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Authors: Chappex N, Schlaepfer J, Fellmann F, Bhuiyan ZA, Wilhelm M, Michaud K

Journal: Journal of forensic and legal medicine

Year: 2015 Oct

Issue: 35

Pages: 62-8

DOI: 10.1016/j.jflm.2015.07.004

Elsevier Editorial System(tm) for Journal of Forensic and Legal Medicine
Manuscript Draft

Manuscript Number: JCFM15-134R1

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Article Type: Original Communication

Keywords: sudden cardiac death, coronary artery disease in the young, sport-related deaths, registries

Corresponding Author: Dr.Med. Katarzyna Michaud, MD

Corresponding Author's Institution: University Center of Legal Medicine

First Author: Nina Chappex, MD

Order of Authors: Nina Chappex, MD; Jurg Schlaepfer, MD; Florence Fellmann, MDPhD; Zahurul Alam Bhuiyan , MDPhD; Matthias Wilhelm, MD; Katarzyna Michaud, MD

Abstract: Purpose: The goal of the study was to assess the causes and analyze the cases of sudden cardiac death (SCD) victims referred to the department of forensic medicine in Lausanne, with a particular focus on sports-related fatalities including also leisure sporting activities. To date, only a few data has been published for Switzerland and for the central Europe.

Methods: This is a retrospective study based on autopsy records of SCD victims, from 10 to 50 years of age, performed at the University Centre of Legal Medicine in Lausanne from 1995 to 2010. The study population was divided into two groups: sport-related (SR) and not sport-related (NSR) SCDs.

Results: During the study period, 188 cases of SCD were recorded: 166 (88%) were NSR and 22 (12%) SR. The mean age of the 188 victims was 37.3 ± 10.1 years, with the majority of the cases being male (79%). A cause of death was established in 84%, and the pathology responsible for death varied according to the age of the victims.
In the NSR group, the mean age was 38.2 ± 9.2 years and there was 82% of male. Coronary artery disease (CAD) was the main diagnosis in the victims aged 30 to 50 years. The majority of morphologically normal hearts were observed in the 15-29 year age range. There was no case in the 10-14 year age range.
In the SR group, 91% of victims died during leisure sporting activities. In this group the mean age was 30.5 ± 13.5 years, with the majority being male (82%). The main cause of death was CAD, with 6 cases (27%) and a mean age of 40.8 ± 5.5 years. The youngest victim with CAD was 33 years old. A morphologically normal heart was observed in 5 cases (23%), with a mean age of 24.4 ± 14.9 years. The most frequently implicated sporting activities were hiking (26%) and swimming (17%).

Conclusion: In this study, CAD was the most common cause of death in both groups. Although this pathology most often affects adults over 35 years of age, there were also some victims under 35 years of age in both groups. SCDs during sport are mostly related to leisure sporting-activities, for which preventive measures are not yet usually established. This study highlights also the need to inform both athletes and non athletes of the cardiovascular risks during sport activities and the role of a forensic autopsy and registries involving forensic pathologists for SR SCD.

Sudden cardiac death among general population and sport related population in forensic experience

ABSTRACT

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In the SR group, 91% of victims died during leisure sporting activities. In this group the mean age was 30.5 ± 13.5 years, with the majority being male (82%). The main cause of death was CAD, with 6 cases (27%) and a mean age of 40.8 ± 5.5 years. The youngest victim with CAD was 33 years old. A morphologically normal heart was observed in 5 cases (23%), with a mean age of 24.4 ± 14.9 years. The most frequently implicated sporting activities were hiking (26%) and swimming (17%).

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INTRODUCTION

Cardiovascular diseases are the most frequent causes of death in industrialized countries. Sudden cardiac arrest is a leading cause of death in children and young adults[1, 2] and can be caused by various heart diseases, such as coronary artery disease (CAD), hypertrophic cardiomyopathy (HCM), ILVH (idiopathic left ventricular hypertrophy), arrhythmogenic right ventricular cardiomyopathy (ARVC) and channelopathies[1, 3, 4].

