic cardiomyopathy) that was likely to be associated with an abnormal electrocardiogram or echocardiogram.[23,24] One of the two athletes had been assessed for presyncope, had a normal electrocardiogram and echocardiogram, was cleared to play competitive sports, and had hypertrophic cardiomyopathy that was diagnosed at autopsy (Patient 12 in Table 1). In addition, two of the competitive athletes who died had no structural abnormalities identified at autopsy, and therefore, the causes of sudden cardiac arrest in these athletes were classified as “primary arrhythmic” (Tables 1 and 4). If we assume that the athlete who had not previously undergone preparticipation screening and had hypertrophic cardiomyopathy had abnormalities that could have been identified by screening, and that the two athletes who died from causes classified as primary arrhythmic might have had a disorder that could have been detected while they were alive, we conclude that, at most, three of these persons could have been identified by preparticipation screening as being at risk for sudden cardiac arrest.

DISCUSSION

We used data on all out-of-hospital cardiac arrests attended by EMS personnel in a defined region of Ontario, Canada, to determine how frequently sudden cardiac arrest occurs among young persons during competitive and noncompetitive sports activities. Over the course of the 6-year study period, we identified 16 cases of sudden cardiac arrest that occurred during competitive sports and 58 cases of sudden cardiac arrest that occurred during noncompetitive sports. Hypertrophic cardiomyopathy and arrhythmogenic right ventricular cardiomyopathy were uncommon in our study population; among the 16 cases of sudden cardiac arrest that occurred during competitive sports, only 2 cases of hypertrophic cardiomyopathy and no cases of arrhythmogenic right ventricular cardiomyopathy were found. Our results indicate that sudden cardiac death during participation in competitive sports is rare, the causes are varied, and more than 80% of cases would not have been identified with the use of systematic clinical preparticipation screening alone or in combination with electrocardiography-based preparticipation screening.

The absolute incidence of sudden cardiac death (i.e., sudden cardiac arrest resulting in death) among athletes has previously been reported to be between 1 in 80,000 and 1 in 200,000 per year.[25,26] The incidence of sudden cardiac arrest during participation in competitive sports in our analysis (0.76 cases per 100,000 athlete-years) is similar to that reported previously[3,5] and includes resuscitated persons, which thus provides a more comprehensive estimate of the incidence. By comparison, the incidence of sudden cardiac arrest in the general population of the same age group has been reported to be 4.84 cases per 100,000 person-years.[22]

Previous studies suggest that hypertrophic cardiomyopathy accounts for a large proportion of sudden cardiac arrests during participation in competitive sports in contemporary North American populations.[27,28] In our cohort, however, hypertrophic cardiomyopathy was an uncommon cause of sudden cardiac arrest. Possible explanations for this unexpected lower rate include the wider age range in our study and genetic differences among populations in different geographic regions; however, a similarly low prevalence has also been reported by others.[4,29,30]

The rarity of sudden cardiac arrest due to structural heart disease that we found in our analysis raises questions about the potential value of preparticipation screening. Structural heart disease, such as hypertrophic cardiomyopathy, is more likely to be detected by electrocardiography than other causes of sudden cardiac arrest and is frequently cited as a reason for undertaking preparticipation screening.[31,32] In a French study[10] involving 6372 competitive athletes, 54 athletes (0.85%) were found to have hypertrophic cardiomyopathy, and all 54 athletes were disqualified from competition. If all the registered athletes in our jurisdiction had been screened, assuming the same prevalence, approximately 3000 athletes may have been identified as having hypertrophic cardiomyopathy and subsequently disqualified. Assuming a more widely quoted prevalence rate of 1 in 500 persons with hypertrophic cardiomyopathy in the general population,[33] 700 athletes with hypertrophic cardiomyopathy could have been disqualified from competition. In contrast, we identified 2 persons who had sudden cardiac arrest due to hypertrophic cardiomyopathy among

competitive athletes during participation in sports activities, 1 of whom had undergone investigations for presyncope and was subsequently cleared for competition.

Among the survivors identified in our study, none had a condition that was likely to have been identified by preparticipation screening. Among the persons who died, our data suggest that systematic preparticipation screening may have identified a maximum of 3 persons who were at risk for sudden cardiac arrest. This conservative estimate assumes that screening would have identified abnormalities in the athlete with hypertrophic cardiomyopathy who had not previously undergone preparticipation screening and that the 2 athletes who died and had normal autopsy results had conditions that might have been identified by screening. In total, assuming that all these athletes could have been determined to be at risk for sudden cardiac arrest with the use of screening, at least 146,000 athletes would have had to be screened to identify 1 person who had sudden cardiac arrest during participation in competitive sports.

