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Background—Although such data are available for young competitive athletes, the prevalence, characteristics, and outcome of sports-related sudden death have not been assessed previously in the general population.

Methods and Results—A prospective and comprehensive national survey was performed throughout France from 2005 to 2010, involving subjects 10 to 75 years of age. Case detection for sports-related sudden death, including resuscitated cardiac arrest, was undertaken via national ambulance service reporting and Web-based screening of media releases. The overall burden of sports-related sudden death was 4.6 cases per million population per year, with 6% of cases occurring in young competitive athletes. Sensitivity analyses used to address suspected underreporting demonstrated an incidence ranging from 5 to 17 new cases per million population per year. More than 90% of cases occurred in the context of recreational sports. The age of subjects was relatively young (mean±SD 46±15 years), with a predominance of men (95%). Although most cases were witnessed (93%), bystander cardiopulmonary resuscitation was only commenced in 30.7% of cases. Bystander cardiopulmonary resuscitation (odds ratio 3.73, 95% confidence interval 2.19 to 6.39, $P<0.0001$) and initial use of cardiac defibrillation (odds ratio 3.71, 95% confidence interval 2.07 to 6.64, $P<0.0001$) were the strongest independent predictors for survival to hospital discharge (15.7%, 95% confidence interval 13.2% to 18.2%).

Conclusions—Sports-related sudden death in the general population is considerably more common than previously suspected. Most cases are witnessed, yet bystander cardiopulmonary resuscitation was only initiated in one third of cases. Given the often predictable setting of sports-related sudden death and that prompt interventions were significantly associated with improved survival, these data have implications for health services planning.

Key Words: arrhythmia • cardiac arrest • athletes • cardiopulmonary resuscitation • defibrillation • bystander help • exercise, physical

Although regular physical activity benefits cardiovascular health,[1] sport, particularly when practiced vigorously, has been shown to increase the risk of dying suddenly during or shortly after exercise.[2,3] The devastating consequences of unexpected sports-related sudden death (SD) and the recent availability of public access defibrillation mandate a thorough understanding of this phenomenon across the general population.[4–6] To date, the large majority of data regarding sports-related SD have focused on young competitive athletes,[7,8] whereas literature on sports-related SD during recreational sports activities in the community remains sparse.[9,10] No prospective evaluation of sports-related SD in the general population, including young competitive athletes, has been published to date.

Clinical Perspective on p 681

Sports-related SDs in young competitive athletes are highly visible and usually attract considerable public and media attention. On the basis of relatively large studies of sports-related SDs in young athletes from the United States and Italy,[7,11] specific preventive measures have been suggested, and some have been introduced in those countries.[7,11,12] Preparticipation screening and emergency response planning, for example, have been associated with a significant decrease in the incidence and mortality of such events in young athletes.[7,11,13,14] Nevertheless, the relatively low absolute number of such events occurring annually among young competitive athletes (estimated at 50 to 75 per

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year in the United States) appears to have influenced authorities in other countries,[8] such as France (Projet d'amendement relatif à l'installationde défibrillateurs dans les installations sportives de grande taille: Mission d'evaluation des politiques publiques—République Française, Mai 2009), where comprehensive preventive strategies (eg, widespread access to automatic external defibrillators) have not been instituted in public sports arenas because of a perceived lack of cost-effectiveness.

The extent to which data on sports-related SD based on young competitive athletes are generalizable to the wider community remains unknown. We hypothesized that sports-related SD would be more prevalent in the general population and thus designed a prospective nationwide observational study over a 5-year period to examine this issue. Our aims were to determine the overall sports-related SD burden in the community, to characterize the circumstances and features of sports-related SD, and to identify the independent factors that influence outcome.

Methods

Setting, Definitions, and Survey Methods

This prospective study was performed in France between April 2005 and April 2010. We included subjects 10 to 75 years old because the context of physical activity can be difficult to assess in the very young, and those older than 75 years only rarely participate in sports. The project was commissioned in 2004 by the Ministère de la Santé et des Sports and was performed by the Institut National de la Santé et de la Recherche Médicale (INSERM). We obtained close collaboration from the French system of mobile intensive care units (Service d'Aide Médicale Urgente [SAMU]). All of the 96 administrative districts throughout France were invited to participate, and 60 of these districts eventually participated (see Appendix for participating centers).

A death was considered to be sudden if it occurred within 1 hour of symptom onset.[7,8,15] Sports-related SD was defined if death occurred during sport or within 1 hour of cessation of sports activity. In most cases, this resulted from an unexpected collapse during physical exertion or immediately after, associated with a previously uneventful clinical course. Sports-related SDs related to trauma (for example, runner or cyclist hit by a car) were excluded, other than for cases of commotio cordis. A "young competitive athlete" was defined as any person 10 to 35 years old who participated in an organized sports program (team or individual sport) that required regular competition and training according to the National Registry from the Ministère de la Santé et des Sports (individuals participating in college-sponsored intramural sports were not considered young competitive athletes).[16] Sports-related SDs that occurred in competitive athletes outside the context of physical activity were not included. Sports participants who survived cardiac arrest after defibrillation and/or cardiopulmonary resuscitation (CPR) were considered to have experienced sports-related SD for the purpose of the present analysis.

