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Characteristics and causes of sports-related sudden death in the general population during the COVID-19 pandemic.

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Abstract:	Purpose: COVID-19 is an independent risk factor for cardiovascular disease. The aim of this study is to determine the burden, characteristics, and causes of sudden death in sport (SrSD) before and after the COVID-19 pandemic in the general population. Methods: Retrospective observational study. Autopsied SrSD studied in Catalonia were consecutively included. Two periods were considered: Before lockdown (January 2019–March 2020) and after lockdown (March 2020–December 2021). Initial care variables and causes of death were collected. Periods were compared, and logistic regression analyses were performed. Results: A total of 156 SrSD were collected, with no differences in the incidence between the study periods. Of the cases, 98.7% were male, with a mean age of 55.8 years (SD

	12.1). Cycling was practised by 40.0%. Coronary artery disease was the leading cause of death, with no difference before and after lockdown. No cases of myocarditis were described. Of the total number of SrSD, 98 (62.8%) received a CPR attempt. After lockdown, the SrSD that occurred in country areas decreased (40.6% vs 24.4 %, p = 0.032), the rate of CPR attempts (54.3% vs 69.8%, p = 0.034) and hands only CPR increased (76.6% vs 57.9%, p = 0.048). Conclusions: There were no changes in the burden and causes of SrSD before and after the COVID-19 lockdown. Differences were found in the SrSD initial care received due to the change of basic life support recommendations and the sport activity habits.
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Abstract:

Purpose:

COVID-19 is an independent risk factor for cardiovascular disease. The aim of this study is to determine the burden, characteristics, and causes of sudden death in sport (SrSD) before and after the COVID-19 pandemic in the general population.

Methods:

Retrospective observational study. Autopsied SrSD studied in Catalonia were consecutively included. Two periods were considered: Before lockdown (January 2019–March 2020) and after lockdown (March 2020–December 2021). Initial care variables and causes of death were collected. Periods were compared, and logistic regression analyses were performed.

Results:

A total of 156 SrSD were collected, with no differences in the incidence between the study periods. Of the cases, 98.7% were male, with a mean age of 55.8 years (SD 12.1). Cycling was practised by 40.0%. Coronary artery disease was the leading cause of death, with no difference before and after lockdown. No cases of myocarditis were described. Of the total number of SrSD, 98 (62.8%) received a CPR attempt. After lockdown, the SrSD that occurred in country areas decreased (40.6% vs 24.4 %, $p = 0.032$), the rate of CPR attempts (54.3% vs 69.8%, $p = 0.034$) and hands only CPR increased (76.6% vs 57.9%, $p = 0.048$).

Conclusions:

There were no changes in the burden and causes of SrSD before and after the COVID-19 lockdown. Differences were found in the SrSD initial care received due to the change of basic life support recommendations and the sport activity habits.

Key words: Sudden cardiac death; Sports; Covid-19; Pandemic

INTRODUCTION

Sports-related sudden death (SrSD) in the general population is a rare event (1), and the impact on the family is usually devastating. Media reporting without rigorous analysis of scientific information can unduly worry athletes and people who participate in physical activity. The Emergency Medical System (EMS) provides out-of-hospital cardiac arrest support and is, therefore, a good source of information on the incidence of SrSD (2). Forensic source-based studies provide accurate and detailed information on the circumstances and causes of sudden death, including toxicological and genetic analysis (3). Although they are scarce, some studies, such as the Oregon Sudden Unexpected Death Study (ORE-SUD), have gathered multiple sources of information that provide more complete information (4). Moreover, forensic source-based studies might also collect SrSD cases that have not been attended by the EMS which is an under-reported issue (1).

The first cases of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) were diagnosed in December 2019 through July 2021, and 4.2 million deaths were reported worldwide (5). During the first waves of the coronavirus disease 2019 (COVID-19), the public was encouraged to stay home, and lockdown measures were implemented in many countries. Spain was one of the most affected countries especially in the beginning of the pandemics and the most densely populated regions, such as Madrid and Catalonia, were the most affected (6) (7). The leading cause of sudden death in sports at > 35 years of age is ischaemic heart disease (3). COVID-19 is an independent risk factor for acute myocardial infarction, both during and after acute infection (8). COVID-19 cardiovascular complications include myocardial injury, pericarditis, coagulopathy, arrhythmias and persistent post-acute risk of adverse cardiovascular outcomes. The COVID-19 vaccination is cardioprotective but is associated with myopericarditis in young males (9).