Our study has several important limitations. First, our analysis was a retrospective analysis, and the cause of death could not always be determined with certainty. We did not have autopsy data for all the persons in the study who died (although anatomical information was available from imaging or autopsy for all the competitive athletes). Second, it is possible that some athletes who had a risk of sudden cardiac arrest may have been identified through “case finding” (i.e., an athlete may have had symptoms or may have been referred for family assessment) and refrained from participation in sports activities, thereby removing themselves from the at-risk cohort of athletes. In addition, some professional athletes (a very small cohort) had already undergone screening. Third, we cannot exclude the possibility that some competitive athletes may have had cardiac arrest during participation in recreational sports and may subsequently have been reported as such (which would again have resulted in lowering the incidence of sudden cardiac arrest in the competitive-athlete group). It is also possible that athletes in the competitive cohort could have been counted more than once if they were registered in multiple sports associations with the Ontario Ministry of Tourism, Culture, and Sport. Fourth, we did not evaluate sudden cardiac arrest in competitive athletes either at rest or more than 1 hour after a sports activity. Finally, we cannot be certain that we have identified all competitive athletes; undercounting would have resulted in an underestimation of rates of sudden cardiac arrest.

In summary, we used data on out-of-hospital cardiac arrests to determine how frequently sudden cardiac arrest occurs during participation in competitive and noncompetitive sports activities among young persons. Among competitive athletes, the incidence of sudden cardiac arrest was estimated to be 0.76 cases per 100,000 athlete-years. Sudden cardiac arrest due to structural heart disease occurred infrequently during competitive sports.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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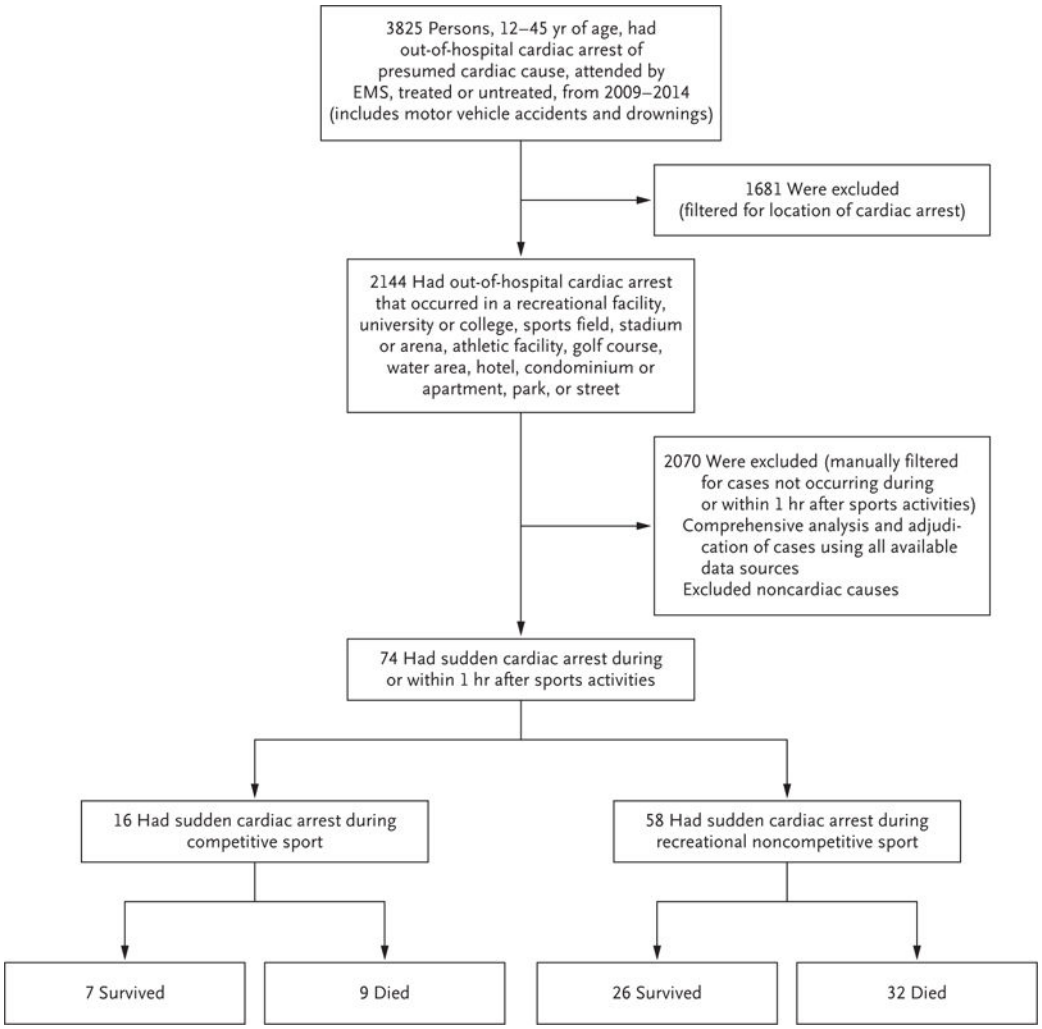