To maximize case detection, 2 complementary independent methods were instituted that have already been used by other groups for young competitive athletes.[8] We tested the efficacy of the following case-detection methodology in France by performing a preliminary 6-month pilot study over 5 districts in 2004. First, a prospective case reporting system was instituted via the mobile intensive care services (SAMU); the French SAMU system is a nationwide emergency medical service accessed via a well-known nationwide free call number. Thus, SAMU is systematically called in cases of cardiac arrest or sudden collapse. Emergency health technicians in SAMU assess these subjects and start resuscitation where required, on site. For each case of sports-related SD during the study period, a specific detailed report form was completed by SAMU and then transmitted to the data collection center (INSERM U970, Paris, France) within the following 3 months. In parallel, a media search program screened for cases from continuous Web-based monitoring via Google Reader using the Really Simple Syndication system for local, regional, and national newspapers (n=275) with the key words "death," "cardiac arrest," and "dizziness." Manual checking of these reports was performed to identify verifiable sports-related SDs in 10- to 75-year-olds, and these cases were followed up if we had not already been notified of them via SAMU; complementary information was then obtained from written accounts or telephone interviews with the local emergency team of the SAMU.

A systematic review of all sports-related SD notifications was undertaken by an independent events committee every 6 months. Three experts in sports-related SD adjudicated cases to exclude SDs unrelated to sports, nonfatal sports-related cardiovascular events, and deaths that did not meet the SD definition, and finally to identify incomplete files that required further information.

Collected Data

Data were collected and registered according to revised Utstein guidelines, with an additional specific focus related to sports activity information.[17,18] Case report forms used by the emergency team of the SAMU included (1) date of arrest, patient identifier, and district of each event; (2) clinical and demographic information (age or date of birth, sex, any personal history of known heart disease, and any cardiovascular symptoms during the 4 preceding weeks); (3) data regarding the setting (recreational or competitive) and level of exercise at the time of the sports-related SD, as assessed by the ambulance officers using a prospectively defined scale of 1 to 8 metabolic equivalents (MET), classified as light (<4 MET), moderate (4 to 6 MET), or vigorous (>6 MET),[19,20] as well as the sports activity being undertaken at the time of the event and the regular training regimen of each subject; (4) circumstances of collapse, location type (sports facility or other area), presence of witnesses, and bystander CPR and defibrillation attempt; (5) detailed information regarding the resuscitation (time of collapse, SAMU call receipt, time SAMU vehicle arrived, CPR initiation, time of first rhythm analysis, and time of achieved return of spontaneous circulation), the initial cardiac rhythm recorded, and the number and timing of delivered defibrillator shocks; and (6) survival status to hospital admission.

Complementary data on survival status and causes of death were managed directly by INSERM U970 in collaboration with hospitals, and in some cases after contact with the patient's regular physician. Status of the patients at hospital discharge was available in the great majority of admitted cases (97.6%). Cause of death could only be obtained in cases in which an autopsy was performed or clinical features at the time of death permitted a confident diagnosis for those who died on site. In France, the performance of an autopsy is at the discretion of the physician certifying the death and is only mandated when the death is regarded as potentially "suspicious." For survivors, neurological status at discharge was evaluated with the Cerebral Performance Categories score.[21]

Importantly, no specific recommendations were specified in the study design regarding emergency care modalities or documentation of causes of death, because the objective of the investigators was to offer a "real-life" descriptive picture of sports-related SD features in France.

Statistical Methods

This report was prepared in compliance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist for observational studies.[22] The primary objective of the study was to provide an estimate of the incidence of sports-related SD in the general population of subjects 10 to 75 years of age. Secondary objectives were to describe population characteristics and identify variables associated with survival.

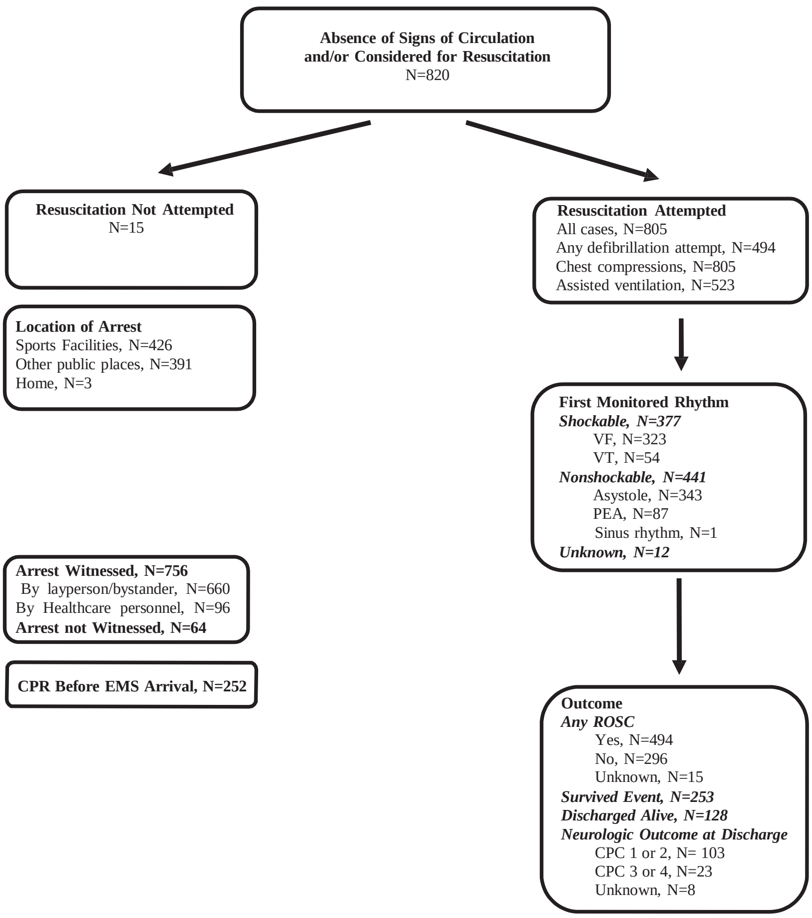

Figure 1. Utstein reporting template for 820 sports-related sudden deaths enrolled in the study. VF indicates ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity; CPR, cardiopulmonary arrest; EMS, emergency medical services; ROSC, return of spontaneous circulation; and CPC, Cerebral Performance Categories score.