The COVID-19 pandemic caused by a virus presented many cases of myocarditis, and several articles put forward recommendations for safe sports practice after the infection had passed (10). In Young competitive athletes the SARS-CoV-2 infection was associated with a low prevalence cardiac involvement and a low risk of clinical events in 1-year follow-up (11) (12). The general population with greater underlying heart disease could be

more exposed to the adverse effects of myocardial injury due to COVID-19 (13). A recent meta-analysis shows that the incidence of SrSD attributable to myocarditis in the pre-pandemic period is low in the general population and there is no data in this respect for the post-pandemic period (14).

During the pandemic in Spain, the Out-of-Hospital Spanish Cardiac Arrest Registry documented fewer resuscitation attempts, lower rates of bystander CPR and lower survival (15). Another study at a worldwide regional level did not find any link between lockdown restrictions and bystanders' willingness to start CPR before the arrival of an ambulance (16). Resuscitation guidelines were adapted to reduce the risk of contagion (17). Limitations in movement during lockdown might have affected sports participation in the general population. To our knowledge, there is little published data on the incidence, causes and circumstances of SrSD in the general population during the COVID-19 pandemic. The objective of this study was to determine the burden, characteristics and causes of SrSD before and after the COVID-19 pandemic in the Catalonia region.

METHODS

Study design

We performed a retrospective observational study using the registry of all SrSD collected by the Institute of Legal Medicine and Forensic Sciences of Catalonia (IMLCFC). Two periods were considered: Before lockdown (1 January 2019–14 March 2020) and during and after lockdown (15 March 2020–31 December 2021). This study was conducted following the guidelines for reporting observational studies (18). Approval of the study protocol was granted by the Research Ethics Committee of the Hospital Universitario de Bellvitge (ref. PR207/21). The authors confirm that patient consent is not applicable to this article due to the nature of its retrospective design involving only deceased patients and the treatment of health data in accordance with the ethics committee. The study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practices.

Setting

Catalonia (Spain) is located in the Western Mediterranean, with an area of 32,108 km^2 and a population of 7,566 million in 2019 (19). It has a population density of 238 inhabitants per square kilometre, concentrated on the coast and in its four provincial capitals. The first state of emergency was declared in Spain on 14 March 2020. Initially, a complete home lockdown was established, which was then progressively relaxed. The third and last state of emergency ended on 8 May 2021. The measures taken to restrict the movement of people varied according to the epidemiological situation. Some districts in Catalonia required short-term lockdowns that restricted the movement of people within the district itself and other restrictive measures until December 2021.

The forensic pathology centres of the IMLCFC study all cases of out-of-hospital deaths via judicial autopsy in accordance with current legislation. In Spain, according to the law of criminal procedure, a forensic autopsy is required for all violent deaths and those in which there is an unknown cause. Sudden deaths related to sports are considered of unknown cause, given that they are rapid and unexpected in a presumably healthy individual. All cases of SrSD that occur in Catalonia are therefore investigated by the IMLCFC.

The Sistema d'Emergències Mèdiques of Catalonia is part of the public health system and is the only EMS that attends out-of-hospital emergency pathology. It has 337 basic life support units equipped with two health emergency technicians (TES), 69 advanced life support (ALS) units equipped with a TES and a nursing professional or a TES, a nursing professional and a doctor, 15 rapid intervention vehicles equipped with a TES and a doctor and 4 medical helicopters that cover 100% of the territory.

Definitions

In the present study, SrSD was defined as that which occurs during sports participation or within an hour following, and for the purposes of the definition, it was decided to include sports in which the activity is > 5 metabolic equivalents, such as vigorous walking or trekking (1). All subjects doing sports, both professionally and recreationally, were included. Solitary sports activity was defined as a sporting activity that is performed alone

and without the company of other people. The practice of individual sports, such as cycling or trekking in a group, was not considered solitary. If, at the moment of cardiac arrest, the victim was alone despite having started the activity with a group, it was considered a solitary sports activity. Country areas were defined as rural or mountain roads and trails located outside large urban areas.

Sudden arrhythmic death syndrome (SADS) is an unexplained sudden death occurring in an individual older than 1 year with negative pathological and toxicological assessment (20).

Variables collected and adjudication of cause of death

The IMLCFC investigators reviewed all the autopsy records and gathered the SrSD cases in a database. The circumstances of death were obtained from witnesses and evidence from the location of the death by the medical examiner on call. The EMS report, the interview with family members and the medical record were assessed to establish the victim's medical background and the circumstances of SrSD. The autopsy examination was carried out following IMLCFC internal protocols and was performed by a team of pathologists specialised in cardiovascular death (21). This protocol includes a complete toxicological analysis and histopathological study, as well as a genetic analysis for any possible familial heart disease in cases under 50 years of age without ischaemic pathology or any other cause of death. The causes of death were assigned following the international guidelines (22).