Figure 1. Identification and Classification of Out-of-Hospital Sudden Cardiac Arrest during Sports in Persons 12 to 45 Years of Age

All 3825 out-of-hospital cardiac arrests that occurred among persons 12 to 45 years of age from 2009 through 2014 and were reported in the Rescu Epistry database were filtered on the basis of the type of location (e.g., a recreational facility) of the cardiac arrest. All 2144 remaining cases were then manually filtered for out-of-hospital cardiac arrests that occurred during or within 1 hour after a sports activity. This remaining cohort of 74 cases was assessed comprehensively with the use of all available records to adjudicate the cause of sudden cardiac arrest; cases of cardiac arrest due to noncardiac causes (e.g., hanging, trauma, mechanical suffocation, asphyxia from drowning, or toxic inhalation) were excluded from the assessment. EMS denotes emergency medical services.

Table 1

Details of Sudden Cardiac Arrest among Competitive Athletes.*

Patient No. (Sex, Age)	Bystander Witnessed; Performed CPR	EMS Response Time	Initial Cardiac Rhythm	No. of Shocks	Outcome	Autopsy	Molecular Autopsy	Cause of Sudden Cardiac Arrest	Basis of Diagnosis†	Previous Cardiac Tests	Follow-up
1 (M, 44 yr)	No; No	ND	VF/VT	1	Admitted to hospital; survived	NA	NA	Ischemic	Angiogram	ECG and echocardiogram normal	PCI and stents placed for coronary artery disease
2 (M, 30 yr)	Yes; Yes	ND	VF/VT	1	Admitted to hospital; survived	NA	NA	Primary arrhythmic	—	None	ECG, angiogram, stress test, and MRI normal; ICD implanted
3 (M, 16 yr)	Yes; Yes	6.5 min	VF/VT	2	Admitted to hospital; survived	NA	NA	Commotio cordis	History	None	In long-term care facility owing to anoxic brain injury
4 (F, 22 yr)	Yes; No	ND	PEA	0	Admitted to hospital; survived	NA	NA	Primary arrhythmic	—	None	ECG and echocardiogram normal; MRI showed possible myocarditis; ICD implanted
5 (M, 25 yr)	Yes; Yes	8.0 min	VF/VT	2	Admitted to hospital; survived	NA	NA	Primary arrhythmic	—	None	ECG, echocardiogram, and angiogram normal; ICD implanted
6 (M, 23 yr)	Yes; Yes	7.9 min	VF/VT	0	Admitted to hospital; survived	NA	NA	Primary arrhythmic	—	None	ECG abnormal ‡; echocardiogram and MRI normal
7 (M, 13 yr)	Yes; Yes	5.4 min	VF/VT	0	Admitted to hospital; survived	NA	NA	Commotio cordis	History	None	ECG, echocardiogram, and stress test normal; incidental anomalous coronaries
8 (M, 35 yr)	Yes; Yes	9.5 min	VF/VT	1	Died in ED	Yes	NA	Ischemic	Autopsy	None	NA
9 (M, 18 yr)	Yes; Yes	11.0 min	Not shockable	3	Died in ED	Yes	No mutations detected	Primary arrhythmic	Normal autopsy	None	NA
10 (M, 27 yr)	Yes; No	4.8 min	Asystole	0	Died in ED	Yes	No mutations detected	Primary arrhythmic	Normal autopsy	None	NA
11 (M, 20 yr)	Yes; Yes	9.1 min	VF/VT	5	Died in ED	Yes	NA	Anomalous coronaries	Autopsy	Unknown	NA
12 (M, 15 yr)	Yes; No	5.2 min	VF/VT	5	Died in ED	Yes	Mutation (variant) of unknown significance§	Hypertrophic cardiomyopathy	Autopsy	ECG and echocardiogram normal	NA
13 (F, 18 yr)	Yes; Yes	7.0 min	PEA	0	Died in ED	Yes	NA	Anomalous coronaries	Autopsy	None	NA
14 (M, 39 yr)	Yes; Yes	ND	VF/VT	1	Died in ED	Yes	NA	Ischemic	Autopsy	None	NA
15 (M, 18 yr)	Yes; No	5.3 min	VF/VT	5	Admitted to hospital; died	No¶	NA	Hypertrophic cardiomyopathy	In-hospital testing	None	NA
16 (F, 12 yr)	Yes; Yes	ND	Not documented	0	Died in ED	Yes	NA	Anomalous coronaries	Autopsy	Previous investigations normal; cleared for competition	NA