The overall incidence of sports-related SD in France was estimated by extrapolation of the incidence of sports-related SD in the 60 participating administrative districts (which represent approximately 70% [33 948 400] of the French population 10 to 75 years of age) to the overall 96 French districts. We calculated the incidence in each participating district by dividing the average number of sports-related SDs reported per year by the locally registered 10- to 75-year-old population.[23] Because there is no evidence to support a triggering effect of light exertion for SD, the primary result regarding calculation of incidence only included cases that occurred during moderate and vigorous exertion (n=780). Moreover, because our estimated incidence of sports-related SD in the general population is almost certainly an underestimate, in addition to providing the global incidence with its 95% confidence interval (CI), 2 scenarios were then calculated based on the 80th and 20th percentiles of the highest reported incidences of sports-related SD across different districts in France.

The specific incidence of sports-related SD among young competitive athletes was calculated according to data from the Ministère de la Santé et des Sports.[16] The participating number of 10- to 35-year-old athletes over the study period was 1 015 293, and this figure was considered stable over time.[16] Because of the constant high level of media coverage of sports-related SDs in young sports participants in France (that is, such reports were considered likely to be comprehensive), we provided only 1 incidence rate calculation for this population.

Two additional sensitivity analyses were performed: First, on cases that occurred during vigorous exertion among the entire population (n=322), and second, among all degrees of exertion among the 10- to 60-year-old age group (n=667). The characteristics of sports-related SDs are described as mean±SD, proportions, or median and interquartile ranges, as appropriate. Qualitative variables were compared with the χ^2 test. All covariates that reached a significance level of $P<0.15$ for survival were then included in an initial multivariable regression model. Odds ratios (ORs) and their 95% CIs were calculated. All tests were 2-tailed, and $P<0.05$ was considered to indicate statistical significance. All data were analyzed at INSERM, Unit 970, Cardiovascular Epidemiology and Sudden Death, Paris, using STATA software version 11.0.

The authors had full access to the data and take full responsibility for its integrity. All authors have read and agree to the manuscript as written.

Results

Incidence Rates of Sports-Related Sudden Death

After 5 years of observation, representing 169 742 000 age-specific person-years, a total of 820 sports-related SDs were recorded (Figures 1 and 2); of these, 51% were first reported by SAMU and 49% by press reports. The proportion of cases reported first by SAMU varied between participating districts (from 32% to 100%). The overall estimate of sports-related SD was 4.6 (95% CI 3.9 to 5.3) per million population per year.

Additional sensitivity analyses were performed to address suspected underreporting of sports-related SD in each district; considering the 80th and 20th highest percentiles of reporting districts, the incidence of sports-related SD throughout France was calculated to be 5.4 and 16.7 cases per million per year, respectively (Table 1). Considering the 60- to 75-year-old population separately did not alter the nature of our findings, because the calculated incidence when we excluded

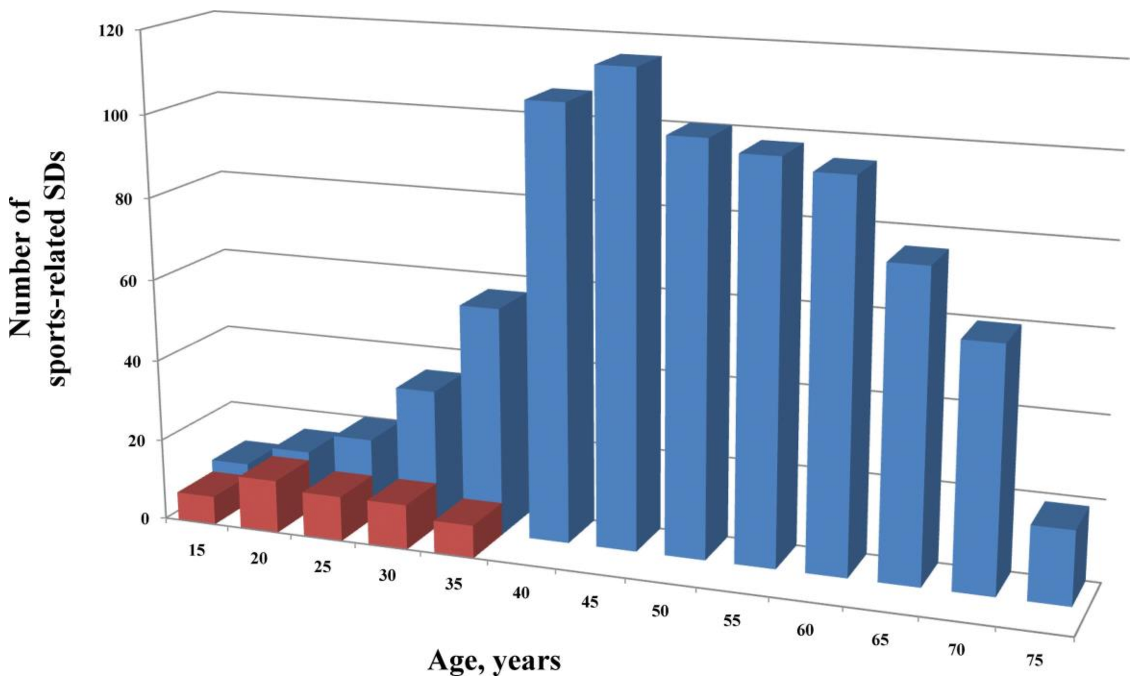

Figure 2. Distribution by age of sports-related sudden deaths (SDs) in the overall population (blue) and among young competitive athletes (red).