The variables of prehospital care of out-of-hospital cardiac arrests are collected following the Utstein style by the professionals attending the cardiac arrest using a tablet connected online to the patient's digitalised medical record (23). The location of the cardiac arrest and symptoms prior to collapse were determined based on information gathered by forensics and the EMS.

Statistical analysis

The incidence rate was calculated by taking the total number of the population aged 10–85 years, according to the Statistical Institute of Catalonia, in January of each year of the study (27). All incidence annual rates were multiplied by 100,000 to get the annual incidence per 100,000 inhabitants, and then the average annual incidence was calculated. The number of

cases by month was obtained, and the average of the two study periods was calculated. A Student's *t*-test was used to assess the difference in the number of cases by month between the two periods. A general descriptive analysis has been made. Quantitative variables are expressed as mean ± standard deviation (SD) or median and interquartile range (IQR). Categorical or binary values are presented as the number of cases and percentages. Quantitative variables for the two study periods were compared using Student's *t*-tests for normal distribution or the Mann–Whitney U test. Categorical or binary values were compared using chi-square tests. For the study of the factors associated with a CPR attempt by the EMS, a univariate study was initially carried out. Subsequently, an independence test was performed by chi-square of the factors that obtained a $p < 0.05$. The independent factors were included in a multivariate logistic regression analysis. All tests were two-tailed, and *p*-values lower than 0.05 were considered statistically significant. All data was analysed with the statistical package IBM SPSS (version 19, SPSS Inc., Chicago, New York, United States).

RESULTS

During the study period, 156 SrSD investigated by forensic autopsy in Catalonia were collected. In 52 cases, basic life support was not performed prior to the arrival of the EMS. Of those, 31 cases were unwitnessed sudden deaths, and the victim was found dead at the scene; in 19 cases, the death was witnessed, but CPR was not initiated until the EMS arrived. In 6 cases, basic life support was initiated but abandoned because of its futility at the EMS arrival. In the other 98 cases, CPR was attempted by the EMS. Figure 1 gives the details of the flow chart for each study period. The annual incidence was 0.84, 0.69 and 0.78 cases per 100,000 inhabitants in the first, second and third year of the study, respectively. The average annual incidence was 0.77 cases per 100,000 inhabitants. The average monthly number of cases was similar between the study periods: 4.7 cases per month in the pre-lockdown period and 4.0 cases per month after lockdown period (95% CI of the mean difference: -1.40 to 2.73, $p = 0.510$).

Clinical variables and causes of death

The present study included 156 patients, 70 (44.9%) in the pre-lockdown period. The clinical variables and their comparisons are shown in Table 1. The mean age was 55.8 years (SD 12.1), ranging between 13 and 84 years; 98.7% were male. Cycling, followed by trekking and running, was the sport most frequently done. After lockdown, SrSD occurred less frequently in country areas (24.4% vs 40.6%, $p = 0.032$), more frequently in the street or interurban ways (26.7% vs 8.6%, $p = 0.04$) and more frequently at home (16.3% vs 5.7%, $p = 0.046$). Regarding cardiovascular risk factors, 26.6% of the sample presented at least one. The variables studied for sudden death as a function of the most often performed sporting activity are shown in Table 2.

Regarding the causes of death, the leading cause was coronary artery disease (66.7%) with no differences before and after lockdown as it shown in Table 1. No cases of myocarditis were reported. Figure 2 shows the autopsy causes of death in the whole sample and the Supplemental Digital Content 1 and 2 the cause of death depending on whether the age is over or under 35 years. In 134 cases (85.9%), toxicology analyses were carried out. After lockdown, an antigen test for COVID-19 was performed in 51 cases and was negative for all of them. Genetic testing took place in 15 cases (9.6%). A genetic alteration associated with channelopathies was found in two cases and, in one case, associated with cardiomyopathy.

A total of 48 (30.8%) cases presented prodromal symptoms in the hour prior to sudden death. Of the total cases, 17.3% presented general malaise, 7.0% chest pain, 3.8% dizziness, 3.2% dyspnoea, and 3.2% reported feeling exhausted before collapsing. The presence of any prodromal symptom was not associated with death from coronary heart disease (OR: 0.84, 95% CI: 0.53–1.33). There was also no association between presenting any prodromal symptoms and receiving BLS prior to the EMS or receiving a CPR attempt by the EMS (OR: 1.14, 95% CI: 0.65–2.02 and OR: 1.11, 95% CI: 0.48–2.57, respectively).