According to the literature, the most common cause of sudden cardiac death (SCD) in the general population is CAD related to coronary atherosclerosis. It occurs more frequently in

adults over 35 years of age, but is also an important cause of death in younger victims especially during sport activities[2, 5]. SCDs in young athletes receive considerable attention from the media and increase the awareness of screening programs. Public interest arises from both the importance of sports in many societies, and from the paradox that physical activities can have both a positive and negative impact on an individual's health[6]. According to several studies, sudden death from cardiovascular disease is the principal cause of death in young athletes during training, and accounts for 75% of all fatalities that occur during sport activities[1, 7-9]. Regular physical activity has a protective influence on health, particularly the cardiovascular system, but it may become deleterious beyond a certain point and can precipitate the occurrence of complications related to pre-existing and silent cardiac diseases[4, 6, 8-17]. An unexpected and suspicious sudden death is often the first symptom of undiagnosed cardiac disease. In Switzerland, unexpected sudden deaths, including those which occur during physical activity, are considered as suspicious and are referred to the forensic medicine department.

The purpose of this study was to investigate the causes of SCD in individuals aged 10 to 50 years, who died either during sport (SR group) or not (not sport related group: NSR). Individuals included in the study were referred to the department of forensic medicine in Lausanne between 1995 and 2010. To date, only a few data has been published for Switzerland[6, 18].

METHODS

Selection of cases

This retrospective study is based on a review of autopsy reports from the University Center of Forensic Medicine in Lausanne. Selected cases were of victims between 10 to 50 years of age who had a clinical history compatible with SCD defined as unexpected death occurring as a result of natural causes in which loss of all functions occurred instantaneously or within one hour of the onset of symptoms. We excluded cases with a non-cardiac cause of death found at autopsy or during toxicological analyses and cases showing marked putrefaction. We chose these age groups (10-50 years) in order to compare our results with existing studies. A subgroup was created for all cases of SCD which occurred during sport activity, including amateur and professional athletes[8], high level sportsmen, and individuals practising leisure sport activities. We define a leisure sportsman as someone practicing a sporting activity 2-3 hours per week, a high level sportsman as someone who trains more than 4 hours per week and an athlete as someone with a regular and intense training who takes part in competitive sports. Cases were grouped according to the age with 5 years interval as for example; 10-14, 15-19, 20-24, etc.

Analysis of cases

The autopsies were performed according to international recommendations[19]. Toxicological analyses were performed in all cases for which no cause of death was established after morphological examination. Anti-doping analyses were performed for the athlete victim of SCD.

The following data were recorded in each case: cause of death, age, weight, height, body mass index (BMI), type of sporting activity (if applicable), symptoms before death, timing

between physical activity and death, risk factor, personal history of cardiac disease, family history, general and cardiovascular medical history and the autopsy results, including complementary toxicological analyses and post-mortem molecular autopsy in selected recent cases. The final cardiovascular pathological diagnoses were classified into the following groups: CAD including acute (thrombosis) and chronic forms (stenosis superior to 75%), HCM and ILVH, ARVC, anomalous origin of coronary artery, inflammatory disease (myocarditis/sarcoidosis), mitral valve prolapse, other valvular abnormalities, conduction system abnormalities and a morphologically normal heart.

RESULTS

General results

Based on these criteria, 188 cases were selected. The mean age was 37.3 ± 10.1 years (32.6 years for women and 38.6 years for men). The number of cases increased with age, especially in men (Fig.1). The number of victim under 35 years old and under 39 years old was respectively 63 (33.5%) and 87 (46.3%). Among the 188 cases, 22 deaths (12%) occurred during sport activities (SR group). In the SR group, cases were distributed homogeneously among the age groups. There were 4 women (17%) and 18 men (82%). The mean age in the SR group was 30.5 ± 13.5 years and there were 2 cases in the 10 to 14 year age group; both were females who died during sport activity. In the NSR group (166 cases), there were 36 women (22%) and 130 men (78%) and the mean age was 38.2 ± 9.2 years.

The cause of death was established in 83.5% of cases (84.3% in the NSR group and 73.4% in the SR group). The hearts were morphologically normal in 16.5% of cases (15.7% in the NSR and 22.7% in the SR groups); for all of these cases, full toxicological and anti-doping analyses were performed and were found to be negative.