the cases in the older age group was 15.9 (95% CI 13.2 to 18.6) per million per year (20th percentile).

Among the 820 reported sports-related SDs, only 50 cases (6%) occurred in young competitive athletes, which yielded an incidence in this group of approximately 10 cases per million per year (Figure 2; Table 1). Compared with young (10 to 35 years old) noncompetitive sports participants, young competitive athletes had a higher risk of sports-related SD (relative risk 4.5, 95% CI 2.3 to 8.7). There were 777 SDs in males and 43 SDs in females (male/female ratio of 20:1), equivalent to incidence rates (20th percentile) of 32.8 and 1.9 million persons per year, respectively (relative risk 17.3, 95% CI 5.9 to 50.0).

Patient Characteristics and Sports-Related Sudden Death Settings

The mean age of the sports-related SD subjects was 46±15 years (range 11 to 75 years; Table 2). Ninety-four subjects (11.7%) had a known history of cardiovascular disease or presented with more than 1 classic cardiovascular risk factor for coronary heart disease. The majority (86.5%) of sports-related SD subjects performed regular sports and/or training. Symptoms, mainly chest discomfort, were reported in the days preceding the sports-related SD in 104 patients (12.7%). These patients were more likely to have sports-related SD due to ischemic heart disease than other participants (92.3% versus 70.7%, $P=0.005$).

Table 1. Estimated Incidence Rates of Sports-Related Sudden Death in the General Population, Amongst Young Competitive Athletes and Young Noncompetitive Sport Participants

	Population	No. of Districts	Incidence Rates, per Million per Year (95% CI)	Estimated Absolute per Year in France
General population (10–75 y)				
Overall	33 948 400	60	4.6 (3.9–5.3)	226
Male	16 195 232	60	9.2 (7.7–10.7)	216
Female	17 753 168	60	0.4 (0.1–0.7)	10
20th percentile	7 239 500	12	16.7 (13.7–19.7)	814
Male	3 474 960	12	32.8 (26.8–38.8)	772
Female	3 764 540	12	1.9 (0.5–3.2)	42
80th percentile	27 950 100	48	5.4 (4.5–6.3)	263
Male	13 116 500	48	10.6 (8.8–12.4)	250
Female	14 833 600	48	0.8 (0.4–1.3)	13
Young competitive athletes	1 015 293	60	9.8 (3.7–16.0)	15
Young noncompetitive participants	12 358 498	60	2.2 (1.4–3.0)	39

CI indicates confidence interval.

Table 2. Characteristics of Patients and Selected Features of 820 Sports-Related Sudden Deaths Included in the Study

	Value
Demographic data	
Age, y	
Mean	46.1±14.8
IQR	37–57
Males	777 (94.8)
Young competitive athlete	50 (6.1)
History of known heart disease*	66 (8.1)
Coronary heart disease	31
Paroxysmal atrial fibrillation	12
Ventricular arrhythmias considered as benign	6
Valvular heart disease	5
Pacemaker placement	5
Dilated cardiomyopathy	3
Others†	4
>1 Cardiovascular risk factor*‡	49 (6.1)
Time of occurrence	
Season	
Winter	158 (19.3)
Spring	258 (31.5)
Summer	243 (29.6)
Autumn	161 (19.6)
Week	
Weekend	336 (41.0)
Time of day	
Morning (6 AM to 12 PM)	287 (35.0)
Afternoon (12 PM to 6 PM)	359 (43.8)
Evening (6 PM to 12 AM)	174 (21.2)
Sport setting	
Sport activities	
Team sports	273 (33.3)
Individual sports	547 (66.7)
Location of occurrence	
Sport facilities	426 (52.0)
Others	394 (48.0)
Intensity of exercise*	
Light	32 (3.9)
Moderate	458 (56.4)
Vigorous	322 (39.7)
Management of sports-related SD	
Sudden death witnessed*	756 (92.6)
Bystander CPR	252 (30.7)
First monitored rhythm*	
Ventricular fibrillation or tachycardia	377 (46.7)
Asystole	343 (42.5)
Pulseless electrical activity	87 (10.8)
Sinus rhythm	1 (0.1)
Shock by external defibrillator	494 (61.1)
Delay, median (IQR), min	
Collapse-to-call received	2.0 (0.5–4.5)
Collapse-to-start of CPR	4.8 (1.2–8.5)
Collapse-to-first defibrillator shock	12.5 (10.5–15.5)

(*Continued*)

Table 2. Continued

IQR indicates interquartile range; SD, sudden death; and CPR, cardiopulmonary resuscitation.

Data are n (%), unless otherwise specified.