Variables of the CPR attempts

Of all the 156 SrSD cases studied, 98 (62.8%) received a CPR attempt by the EMS. Over the two study periods, the percentage of those attempts increased (69.8% vs 54.3%, $p =$

0.874). Univariate analysis and a subsequent multivariate study determined the factors associated with a CPR attempt by the EMS, as shown in Supplemental Digital Content 3 and 4. Witnessed cardiac arrest and cycling were factors independently associated with a CPR attempt (OR: 3.35, 95% CI: 1.65–6.80 and OR: 2.50, 95% CI: 1.19–5.28, respectively). However, doing sports in the country areas was independently associated with a lower likelihood of a CPR attempt (OR:0.40, 95% CI: 0.19–0.86).

Table 3 shows the comparison across the two study periods of all the variables among patients who received a CPR attempt. No differences were found in the rate of BLS prior to the arrival of the EMS or the rate of bystander CPR. In the second period, there were more cases of victims receiving hand-only CPR prior to EMS arrival (76.6% vs 57.9%, $p = 0.048$).

DISCUSSION

This study shows that considering 2019 as a control period, there was no increase in the incidence of SrSD during the COVID-19 pandemic. Autopsy findings showed no differences in causes of SrSD. However, in the second period, lockdown measures conditioned changes and SrSD occurred less frequently in the country areas and victims of SrSD were more frequently attended with a CPR attempt by the EMS.

In our series, the EMS attempted CPR in only two out of three cases. This was because one out of five SrSD were unwitnessed incidents and the victims were found dead at the scene, in some cases after a long period of time. In those cases, the medical examiner is contacted directly by the law enforcement authorities and the EMS is not involved. Other witnessed cases did not receive BLS and were declared dead by the time the EMS arrived, which can be more common in country areas and isolated locations. Other studies that combined forensic and EMS data sources were conducted in metropolitan areas or did not record cases that occurred in isolated places(4) (24). Other studies conducted in our setting during the pandemic period reported a decrease in CPR attempts in the general population [15]. The results of our study regarding the increased of CPR attempts after lockdown, which may seem paradoxical, are justified by the inclusion of multiple sources of information in the

context of SrSD. This has obvious consequences for the design of registers dedicated to SrSD and has allowed us to form a unique picture from a wide perspective.

In Catalonia, lockdown measures were particularly strict, especially during the first pandemic waves. The results of our study show that the sports activity habits of the general population changed since people stayed nearer to urban areas during the pandemic. A recent meta-analysis has evaluated the impact on survival of BLS. The installation of automated external defibrillators (AED) in sports facilities and more general training in BLS have been recommended (25). Areas farthest from urban areas are the most difficult to cover with an AED network away from the so-called 'health corridors'. Cycling, trekking and running are the most frequently associated with SrSD in this series and commonly occur in country areas. Cycling seems to be the most commonly associated with attempted CPR, possibly because it is more likely to be a non-solitary activity and/or occur in more visible places for possible witnesses. It would seem reasonable, therefore, to practice sports in a group when it is done in isolated places, especially for those at cardiovascular risk or with underlying heart disease(4). In these cases, wearable monitoring systems that can raise an alarm at an EMS coordination centre might also be an effective preventive measure in the case of sudden collapse or with the presence of any symptom (26). We should bear in mind that one-third of the SrSD studied in our series presented symptoms before the collapse. Another noteworthy aspect found in relation to basic life support in the pandemic period is the increase in hands only CPR as recommended in the guidelines to reduce the risk of contagion [17].

Few studies have assessed SrSD in the general population by combining data from a complete autopsy study with EMS data. The multiple-source registry ORE-SUD included middle-aged patients between 35 and 65 years of age(4). Another large study conducted in France and Germany included only those under 35 years of age (24). The mean age of our sample is slightly older than other series, which have included all ages based on registries of EMS and web-based news screening (27). In our series, only two of the 156 registered cases were women, making it difficult to draw any conclusions. The present study is, by sex, in agreement with other registries showing a lower incidence of SrSD in women (28).