Molecular autopsies were proposed to investigating district attorney since the appearance of technical tools but considering their cost, this recommendation was accepted only in selected recent cases. Post-mortem genetic analyses were performed after genetic counselling of families using direct sequencing for the verification of genetic variants in *KCNH2*, *KCNQ1*, *SCN5A* and later also for *RyR2* gene mutations. Considering the complexity of post-mortem genetic testing in the forensic context, after the introduction of the Swiss Law of Genetic, the samples were stored for disposition of families and analysed only after the contact of families and a multidisciplinary consultation. Post-mortem genetic testing for channelopathies was performed in nine cases and did not reveal any known mutation. The data concerning the medical and family history were collected by the police during the judicial investigations and transmitted to the forensic pathologists. Contact between the family doctor and the forensic pathologist was established in a few of the cases and negative information was not reported. A family history of cardiac-related death was reported in 12 cases (6.4%), including 10 men with CAD (8 in NSR group and 2 in SR group), one woman with HCM and another with a morphologically normal heart (both in the NSR group). A prodrome such as chest pain, palpitations or ill-being was reported in 71 cases (37.8%), including 49 cases (37.7%) in the NSR male group, 14 cases (38.9%) in the NSR female group and 8 cases (36.4%) from the SR group (2 women and 6 men). Hypercholesterolemia was reported in 11 cases (5.8%), affecting mainly men, with a mean age of 43.4 ± 4.5 years and a mean BMI of 30.5 ± 6.6 kg/m². 10 of these 11 deaths were due to CAD.

For the patients with a normal heart (26 cases), the clinical histories reported epilepsy in 6 cases of the NSR group, family history of sudden cardiac death for 3 other cases and sudden collapses without information of family history in 4 cases. It should be underlined again that the medical information were not systematically reported.

The mean BMI for all cases was 26.0 ± 6.0 kg/m², with the majority being in the group with a BMI of 25-29.9 kg/m². Most of the CAD cases were in the 25-29.9 BMI group, while the majority of cases with cardiomyopathies (non-ischemic) and with morphologically normal hearts were in the 20-24.9 BMI group.

Causes of death in the NSR group

CAD was the most common cause of death in the NSR group, with 62 males (48%) and 11 females (31%). The mean age of victims with CAD was 42.4 ± 5.9 years, while the mean age of victims without CAD was 35.8 ± 10.0 years; 4 victims were between 28 and 30 years old. Acute coronary thrombosis was found in 15 cases (9%), with a mean age of 40.6 ± 7.5 years. Chronic coronary artery disease with a stenosis superior to 75% was observed in 40 cases (24.1%), with a mean age of 43.1 ± 5.2 years. Both acute and chronic forms were observed in 17 cases (10.2%), with a mean age of 42.3 ± 6.0 years. The number of deaths related to CAD increased with age, with 36% in the 45-50 year group (Fig.2). An increase of chronic CAD was noted after the age of 35. We found a majority of chronic forms in the NSR group (53%). The second cause of death was HCM and ILVH, with 29 cases (17%) having a mean age of 38.6 ± 8.8 years, including 29 men. A morphologically normal heart was found in 26 cases (16%), with a mean age of 33.3 ± 11.2 years, including 16 men (12%) and 10 women (28%).

The main causes of death varied according to age. There was no case in the 10-14 year age range. A morphologically normal heart was the main finding in the 15-19 year age

population. In the 20-24 year age group the main findings were a morphologically normal heart, HCM and ILVH and myocarditis. In the 25-29 year age group both, a morphologically normal heart or CAD were the main findings. In the 30-50 year age group, CAD was the main cause of SCD.

Causes of death in men versus women

The most common cause of SCD in men was CAD (Table 1), the number of cases increasing with age. The second cause of death was HCM and ILVH present in 29 cases (17%). The third cause of death was myocarditis, present in 7 cases (5%).

The most common cause of SCD in women was also CAD (Table 1), all victims being aged between 30 to 50 years. The second most common cause of death was myocarditis, present in 7 cases (19%). The third cause was valvular abnormalities, present in 3 cases (8%).

SR group

The details of the cases are presented in Table 2. Sport-related deaths involved a variety of activities: hiking, swimming, downhill skiing, cross-country skiing, cycling, volleyball, tennis, badminton, football, gymnastics, sailing and hockey arbitration. The most commonly involved sport was hiking, including 5 cases (23%), 2 recreational and 3 experienced hikers. Swimming was the second most commonly involved sport, with 4 cases (18%), 3 recreational swimmers and one amateur athlete. Thirteen victims (59%) performed sporting activities occasionally, 8 (36%) had a high level of training and 2 (9%) were amateur athletes (Table 2). In 13 cases (60%), death occurred during the sporting activity and in 9 cases (40%) minutes to hours after cessation of sports activity.

CAD was the main cause, with 6 cases (27%), the youngest victim being 33 years old. The mean age of victims with CAD was 36.5 ± 5.5 years while the mean age of victims without CAD was 30.4 ± 13.5 years. CAD was the principal cause of death in the 45-50 year age group. CAD with acute coronary thrombosis was observed in 4 cases with a mean age of 41.3 years, while chronic coronary atherosclerosis with a stenosis greater than 75% was observed in 2 cases, with a mean age of 40.0 ± 7.0 years. A morphologically normal heart was observed in 5 cases (23%) with 3 victims aged 15 years old and the others 28 and 49 years old respectively. HCM or ILVH was found in 4 cases (18%), with victims being 15, 32, 42 and 50 years old. ARVC was present in 3 cases (14%), with victims being 16, 19 and 33 years old. ARVC was the main cause of death in sportsmen between 15 to 19 years old. Myocarditis was found in 2 victims (9%) aged 37 and 39 years.