*The specific type of sports activity in which each patient was participating is not specified to preserve patient confidentiality. CPR denotes cardiopulmonary resuscitation, ECG electrocardiogram, ED emergency department, EMS emergency medical services, ICD implantable cardioverter–defibrillator, MRI magnetic resonance imaging, NA not applicable, ND not documented, PCI percutaneous coronary intervention, PEA pulseless electrical activity, VF ventricular fibrillation, and VT ventricular tachycardia.

[†] A dash indicates no diagnosis.

[‡] The patient had an abnormal electrocardiogram, with diffuse T wave inversions, but hypertrophic cardiomyopathy and long-QT syndrome were ruled out after expert consultation.

[§] The mutation detected was *TNNI3* Arg141Gln.

[¶] In-hospital investigations confirmed the diagnosis; therefore, an autopsy was deemed unnecessary.

Table 2

Total Number of Sudden Cardiac Arrests among Competitive Athletes, According to Type of Sport.

Sport	Estimated No. of Athletes in 2012	Total Sudden Cardiac Arrests from 2009 through 2014
Race events *	73,382	4
Alpine skiing	1,793	0
Baseball	6,343	1
Basketball	9,668	2
Cycling	1,100	0
Gymnastics	3,551	0
Ice hockey	116,390	2
Jujitsu	1,230	2
Lacrosse	6,474	0
University or college team	20,485	0
Rugby	4,420	1
Soccer	11,265	4
Softball	3,394	0
Swimming	5,442	0
Tennis	1,569	0
Volleyball	4,065	0
All other registered sports †	81,928	0
Total	352,499	16

* This category includes events such as marathons, biathlons, triathlons, and obstacle course races.

† This category includes sports such as badminton, ball hockey, boxing, cross country running, curling, disc sports, diving, equestrian, fencing, field hockey, football, rowing, sailing, Special Olympics, table tennis, handball, water polo, weight lifting, wheelchair sports, and wrestling.

Table 3

Incidence of Sudden Cardiac Arrest among Competitive Athletes.

Variable	Age Group			
	12–17 yr	18–34 yr	35–45 yr	All
Athlete-years of observation from 2009 through 2014	342,600	1,036,974	735,420	2,114,994
No. of athletes who had sudden cardiac arrest	4	9	3	16
No. of cases per 100,000 athlete-yr	1.167	0.868	0.408	0.756

Table 4

Causes of Sudden Cardiac Arrest among Competitive and Noncompetitive Athletes, According to Age Group.

Variable	Age Group			
	12–17 yr	18–34 yr	35–45 yr	All
Competitive				
No. of athletes	4	9	3	16
Percent of athletes who survived	50.0	44.4	33.3	43.8
Diagnosis				
Ischemic*	0	0	3	3
Primary arrhythmic	0	6	0	6
Structural†	2	3	0	5
Commotio cordis	2	0	0	2
Noncompetitive				
No. of athletes	9	18	31	58
Percent of athletes who survived	66.7	50.0	35.5	44.8
Diagnosis				
Ischemic*	0	5	21	26
Primary arrhythmic	4	5	0	9
Unknown	2	2	0	4
Structural‡	3	6	8	17
Other§	0	0	2	2

*This diagnosis refers to coronary artery disease.

†This category includes hypertrophic cardiomyopathy and anomalous coronary arteries.

‡This category includes hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, tetralogy of Fallot, and other cardiomyopathies.

§This category includes aortic dissection and unspecified cardiac disease.