Regarding the cause of death, no differences were reported in relation to the COVID-19 pandemic. The prevalence of acute coronary artery disease remained unchanged despite the known association between acute COVID-19 infection and thrombus generation. The low-risk profile and the low rate of COVID-19-positive cases in our sample may justify these results (29). Likewise, only one case of pericarditis with no association with COVID-19 vaccination was diagnosed, and there was no case of myocarditis. It should be noted that myocarditis associated with COVID-19 vaccination is rare, and its clinical course is favourable (30). No confirmed cases of athletes experiencing cardiac complications after mRNA vaccination have been reported (31). Taking into account the high incidence of COVID-19 cases during the pandemic and the high rate of complete vaccination that exceeded 85% of the population in our setting, this study provides data in favour of the safety of sports practice during a SARS-coronavirus pandemic (32). Chronic coronary artery disease was the most frequently reported cause in patients older than 35 years of age, as in another series of SrSD (4). Ventricular hypertrophy associated with arterial hypertension was the attributed cause of sudden death at a similar frequency to another autopsy series collected in the Mediterranean area (33). Underlying cardiac pathology is another known risk factor because hearts with a pathology cannot withstand the increase in cardiac output and the adrenergic discharge that sports produce, and consequently, malignant arrhythmias appear that can cause cardiac arrest. In our series, 16.7% of the population studied, were aware of having an underlying cardiac pathology, similar to other series (4)(34). The prevalence of cardiovascular risk factors in our study population was low compared to other series (4). However, coronary artery disease is responsible for three out of four SrSD, which highlights the importance of the new atherosclerosis risk detection methods based on artificial intelligence that will improve preventive strategies (35). A medico-legal autopsy can collect very important information in relation to the pathologies that cause SrSD. In cases of a confirmed genetic component, it would be very valuable to give corresponding advice to first-degree relatives. A genetic test was carried out for nearly 10% of our sample subjects, some 50% more than other series (24).

The limitations of the present study lie in its retrospective nature. Data on the amount and level of physical fitness of each victim and the intensity of the sports activity at the time of collapse was not available as in other similar studies, therefore, the comparison of

incidence between the study periods should be interpreted with caution. There were no reported cases of SrSD where an autopsy was not performed due to the risk of infection even at the peak of the pandemic as safety measures were taken. Nor did the study include survivors of a SrSD, which does not allow us to calculate the incidence accurately. In 2022, a registry of out-of-hospital cardiac arrest and sudden cardiac death in Catalonia (RAIMCAT) was launched. It is a prospective registry that collects symptoms and circumstances of deaths and collects data from autopsy studies and survivors. We hope to use this more complete data to conduct an incidence study in the future.

In conclusion, The burden of SrSD did not increase in the context of the COVID-19 pandemic. There were no changes in the causes of SrSD in the general population through lockdowns. This study provides data regarding the safety of sports practice during a pandemic due to the SARS-coronavirus. Differences were found between the two study periods in the SrSD initial care received due to the change of basic life support recommendations and the sport activity habits during the pandemic.

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Declaration of interest

No conflict of interest to declare. The results of the present study do not constitute endorsement by ACSM. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

List of Supplemental Digital Content

. Supplemental Digital Content 1.docx: Adjudicated causes of < 35 years old autopsied sports-related sudden death.

. Supplemental Digital Content 2.docx: Adjudicated causes in > 35 years old autopsied sports-related sudden death.

. Supplemental Digital Content 3.docx: Univariate analysis of factors associated with receiving a CPR attempt by the Emergency Medical System.

. Supplemental Digital Content 4.docx: Multivariable logistic regression analysis of EMS CPR attempt associated variables.

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Figure captions

Figure 1. Flow chart

EMS= Emergency Medical System, BLS= Basic life support

Figure 2. Adjudicated causes of all autopsied sports-related sudden death

Total patients studied (n = 156); Acute coronary heart disease (n = 48); Chronic coronary heart disease (n =56); Ventricular hypertrophy (n =15), Hypertensive heart disease (n = 10), Unspecified (n = 5); Cardiomyopathy (n = 8), Hypertrophic cardiomyopathy (n = 3), Dilated (n = 2), Unspecified (n = 2), ARVC (n = 1); SADS (n = 18); Primary electrical disease (n = 2), SQTL (n = 2); Other cardiac (n = 1), Pericarditis (n = 1); Other no cardiac (n = 8), Gastrointestinal haemorrhage (n = 3), stroke (n = 2), Pulmonary embolism (n = 1); Infection (n = 1); Steinert disease (n = 1).