The main causes of death varied with age. There were only 2 cases in the 10 to 14 year range, one with an anomalous origin of the left coronary artery with an intra-mural course, and one with heart conduction abnormalities (fibromuscular dysplasia of the AV node artery). In the 15 to 29 year range, a morphologically normal heart was the main finding. In the 30 to 44 year group there were cases of HCM, myocarditis and CAD. After 45 years of age, the main finding was CAD.

In the SR group, there were 2 cases involving athletes (N^{o} 7 and 9 in Table 2).

The first was a 16 year old girl who already shown faintnesses in previous trainings and died during swim practice with a diagnosis of ARVC. The second was a 28 year old man; a few months before death he had normal cardiac screening exam and he died after playing tennis with a morphologically normal heart although at the upper limit of predicted weight values (http://calc.chuv.ch/Heartweight)[20], the molecular autopsy was not ordered by the district attorney.

DISCUSSION

Deaths of cardiac origin are very common in developed countries. The exact incidence of SCD is unknown, but it is estimated to be between 36 to 128 deaths per 100,000 person-years in the general population and between 0.4 to 13.4 deaths per 100,000 person-years in the young[4]. According to several literature sources, the causes of SCD depend on the age of the victim, the most frequent being CAD[2, 7, 9, 10, 12, 14, 16, 21]. In post-mortem studies, atherosclerotic CAD was reported to be the most common finding in victims over 35 years old, and was reported to increase with age[7, 9, 14, 16]. Accordingly, in our study, CAD is the main cause of SCD in the NSR group. Some authors suggest that atherosclerotic heart disease increases after the age of 30 years[1, 14]. In a study by Meyer et al[1], CAD was the most common cause of cardiac death in victims aged 25 to 35 years. The results of our study are in accordance with the current literature data, which show a predominance of CAD in victims over 35 years and a predominance of cardiomyopathies in those under 35 years. In our study, there were 4 cases in the age range of 28 to 30 years for which CAD was found to be the cause of death. All 4 cases had risk factors for CAD as hypercholesterolemia and positive family history. The second most common cause of SCD in the NSR group was HCM or ILVH. This finding is in accordance with the studies of Subirana[7] and Eckart[14], showing that hypertrophic (and hypertensive) cardiomyopathies are second to CAD on the list of causes. In this study, a morphologically normal heart was found in 16% of the NSR group and was the main finding in the 15-19 year group, accounting for 6 out of the 9 cases (67%). Such deaths are generally linked to channelopathies. In our study, the post-mortem genetic testing was performed only for a few cases. Even if results were negative, we are not able to exclude that the death was

related to channelopathy considering the diagnostic yield of genetic tests. According to the literature, the percentage of normal hearts found in SCD victims varies between 6-53%[3], with a higher proportion of sudden unexplained death in victims under 35 years of age[10, 14].

Sport-related SCDs have been investigated by many researchers, whose primary focus has been on athletes. Their results show that HCM, ARVC and unexplained death are the three most common causes of death in athletes[5, 8, 15, 21-23]. In our study, 90% of victims in the SR group died while performing leisure or high level sporting activities (non athletes), thus it is difficult to compare these results with the literature data concerning the athletic population. Only a few studies have been published on SCD related to leisure sporting activities[4, 12, 13, 17, 24]. The findings in this study are in accordance with the study of Marijon[24], which shows that SCDs that occur in the non-athlete are more frequent than previously thought. In this French study, however, autopsies were performed only in a minority of cases and the exact causes of death were not confirmed.