*Data were missing for history of known heart disease (for 8 subjects), cardiovascular risk factors (11), intensity of exercise (8), presence of witness (4), and monitored rhythm (12). Percentages were calculated on the basis of the total number of known events.

†Others denote operated congenital heart disease (2), history of Kawasaki disease (1), or Marfan syndrome (1).

‡Cardiovascular risk factor included known/treated diabetes mellitus, dyslipidemia, systemic hypertension, obesity, current smoker, and family history of premature coronary heart disease.

Sports-related SD actually occurred during sports activity in 92%, immediately after (within 30 minutes) in 7.4%, and only rarely more than 30 minutes after cessation of sports activity. Most sports-related SDs were observed during cycling (30.6%), running (21.3%), or soccer (13.0%), the sport activities most practiced in France (Figure 3). Sports-related SDs during team sports activities occurred at a younger age than during individual sports (33±11 versus 51±13 years, $P<0.0001$). Half of the sports-related SDs (51.9%) occurred in public sports facilities (such as a gymnasium or a stadium), and 99.8% of these were witnessed. Bystanders in sports facilities were slightly more likely to initiate CPR than were bystanders outside these settings, but this difference was not statistically significant (35.5% versus 30.8%, $P=0.15$). Among cases outside these settings, 83.4% were witnessed. There were more sports-related SDs on Sunday ($P<0.0001$, asymptotic test for binomial proportions), but no significant circadian variation was observed.

Bystander Cardiopulmonary Resuscitation, Advanced Life Support, and Predictors of Survival

Bystander CPR was initiated in 252 cases (30.7%). Median time from collapse to CPR initiation was 4.8 minutes (interquartile range 1.2 to 8.5 minutes). The initial cardiac rhythm was ventricular fibrillation or pulseless fast ventricular tachycardia in 377 cases (46.1%), with a mean number of shocks in this group of 5.3±3.8 (range 1 to 19).

A total of 253 of the 820 subjects (30.8%; 95% CI 27.7% to 34.0%) survived to hospital admission, and among them, vital status at time of discharge was known for 247 (97.6%). One hundred twenty-eight of these subjects survived to hospital discharge, giving an overall survival rate to hospital discharge of 15.7% (95% CI 13.2% to 18.2%). The majority of these (103 of 126 for whom neurological assessment was established) presented with a Cerebral Performance Categories score of 1 or 2, good enough to allow normal life or part-time work in a sheltered environment. The highest survival rates (=50%) were in the Burgundy (Côte-d'Or) and Nord-Pas-de-

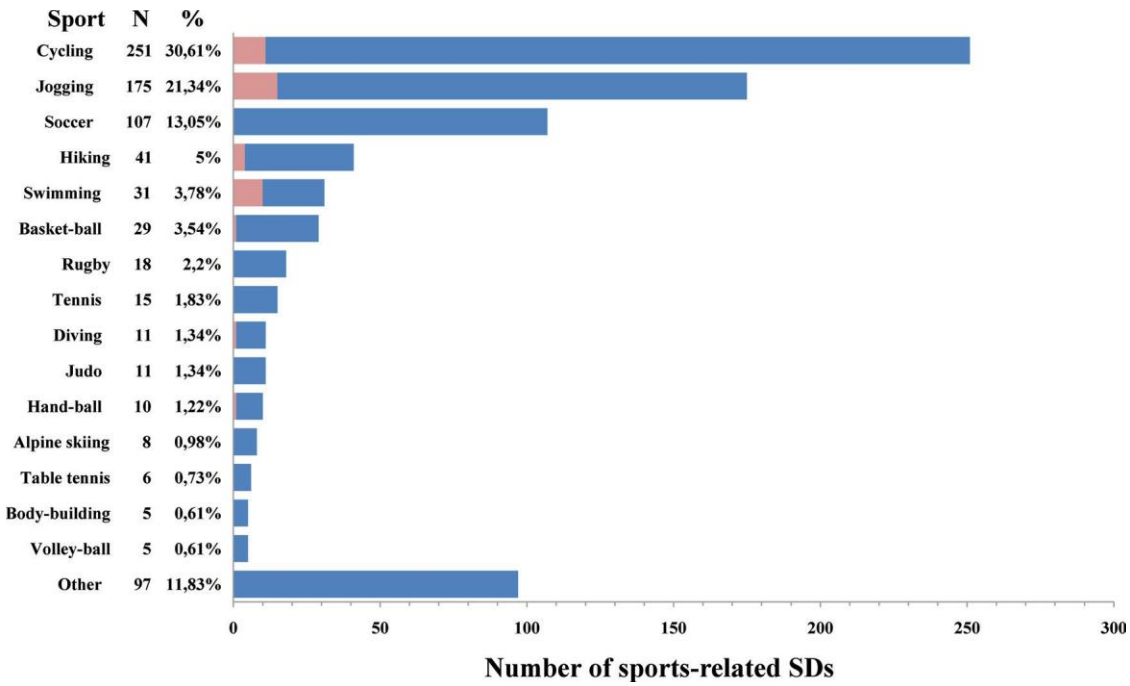

Figure 3. Sports engaged in at the time of sudden death (SD) in 820 sports participants. Shaded proportions of the bars represent the female ratio.

Calais (Nord) districts, where bystanders initiated CPR in more than 90% of cases.