Table 1

Table 1. Clinical variables in all the study population and their comparison before and after lockdown

	Total	**Previous lockdown**	**Post lockdown**	***p*-value**
n	156	70 (44.9)	86 (55.1)	
Epidemiological variables				
Age (years)	55.8 (12.1)	56.4 (11.5)	55.3 (12.6)	0.598
Male sex	154 (98.7)	69 (98.6)	85 (98.8)	0.883
Body Mass Index	28.9 (4.3)	28.9 (4.7)	28.8 (4.0)	0.972
Season				
Winter	38 (24.4)	24 (34.3)	14 (16.3)	0.014
Spring	42 (26.9)	23 (32.9)	19 (22.1)	
Summer	45 (28.8)	11 (15.7)	34 (39.5)	
Autumn	31 (19.9)	12 (17.1)	19 (22.1)	
Sport				
Cycling	64 (41.0)	28 (40.0)	36 (41.9)	0.812
Trekking	28 (17.9)	14 (20.0)	14 (16.3)	0.675
Running	14 (9.0)	4 (5.7)	10 (11.6)	0.264
Swimming	10 (6.4)	2 (2.9)	8 (9.3)	0.187
Bodybuilding	10 (6.4)	2 (2.9)	8 (9.3)	0.187
Paddle D	5 (3.2)	3 (4.3)	2 (2.3)	0.403
Dancing	4 (2.6)	3 (4.3)	1 (1.2)	0.237
Basketball	3 (1.9)	0 (0.0)	3 (3.5)	0.253
Tennis	2 (1.3)	1 (1.4)	1 (1.2)	0.698
Alpine skiing	2 (1.3)	2 (2.9)	0 (0.0)	0.200
Soccer	1 (0.6)	0 (0.0)	1 (1.2)	1.000
Others	14 (9.0)	12 (17.1)	2 (2.3)	0.002
Characteristics of Sudden Death				
Unwitnessed cases found death	31 (19.9)	16 (22.8)	15 (17.4)	0.841
Witnessed	88 (56.4)	39 (55.7)	49 (57.0)	0.874
BLS previous EMS	79 (50.6)	30 (42.9)	49 (57.0)	0.079
1 h after sport	23 (14.7)	7(10.0)	16(18.6)	0.174
Type of sport activity				
Recreational activity	147 (93.0)	63 (90.0)	82 (95.3)	0.114
Solitary activity [a]	55 (35.3)	24 (34.3)	31 (36.0)	0.819
Sports competition	9 (5.8)	7 (10.0)	2 (2.3)	0.079
Location				
Home	18 (11.5)	4 (5.7)	14 (16.3)	0.046
Sports centre	25 (16.0)	12 (17.1)	13 (15.1)	0.731
Country areas	49 (31.4)	28 (40.6)	21 (24.4)	0.032
Street/interurban way	29 (18.6)	6 (8.6)	23 (26.7)	0.004
Background				
Diabetes	6 (3.8)	2 (2.9)	4 (4.7)	0.692
Hypertension	21 (13.5)	6 (8.6)	15 (17.4)	0.106
Dislypemia	18 (11.5)	7 (10.0)	11 (12.8)	0.625
Current smoker	5 (3.2)	2 (2.9)	3 (3.5)	0.824
Previous cardiac disease	22 (14.1)	9 (12.9)	13 (15.1)	0.753
Autopsy findings				
Coronary heart disease	104 (66.7)	49 (70.0)	55 (64.0)	0.426
Acute	48 (30.8)	24 (34.3)	24 (27.9)	0.391
Chronic	57 (36.5)	26 (37.1)	31 (36.0)	0.888

Cardiomyopathy	8 (5.1)	3 (4.3)	5 (5.8)	0.667
Ventricular hypertrophy	15 (9.6)	8 (11.4)	7 (8.1)	0.488
Primary electrical disease	2 (1.3)	2 (2.9)	0 (0.0)	0.200
SADS	18 (11.5)	6 (8.6)	12 (14.0)	0.295
Other cardiac	1 (0.6)	0 (0.0)	1 (1.2)	1.000
Other no cardiac	8 (5.1)	2 (2.9)	6 (7.0)	0.297
Toxic Test	134 (85.9)	57 (81.4)	77 (89.5)	0.148
Ethanol positive	9 (5.8)	6 (8.6)	3 (3.5)	0.301
Other positive toxic test	11 (8.2)	7 (12.2)	4 (5.2)	0.121
Genetic test performed	15 (9.6)	5 (7.1)	10 (11.6)	0.410

Data are expressed as mean and SD for quantitative variables, frequency (N), and percentage for categorical variables. BLS=Basic life support; EMS=Emergency Medical System.

a. Cardiac arrests occurring within one hour after the sport were excluded.