As aforementioned, CAD is a less common finding as hypertrophic or arrhythmogenic cardiomyopathies in competitive athletes. The study by Corrado et al[9] showed that CAD is the second most common cause of death in athletes (the first being ARVC). In a study performed by Maron, CAD ranked below hypertrophic cardiomyopathy, congenital coronary anomaly and other cardiomyopathies as the most frequent cause of death[8]. CAD remains the principal cause of SCD for victims who die during recreational sport and military training[6, 14]. In the present study, CAD was the main cause of death in the SR group with the youngest victim being 33 years old. In several studies, HCM was found to be the principal cause of sport-related SCD, both in athletes and in non competitive sportsmen[4, 8, 12, 15, 17, 25]. The differentiation between an athletic heart and a borderline case of HCM can prove difficult, as underlined by many authors. In our study, hypertrophic heart

is the second most common cause of SCD in the sport-related population. The percentage of morphologically normal hearts in the SCD sports-related population is not systematically reported in the literature. Available results vary from 7 to 23% in athletes[9, 15] and from 4.5 to 12.5% in leisure sporting-activity[12, 17, 24]. In this study, a morphologically normal heart was present in 23% of the cases.

The incidence of SCD in the sport-related population has been analysed by many authors[18, 23-25] (Table 3), but not many data was published for Switzerland. A 2010 Danish study reported that the incidence of SCD in competitive athletes was higher than that for the general population[23]. Corrado et al found that the percentage of sport-related SCD (out of all SCDs) was 18% in Italy[9], while Wilhelm et al published 15% for the canton of Bern[6], and this study found 12% for the canton of Vaud. The relatively low number of athletic victims may be a result of the efficacy of the preventative screening programs, and may be related to the fact that not all deaths were followed by an autopsy. For these reasons, and given that only the preliminary data are available for Switzerland, a registry was recently established in order to determine the real incidence of sport-related SCD in athletes[6].

The types of sports practiced by the leisure sportsmen were different from those practiced by the athletes. Several authors have mentioned running, cycling and soccer as the main sports involved in SCD events, while in our study, the main sports involved were hiking and swimming[6, 12, 14, 17, 24]. This is not surprising considering that many people hike in Switzerland. In addition, swimming increases the risk of cardiac arrhythmias[8, 15] while also increasing the risk of submersion deaths.

The observations of this study on the Swiss population concerning the causes of SCD are in accordance with the current literature. In the SR group, SCD mostly occurred in victims

during leisure or high level sporting activities and only a few cases concerned athletes. In this population, a morphologically normal heart (in younger victims) and CAD (in older victims) were the main observations. Coronary artery disease is the main cause of SCD and can be observed in younger victims, even under 30 years of age, who present with cardiovascular risk factors. There is a real need to inform the general public about the increased cardiovascular risks associated with sport activities; furthermore, prevention screening should be considered at any age and not only limited to patients older than 50 as usually performed.

CONCLUSION

CAD is the most frequent cause of SCD in general and in sport related populations, involving also young victims and highlighting the need to inform of the cardiovascular risks during sport activity and focus the prevention of CAD.

The exact incidence of SCD is unknown in Switzerland and probably under-estimated, which would require a common registry method in order to update epidemiological data.

LIMITATIONS

We acknowledge that it is a retrospective study collecting cases over a long period of time, which implies changes in available diagnostic resources such as molecular autopsy. The molecular autopsy was not available in our practice before 2004 and we performed these analyses only for selected cases as the legal and ethical aspects of molecular autopsies are complex in the forensic approach [26, 27]. Another limitation was overlapping of diagnosis

of HCM and ILVH. Indeed, in some cases available data did not allow classifying the cases more distinguishably. However, a similar overlapping between HCM, hypertrophic heart, possible hypertrophic heart, unexplained increase in cardiac mass that did not meet full diagnostic criteria for HCM are also observed in other published studies of this nature [4, 8, 12, 24]. The different methodologies used in the published studies concerning sudden death, and the low numbers of athletes in the studies prevent cross study comparisons. Moreover, we did not consider the cases that received only an external examination; not all cases of SCD were followed by an autopsy or referred to the forensic medicine institute. All these factors contribute to the underestimation of the true number of SCD.

PERSPECTIVE

A future goal is to increase the autopsy rate for sudden cardiac death victims, especially in the young and in the sport-related population. The registry should be supported in order to determine the exact incidence and cause of death. This may enable the propagation of information in the hopes of preventing death, even for leisure sporting participants.