Univariable analyses for factors associated with survival to hospital discharge are shown in Table 3. According to multiple logistic regression analysis, the following factors were independently associated with survival to hospital discharge: Bystander CPR (OR 3.73, 95% CI 2.19 to 6.39, $P<0.0001$), time from collapse to start of CPR (OR 1.32, 95% CI 1.08 to 1.61, $P=0.006$), and the initial use of cardiac defibrillation (OR 3.71, 95% CI 2.07 to 6.64, $P<0.0001$). Additional sensitivity analyses among cases of sports-related SD associated with vigorous exertion and among the 10- to 60-year-old population did not demonstrate significant differences regarding predictors for survival compared with the overall population.

Cardiovascular Abnormalities Associated With Sports-Related Sudden Deaths

The proportion of cases with a clear diagnosis remained low (24.7%), particularly among subjects who died on site (5.1%). Cause-of-death analysis among young competitive athletes and the general population is presented in Figure 4. Although 64% of sports-related SDs among young competitive athletes had the cause elucidated, this was only available for 22% of SDs among the general population.

Among the 203 cases in which it was possible to ascertain the cause of death with clinical certainty or from anatomopathological investigations, causes were cardiac in origin in all but 4 cases (98.0%). Acute coronary syndrome was the principal cause of cardiac arrest during sports (152 subjects, 74.9%); other cardiovascular causes of death or pathological findings included hypertrophic cardiomyopathy (7 subjects), possible hypertrophic cardiomyopathy (6), congenital cardiac abnormality (5, including 2 cases of aberrant coronary artery), dilated cardiomyopathy (5), myocarditis (5, including 1 case of sarcoidosis), arrhythmogenic right ventricular dysplasia (3), early repolarization syndrome (2), Wolff-Parkinson-white syndrome (1), familial long-QT syndrome (1), mitral valve prolapse (2), and commotio cordis (1). Noncardiac causes were found in 4 cases, ascribed to epilepsy, ruptured cerebral artery, stroke, and ruptured ascending aorta, respectively. The remaining 9 cases were ascribed to idiopathic ventricular fibrillation because no cardiac abnormality was observed. Among the 820 patients, drugs or anabolic steroids were reported to have been implicated in death in 2 cases.

Discussion

In this prospective study of 820 cases of sports-related SDs and resuscitated cardiac arrests in a general population, we have identified a higher burden of this event than previously suspected from comprehensive surveys of sports-related SD in young competitive athletes. We found that the majority of such events were witnessed (93%), although bystander CPR was initiated in fewer than one third of the cases. Given the often predictable setting of sports-related SD and that prompt interventions were significantly associated with improved survival, these data have implications for health services planning. In particular, education about CPR for sports participants and availability of public access defibrillation in sports facilities have the potential to achieve substantial improvements in outcomes.

Previously published data on the incidence of sports-related SDs observed in competitive young athletes have documented an incidence of 6 to 9 per million such competitors per year.[7,8] The present data among young competitive athletes are very consistent with these estimates. The largest

Table 3. Univariate Analysis for Survival to Hospital Discharge

Predictors of Survival: Variables	OR	95% CI	*P*
Women vs men	1.59	0.76–3.32	0.21
Age, y			
10–30	1.00		<0.0001
31–50	0.60	0.36–0.99	
51–75	0.26	0.15–0.44	
Known CVD vs others	0.56	0.28–1.12	0.10
Seasons			
Winter	1.00		0.18
Spring	1.61	0.92–2.84	
Summer	1.13	0.62–2.04	
Autumn	1.64	0.89–3.00	
Weekend	1.60	1.10–2.32	0.01
Team sports	0.98	0.66–1.45	0.92
Intensity of exercise			
Light	1.00		0.002
Moderate	1.70	0.40–7.51	
Vigorous	3.36	0.78–14.5	
Sport facilities vs others	2.83	1.88–4.25	<0.0001
Competitive vs recreational setting	1.32	0.83–2.12	0.24
Young competitive athlete	1.62	0.82–3.18	0.16
Presence of witness	6.73	1.62–27.8	0.009
Bystander CPR	9.83	6.42–15.04	<0.0001
Collapse to start of CPR delay, min			
0–2	1.00		<0.0001
3–4	0.44	0.22–0.91	
5–10	0.13	0.06–0.28	
11–20	0.10	0.05–0.23	
Initial shockable rhythm	9.60	5.88–15.70	<0.0001

OR indicates odds ratio; CI, confidence interval; CVD, cardiovascular disease; and CPR, cardiopulmonary resuscitation.

previous European study of sports-related SDs, from Veneto, Italy, included 55 cases of sports-related SDs in young competitive athletes documented over a 25-year period.[7,24] Maron et al[8] reported 1866 cases of SD in young competitive athletes over a 27-year period in the United States, 50% of which were traumatic, of noncardiac origin, or did not occur during sporting activity. Taken together, these data suggest that approximately 50 to 75 SDs in young competitive athletes would occur annually in the United States, and approximately 10 to 15 such events would occur in France each year. The focus on this group of healthy young athletes is highly understandable given the substantial social and emotional impact of sudden and unexpected deaths in this group.[25]

However, data showing relatively low absolute numbers of events in young athletes per year have influenced health authorities in many countries regarding the institution of widespread early response measures. In France in May 2009, for example, draft legislation proposing the installation of automatic external defibrillators in sporting arenas was eventually rejected after evaluation by an economic expert committee that concluded that this would not be cost-effective based on the 10 to 15 expected such cases yearly.