Table 2. Variables studied for sudden death as a function of the type of sporting activity most often performed

	Cycling	Trekking	Running	Swimming
n	64	28	14	10
Age	56.7 (9.4)	58.5 (10.1)	50.7 (13.1)	59.0 (15.3)
Male sex	64 (100)	64 (100)	13 (92.9)	10 (100)
Body Mass Index	28.3 (4.9)	29.8 (4.5)	29.4 (4.1)	27.8 (8.0)
Background				
One or more cardiac risk factors	18 (28.1)	8 (28.6)	4 (28.6)	2 (20.0)
Previous cardiac disease	12 (18.8)	2 (7.1)	2 (14.3)	3 (30.0)
Sports sudden death variables				
Solitary activity	27 (42.1)	12 (42.8)	9(64.2)	2(20.0)
Recreational activity	61 (95.3)	29 (100)	11 (78.6)	9 (90.0)
1 h after sport	6 (9.4)	1 (3.6)	2 (14.3)	3 (30.0)
Location				
Country areas/sea	38 (59.4)	25 (89.3)	3 (21.4)	4 (40.0)
Home	6 (9.4)	0	5 (35.7)	2 (20.0)
Street/interurban way	18 (28.1)	3 (10.7)	6 (42.9)	1 (10.0)
Sports centre	2 (3.1)	0	0	3 (30.0)
Cause of cardiac arrest				
Coronary heart disease	46 (71.9)	18 (64.3)	8 (57.1)	5 (50.0)
CPR variables				
Witnessed cardiac arrest	35 (54.7)	14 (50.0)	6 (42.9)	5 (50.0)
BLS previous EMS	38 (59.4)	11 (39.3)	8 (57.1)	7 (70.0)
EMS CPR attempt	46 (71.9)	11 (39.3)	6 (42.9)	9 (90.0)
VF/TV as initial rhythm	13 (28.2)	3 (27.2)	2 (14.3)	1 (11.1)
AED used	11 (17.2)	4 (14.3)	3 (21.4)	4 (40.0)

Data are expressed as mean and SD for quantitative variables, frequency (N), and percentage for categorical variables. BLS=Basic life support; EMS=Emergency Medical System; CPR=Cardiopulmonary resuscitation

Table 3. Clinical variables in all the resuscitation attempts by the Emergency Medical System and their comparison before and after lockdown

	Total	**Previous lockdown**	**Post lockdown**	***p*-value**
n	98 (62.8)	38 (54.3)	60 (69.8)	0.034
Witnessed cardiac arrest	66 (67.3)	27 (71.0)	39 (65.0)	0.534
By bystander	58 (87.9)	25 (92.6)	33 (84.6)	0.338
Other services non-EMS staff	4 (5.9)	1 (3.7)	3 (7.7)	
EMS	4 (5.9)	1 (3.7)	3 (7.7)	
Time to first BLS (min)	5 (10)	6 (9)	4 (10)	0.326
Time to ambulance ALS (min)	20 (17)	22 (21)	20 (16)	0.812
BLS previous EMS	74 (75.5)	28 (73.7)	46 (76.6)	0.792
By bystander	55 (74.3)	20 (71.4)	35 (76.1)	0.657
Other services non-EMS staff	19 (25.7)	8 (28.6)	11 (23.9)	
Hands-only CPR previous EMS	68 (69.4)	22 (57.9)	46 (76.6)	0.048
Defibrillation previous EMS	32 (32.6)	12 (25.5)	20 (27.4)	0.822
AED used	32 (32.6)	14 (36.8)	18 (30.0)	0.331
AED origin:				0.045
Public access	7 (21.9)	5 (35.7)	2 (9.5)	
Mobile AED	9 (28.1)	5 (35.7)	4 (19.0)	
BLS non-EMS AED	16 (50.0)	4 (28.6)	12 (66.7)	
Initial rhythm				0.041
VF/TV	23 (23.3)	11 (29.0)	12 (20.0)	
Pulseless electrical activity	8 (8.2)	4 (10.5)	4 (6.6)	
Asystole	67 (68.5)	23 (60.5)	44 (73.3)	
Number of total defibrillations				0.060
0	3 (9.4)	2 (16.7)	1 (5.0)	
1	14 (43.4)	8 (66.7)	6 (30.0)	
2	6 (18.8)	1 (8.3)	5 (25.0)	
≥ 3	9 (28.4)	1 (8.3)	8 (40.0)	
Presumed EMS cardiac cause	87 (88.8)	36 (94.7)	52 (86.6)	0.328
Airway management				0.194
Endotracheal tube	77 (78.6)	28 (73.7)	49 (81.7)	
Bag mask	21 (21.4)	10 (26.3)	11 (18.3)	
Mechanical chest compressions	53 (34.0)	17 (45.9)	36 (60.0)	0.177
Return of spontaneous circulation	2 (2.0)	0 (0.0)	2 (3.3)	0.523

Data are expressed as median and interquartile range for quantitative variables, frequency (N), and percentage for categorical variables. ALS: Advanced life support; EMS: Emergency Medical System; CPR: Cardiopulmonary resuscitation; AED: Automatic external defibrillation; BLS: Basic life support; VF: ventricular fibrillation; VT: Ventricular tachycardia.