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fig 1

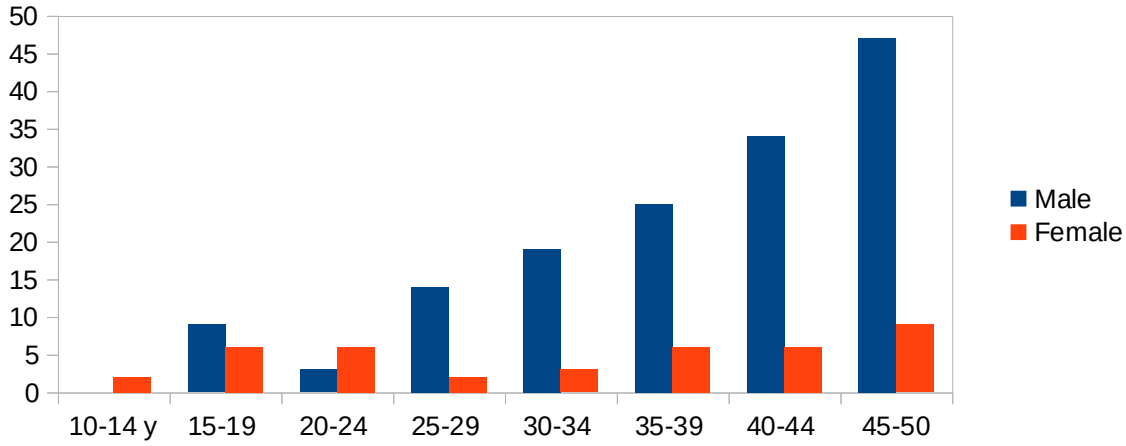

Figure 1 Number of cases of presumed SCD according to age and gender in the studied population (n=188). There is an increase with age in males, while female groups are more constant between different ages

fig 2

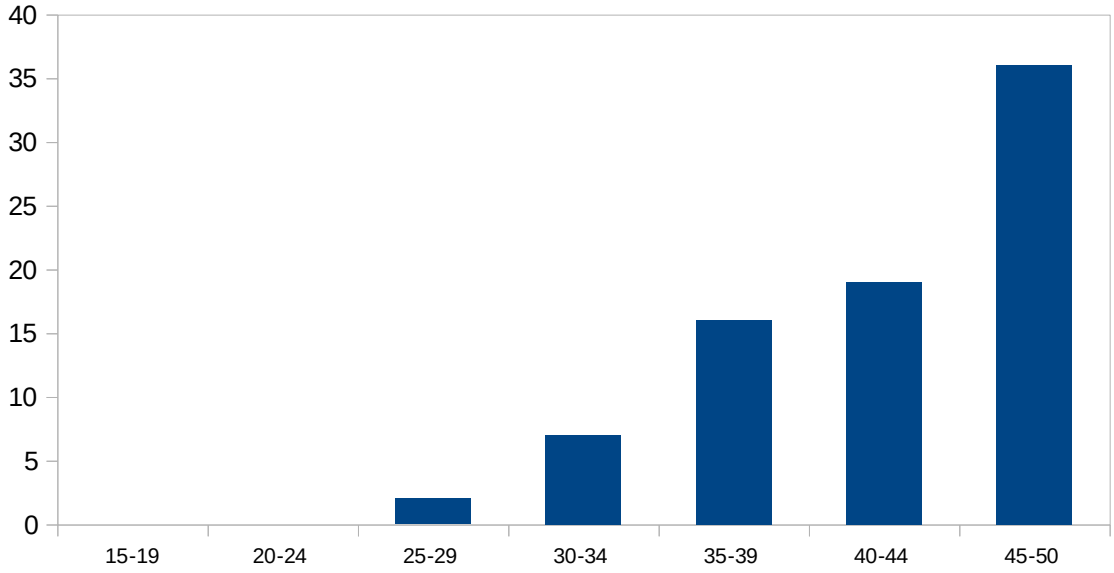

Figure 2 Number of cases of ischemic heart disease according to age in the studied population (n =78). There is an increase of ischemic cardiopathy with age, with 36% of cases in the 45-50 year group. The younger age groups are not spared by this pathology