Data concerning the risk of sports-related SD among recreational sports participants, who accounted for more than 90% of cases in the present study, are relatively sparse. These data come from a limited number of retrospective studies that involved small numbers of cases and most often were in regard to only 1 sports activity.[9,10,26–32] To date, only 1 study attempted to evaluate sports-related acute cardiovascular events in the general population, with no specific focus on SD.[33] Other available data from autopsy series contribute information on likely causes of SD; however, these are associated with bias and do not allow calculation of the population burden of sports-related SD.[34–38] Finally, to the best of our knowledge, sports-related SD has never been evaluated in the general population, including athletes and recreational sports participants across a wide age range. The present study revealed a much higher prevalence of sports-related SD in the general population than previously suspected (estimated at approximately 4250 cases in the United States or 800 cases in France each year in the 10- to 75-year-old age group). The present data demonstrated that although risk for sports-related SD remains higher in young competitive athletes than in 10- to 35-year-old noncompetitive sports participants, the absolute risk appears to be higher in the general population. In the present series, although the survival rate to hospital discharge after sports-related SD (approximately 16%) was substantially higher than the published rates of survival after SD in general, at approximately 7% to 8%,[39] there may still be substantial room for improvement. For example, 90% of sports-related SDs in the present series were witnessed, but bystander CPR was commenced in only one third of these cases. The data from 2 French districts where resuscitation rates of more than 90% were associated with survival rates of approximately 50% support calls for more extensive population-based CPR education. Because the population is relatively young and such settings offer optimal chances for survival, these data should prompt the development of preventive measures based on public education. Moreover, these results also raise the question of systematic screening, especially for ischemic heart disease, among male recreational sports participants with cardiovascular risk factors.

We note the striking male predominance in sports-related SD in the present series. Based on sports participation rates in France, this is not simply the reflection of a greater male participation but likely the consequence of a higher risk profile in men. The reasons for this sex difference is unclear, but it could be related to the known higher prevalence of coronary disease in young and middle-aged men than in women. Differences in the mode of physical activity and training between sexes may also be relevant.

We acknowledge that the present study has a number of potential limitations. First, we observed important differences in incidences among districts. One possible explanation is that this may reflect real differences in incidences due to subject characteristics or sports activities. However, the ratio of emergency medical services cases to total cases varied markedly among districts, which leads us to favor a different

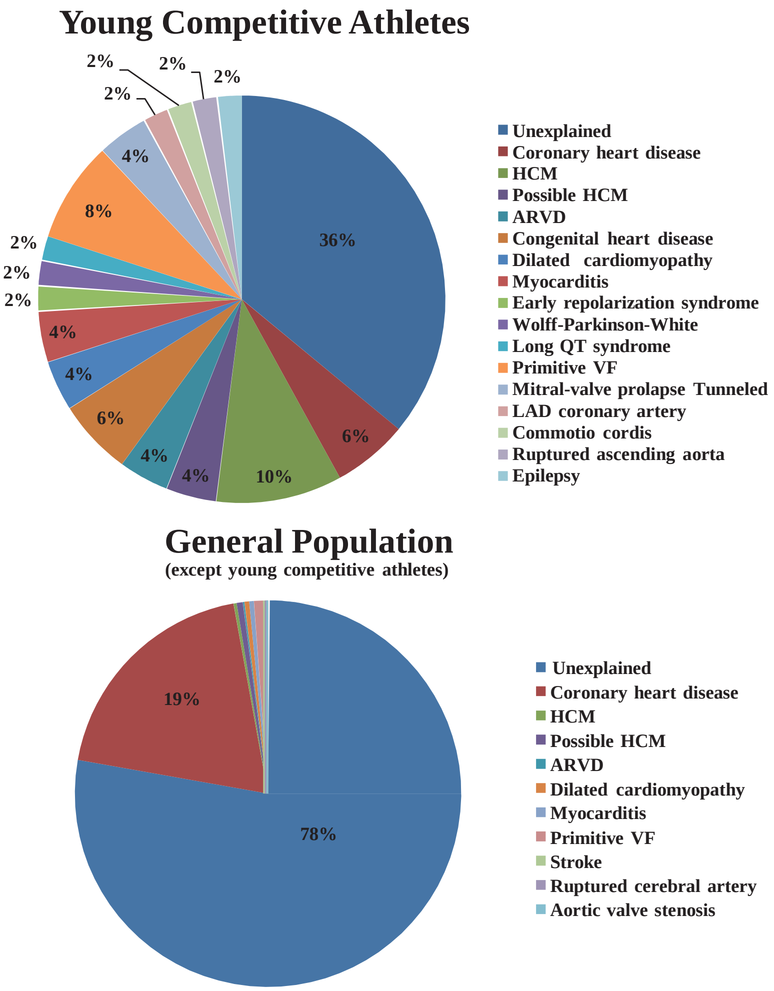

Figure 4. Cardiovascular abnormalities associated with sports-related sudden death in 820 subjects among the young competitive group (n=50) and the general population (n=770). HCM indicates hypertrophic cardiomyopathy; ARVD, arrhythmogenic right ventricular dysplasia; VF, ventricular fibrillation; and LAD, left anterior descending.