Figure 1

Figure 1. Flow chart

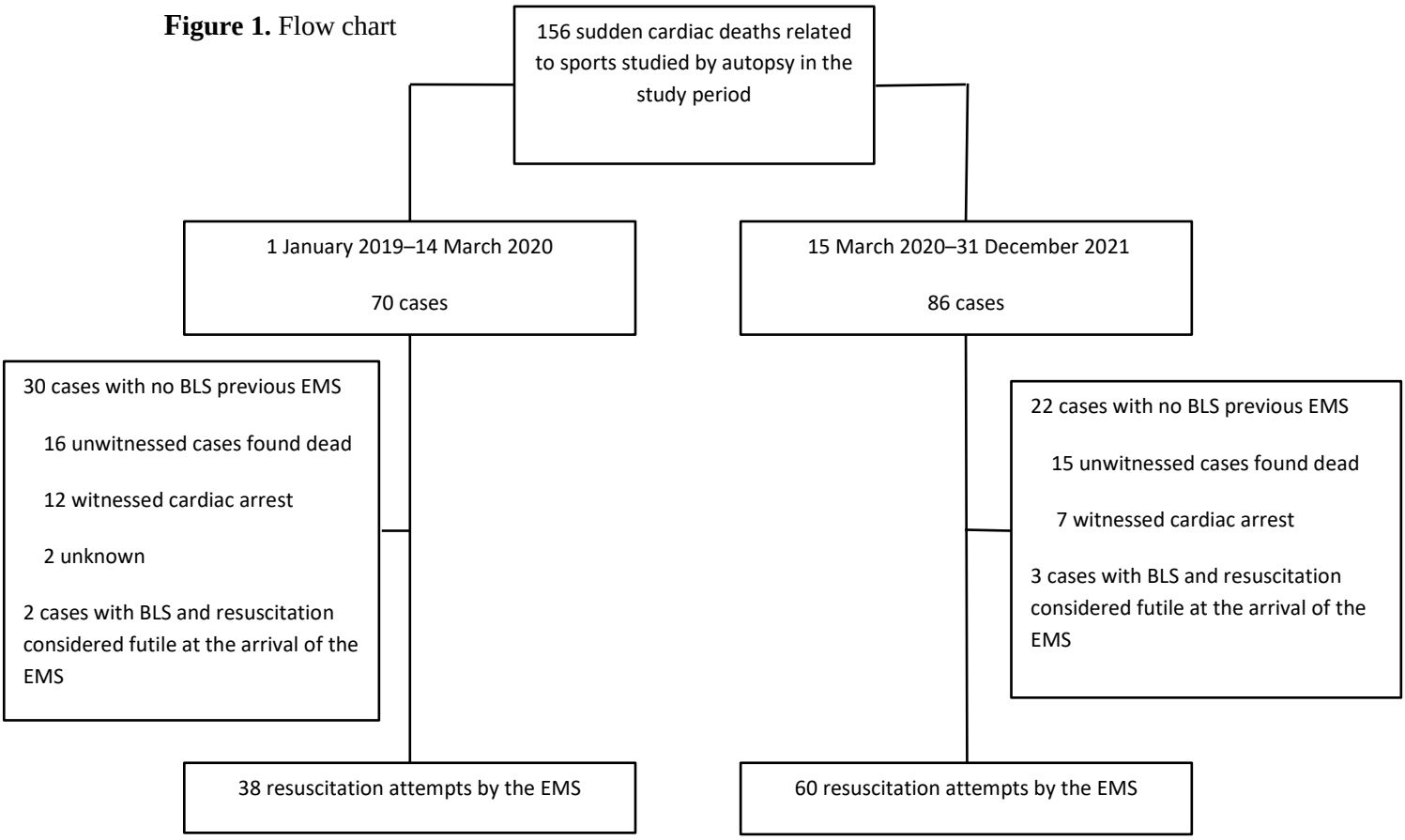

Figure 2

Figure 2. Adjudicated causes of all autopsied sport-related sudden death