Fig3 revised

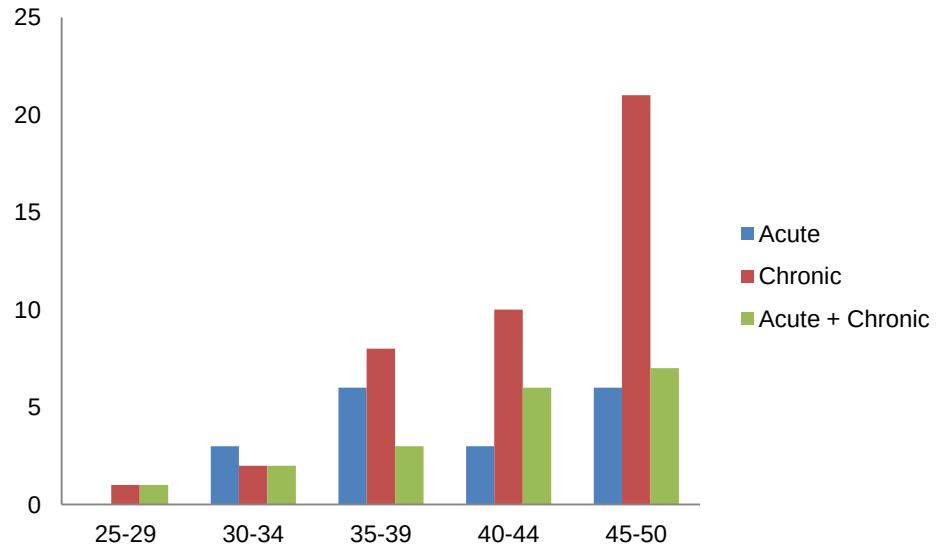

Figure 3

Number of cases of SCD related to the age and type of ischemic cardiopathy for all cases of CAD (n = 78). There is an increase in the chronic form with age

table 1 revised

Observation	Number of cases		Mean age +/- SD	
Heart observation	Male	Female	Male	Female
CAD	62	11	42.5 +/- 5.8 Min 28 Max 50	41.7 +/- 6.6 Min 30 Max 49
HCM and ILVH	29	0	39.3 +/- 8.2 Min 24 Max 50	/
ARVC	5	2	30 +/- 6.8 Min 23 Max 39	32 +/- 11.3 Min 24 Max 40
Myocarditis	7	7	34.4 +/- 11.6 Min 19 Max 46	29.9 +/- 10.9 Min 18 Max 45
Anomalous origin of CA	4	1	35.7 +/- 7.0 Min 29 Max 43	41 +/- 0 Min 41 Max 41
Mitral valve prolapse	0	2	/	30 +/- 11.3 Min 22 Max 38
Other valvular abnormalities	5	3	35.7 +/- 6.0 Min 28 Max 41	37.5 +/- 4.9 Min 34 Max 41
Morphological normal heart	16	10	35 +/- 10.0 Min 16 Max 50	27 +/- 11.5 Min 17 Max 47
Other	2	0	30 +/- 5.7 Min 26 Max 34	/
Total	130	36		

Table 1 Number of cases of SCD and age according to cause of death in the general male and female population (n=166).
CAD (coronary artery disease), HCM (hypertrophic cardiomyopathy), ILVH (idiopathic left ventricular hypertrophy), ARVC (arrhythmogenic right ventricular cardiomyopathy), CA (coronary artery)

N°	Age	Sex	BMI [kg/m^2]	Weight [kg]	Heart weight [g]	Sport	Level of sport	Observation
1	11	F	21.7	45	190	Hiking	Occasional, recreational	Anomalous origin of coronary arteries
2	11	F	16.3	32	150	Cross-country skiing	Occasional, recreational	Abnormalities of conduction system of the heart
3	15	M	22.2	72	400	Hiking	Occasional, recreational	Hypertrophic heart
4	15	M	29.4	90	370	Swimming	Occasional, recreational	Morphologically normal heart
5	15	M	19.6	56	320	Swimming	Occasional, recreational	Morphologically normal heart
6	15	M	19.6	60	310	Gymnastics	Occasional, recreational	Morphologically normal heart
7	16	F	18.6	52	380	Swimming	Athlete	Arrythmogenic cardiomyopathy
8	19	M	24.5	76	450	Football	High level	Arrythmogenic cardiomyopathy
9	28	M	22.9	80	450	Tennis	Athlete	Morphologically normal heart
10	32	M	27.7	103	485	Volleyball	High level	Hypertrophic heart
11	33	M	26.6	87	470	Cycling (stress test)	Occasional, recreational	Ischemic cardiopathy (chronic)
12	33	M	21.6	66	260	Swimming	Occasional, recreational	Arrythmogenic cardiomyopathy
13	37	M	21.2	75	480	Hiking	High level	Myocarditis
14	38	M	23.9	70	400	Cross-country skiing	Occasional, recreational	Ischemic cardiopathy (acute)
15	39	M	26.5	84	440	Badminton	Occasional, recreational	Ischemic cardiopathy (acute)
16	39	M	20.5	62	360	Hiking	High level	Myocarditis
17	41	M	26	88	440	Downhill skiing	Occasional, recreational	Ischemic cardiopathy (acute)
18	42	M	27.7	98	550	Cycling	High level	Hypertrophic heart
19	47	M	26.9	75	420	Sailing	Occasional, recreational	Ischemic cardiopathy (chronic)
20	47	M	27.8	90	430	Arbitration (hockey)	High level	Ischemic cardiopathy (acute)
21	49	F	22.7	64	340	Hiking	High level	Morphologically normal heart
22	50	H	28.7	91	430	Downhill skiing	Occasional, recreational	Hypertrophic heart