explanation, ie, that the variability of reported incidences across different districts reflects a variable degree of underreporting. Our estimated incidence of sports-related SD in the general population is also almost certainly an underestimate. In addition to underreporting, this is also due in part to the consideration of the entire 10- to 75-year-old population as being potentially at risk of sports-related SD rather than estimating the proportion who were actually participating in sports (this is because there are no reliable data to estimate actual recreational sports participation). This has been the rationale for the use of sensitivity analyses to provide a range of incidence of community-based sports-related SD. Second, autopsy rates are very low in France, where they are performed at the discretion of the certifying physician rather than mandated by law. The present results among young competitive athletes, including the rate of cases without precise diagnosis, are consistent with the study of the largest cohort to date performed by Maron and colleagues in the United States.[8] On the other hand, we offered a different view from the general population with a majority of cases considered ischemic cardiovascular events but that ultimately remained without a precise diagnosis. Further efforts for better identification of cause of death, including postmortem molecular analysis, are crucial in this context, in which early diagnosis of familial cardiomyopathy or channelopathy may be vital for relatives.[40]

In summary, we have documented a substantially higher incidence of sports-related SD in the general population than suspected previously from studies focused on competitive young athletes. Depending on the degree of underreporting present in our sample, we estimate from 5 to 17 cases of sports-related SD occur per million individuals residing in France per year. Most such events occur in previously healthy men 35 to 65 years old, happen in a public area, and are witnessed by bystanders. Given the often predictable setting of sports-related SD and that prompt interventions including bystander CPR and defibrillation were significantly associated with improved survival, these data have implications for health services planning.

Appendix

Participating Centers

The investigators and coordinators participating in the study were as follows (numbers given are French administrative division numbers):

02 Aisne, Dr F. Degrootte; 05 Hautes-Alpes, Dr M. Tashan; 06 Côte d'Azur, Dr D. Grimaud; 13 Bouches-du-Rhône, Dr V. Vig; 14 Calvados, Dr D. Bonnieux; 16 Charente, Dr R. Loyant; 17 Charente-Maritime, Dr A. Mounios; 18 Cher, Dr F. Bandaly; 21 Côte-d'Or, Dr M. Freysz; 22 Côtes-d'Armor, Dr C. Hamon; 24 Dordogne, Dr M. Gautron; 25 Doubs, Dr M.C. Maillot; 26 Drôme, Dr C. Zamour; 28 Eure-et-Loir, Dr N. Letellier; 29 Finistère, Dr D. Lazou; 31 Haute-Garonne, Dr J.L. Ducasse; 32 Gers, Dr J.M. Guez; 33 Gironde, Dr

M. Thicoipe; 34 Hérault, Dr P. Benatia; 36 Indre, Dr L. Soulat; 37 Indre-et-Loire, Dr A. Fusciardi; 38 Isère, Dr K. Berthelot; 39 Jura, Dr A. Elisseeff; 40 Landes, Dr R. Ricard; 41 Loir-et-Cher Dr Solo Randriamalala; 42 Loire, Dr T. Guerin; 44 Loire Atlantique, Dr V. Debierre; 45 Loiret, Dr S. Narcisse; 48 Lozère, Dr M. Chassing; 51 Marne, Dr A. Léon; 52 Haute-Marne, Dr J. Milleron; 55 Meuse, Dr M. Vedel; 56 Morbihan, Dr F. Charland; 59 Nord, Dr N. Benameur; 60 Oise, Dr T. Ramaherison; 62 Pas-de-Calais, Dr L. Hapka; 63 Puy-de-Dôme, Dr J. Meyrieux; 64 Pyrénées-Atlantiques, Dr I. Pouyanne; 65 Hautes-Pyrénées, Dr J. Khazaka; 67 Bas Rhin, Dr J.C. Bartier; 68 Haut-Rhin, Dr A. Goulesqueb; 69 Rhône, Dr P.Y. Gueugniaud; 70 Haute-Sâone, Dr T. Elcadi; 71 Sâone-et-Loire, Dr B. Girardet; 72 Sarthe, Dr C. Savio; 75 Paris, Dr D. Jannière; 76 Seine-Maritime, Dr B. Dureuil; 77 Seine et Marne, Dr J.Y. Le Tarnec; 78 Yvelines, Dr S. Templer; 80 Somme, Dr C. Ammirati; 81 Tarn, Dr M.G. Vaissière; 83 Var, Dr J.J. Raymond; 84 Vaucluse, Dr P. Olivier; 88 Vosges, Dr H. Tonnelier; 89 Yonne, Dr M. Duche; 90 Territoire-de-Belfort, Dr A. Kara; 92 Hauts-de-Seine, Dr M. Baer; 93 Seine-Saint-Denis, Dr F. Adnet; 94 Val-de-Marne, Dr C. Vallier; 95 Val-d'Oise, Dr C. Ramaut.

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Disclosures

None.

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CLINICAL PERSPECTIVE

To date, the majority of data regarding sports-related sudden death (SD) have focused on young competitive athletes, and few data concerning sports-related SD in the general population have been available. In this 5-year observational study of SD occurring during sports in competitive and recreational participants 10 to 75 years of age, we have found that although the risk for sports-related SD remains higher in young competitive athletes than in young noncompetitive sports participants, the absolute risk is otherwise higher in the general population. The present study revealed approximately 800 cases in France each year compared with the 15 annual cases among young competitive athletes. Case subjects were relatively young (46±15 years), predominantly males (95%), and without any prior history of heart disease. Half of the observed cases occurred in sports facilities, and almost 90% of events were witnessed; however, the rate of bystander cardiopulmonary resuscitation was low, initiated in fewer than one third of cases. Given the often predictable setting of sports-related SD and that prompt interventions including bystander CPR and defibrillation were significantly associated with improved survival in the present study, these data have implications for health services planning.