Table 2 Details of the sport-related cases of SCD
F (female) M (male)

table 3

Study	Period	Age group	Mean age: NSR/SR	Population, country	Number of cases	Number of sport-related cases	Level of sport	Principal cause of death		Morphologically normal heart	
								Non sport-related death	Sport-related death	Non sport-related death	Sport-related death
Corrado	1979-1999	12-35 y	27/22 y	Italy (Veneto)	300	55 (18%)	Competition	CAD	1st ARVC 2nd CAD	1 (2%)	17 (7%)
Subirana and al.	NA	12-80 y	54	Spain	204	-	-	CAD	-	7 (3%)	-
Bayés de Luna	NA	NA	NA	Spain (Catalonia and Andalusia)	204	-	-	CAD	-	14 (7%)	-
Eckart	1998-2008	≥18 y	38 y	American military population	902	361 (40%)	Recreational	CAD	CAD	187 (21%)	NA
Basso	1978-1993	≤35 y	NA	Italy (Veneto)	163	NA	Competition	CAD	ARVC	10 (6%)	NA
Di Gioia	2001-2005	1-40 y	30 y	Italy (Lazio)	100	16 (16%)	Recreational and competition (12%)	CAD	CCAA	20 (20%)	NA
Tabib A.	1980-1995	2-65 y	35 y	France (Lyon, St-Etienne)	80	80 (100%)	Recreational	-	HCM	-	NA
Maron	1980-2006	8-39 y	18 y	United States	690	690 (100%)	Competition	-	1st HCM 2nd CCAA	-	NA
Noronha	1996-2008	6-60 y	28 y	United Kingdom	118	118 (100%)	Competition	-	ILVH	-	27 (23%)
Wilhelm M. et al.	1999-2008	10-39 y	30/29 y	Switzerland (Bern)	89	13 (15%)	Recreational + competition (31%)	NA	IHD	NA	NA
Allouche	2005-2009	15-79 y	33 y	Tunisia	32	32 (100%)	Recreational	-	HCM	-	4 (12.5%)
Suarez*	1995-2010	9-69 y	37 y	Spain	8862	168 (1.8%)	Recreational + competition (1.8%)	IHD	CAD (recreational) HCM (competition)	NA	19 (11%)
Marijon	2005-2010	10-75 y	46 y	France	199	199 (100%)	Recreational + competition (6%)	-	CAD (recreational) HCM (competition)	-	9 (4.5%)
La Harpe	1980-1989	17-67 y	48 y	Switzerland (Genève)	19	19 (100%)	Recreational	-	CAD	-	NA
Our study	1995-2010	10-50 y	38/30.5 y	Switzerland (Lausanne)	188	22 (12%)	Recreational + competition (9%)	CAD	CAD	26 (16%)	5 (23%)

Table 3 Series of SCD in different sport-related populations. CAD (coronary artery disease), IHD (ischemic heart disease), ARVC (arrhythmogenic right ventricular cardiomyopathy), HCM (hypertrophic cardiomyopathy), ILVH (idiopathic left ventricular hypertrophy), CCAA (congenital coronary artery anomalies); NA (not available).
* all sudden deaths

ACKNOWLEDGMENTS

We are grateful to, Allison Felley Jacquemont and Patrice Mangin for the careful reading of this manuscript.

CONFLICT OF INTEREST

There are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Title page

Title: Sudden cardiac death among general population and sport related population in forensic experience

Authors: Nina Chappex (1)
Jürg Schlaepfer (2)
Florence Fellmann (3)
Zahurul A. Bhuiyan (3)
Matthias Wilhelm (4)
Katarzyna Michaud (1)

(1) University Center of Legal Medicine, Lausanne and Geneva, Chemin de la Vulliette 4, 1000 Lausanne 25, Switzerland
(2) Department of Cardiology, University Hospital of Lausanne, 1011 Lausanne, Switzerland
(3) University Hospital of Lausanne, Service of Medical Genetics, 1011 Lausanne, Switzerland
(4) Department of Cardiology, University of Bern, 3010 Bern

Corresponding author:

Katarzyna Michaud
katarzyna.michaud@chuv.ch
Centre universitaire romand de médicine légale,
Chemin de la Vulliette 4, 1000 Lausanne 25, Switzerland
Telephone: +41213147070
Fax: +41213147090