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ORIGINAL RESEARCH

# Sudden Cardiac Arrest During Sports Activity in Older Adults

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## ABSTRACT

**BACKGROUND** Sports activity among older adults is rising, but there is a lack of community-based data on sports-related sudden cardiac arrest (SrSCA) in the elderly.

**OBJECTIVES** In this study, the authors investigated the prevalence and characteristics of SrSCA among subjects ≥65 years of age in a large U.S. population.

**METHODS** All out-of-hospital sudden cardiac arrests (SCAs) were prospectively ascertained in the Portland, Oregon, USA, metro area (2002-2017), and Ventura County, California, USA (2015-2021) (catchment population ~1.85 million). Detailed information was obtained for SCA warning symptoms, circumstances, and lifetime clinical history. Subjects with SCA during or within 1 hour of cessation of sports activity were categorized as SrSCA.

**RESULTS** Of 4,078 SCAs among subjects ≥65 years of age, 77 were SrSCA (1.9%; 91% men). The crude annual SrSCA incidence among age ≥65 years was 3.29/100,000 in Portland and 2.10/100,000 in Ventura. The most common associated activities were cycling, gym activity, and running. SrSCA cases had lower burden of cardiovascular risk factors ($P = 0.03$) as well as comorbidities ($P < 0.005$) compared with non-SrSCA. Based on conservative estimates of community residents ≥65 years of age who participate in sports activity, the SrSCA incidence was 28.9/100,000 sport participation years and 18.4/100,000 sport participation years in Portland and Ventura, respectively. Crude survival to hospital discharge rate was higher in SrSCA, but the difference was nonsignificant after adjustment for confounding factors.

**CONCLUSIONS** Among free-living community residents age ≥65 years, SrSCA is uncommon, predominantly occurs in men, and is associated with lower disease burden than non-SrSCA. These results suggest that the risk of SrSCA is low, and probably outweighed by the high benefit of exercise. (J Am Coll Cardiol EP 2023;9:893-903) © 2023 by the American College of Cardiology Foundation.

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**ABBREVIATIONS AND ACRONYMS**

**CAD** = coronary artery disease

**COPD** = chronic obstructive pulmonary disease

**CPR** = cardiopulmonary resuscitation

**EMS** = emergency medical services

**MI** = myocardial infarction

**SCA** = sudden cardiac arrest

**SrSCA** = sports-related sudden cardiac arrest

Sudden cardiac arrest (SCA) is a global public health problem, causing more years of potential lives lost than any individual cancer.[1] In the United States, approximately 320,000 to 360,000 individuals experience SCA every year.[2] The survival rate remains low, because over 90% of SCAs result in sudden cardiac death.[3] During recent decades, SCA incidence has decreased among the working-age population, but overall incidence has remained relatively stable, indicating that the SCA occurrence has shifted even more to older individuals.[2] Although SCA is considered a sudden and unexpected event, it is usually precipitated by a combination of existing cardiac substrate disease and a wide variety of triggers that also include sporting activity.[4]

Sports activity has strong long-term beneficial effects on cardiovascular health and overall well-being; yet, physical activity may trigger life-threatening arrhythmias in vulnerable patients (ie, "the exercise paradox"). Approximately 5% to 6% of all SCAs are associated with sports activity (sports-related sudden cardiac arrest [SrSCA]).[5,6] Cases that occur in young athletes receive more media attention, but in absolute numbers, it is possible that the majority of SrSCAs occur in older individuals.[7]

Previous studies have provided detailed evaluations of SrSCA in the young and middle-aged (age 35 to 65 years),[6,8-10] but the burden and characteristics of SrSCA in the elderly are not well known. Importantly, there are no community-based data on free-living residents from large catchment populations. Regular physical activity has strong beneficial effects on overall health in the elderly, and the mean age of sports activity participants is increasing.[11,12] A better understanding of SrSCAs in the older adult has the potential to translate into improved clinical guidance as well as public health education to achieve the health benefits of sports activity while minimizing any associated risks. Leveraging data from 2 prospective studies that include all out-of-hospital SCAs in these communities, we investigated the incidence, characteristics, and temporal trends of SrSCA in subjects >65 years (**Central Illustration**).

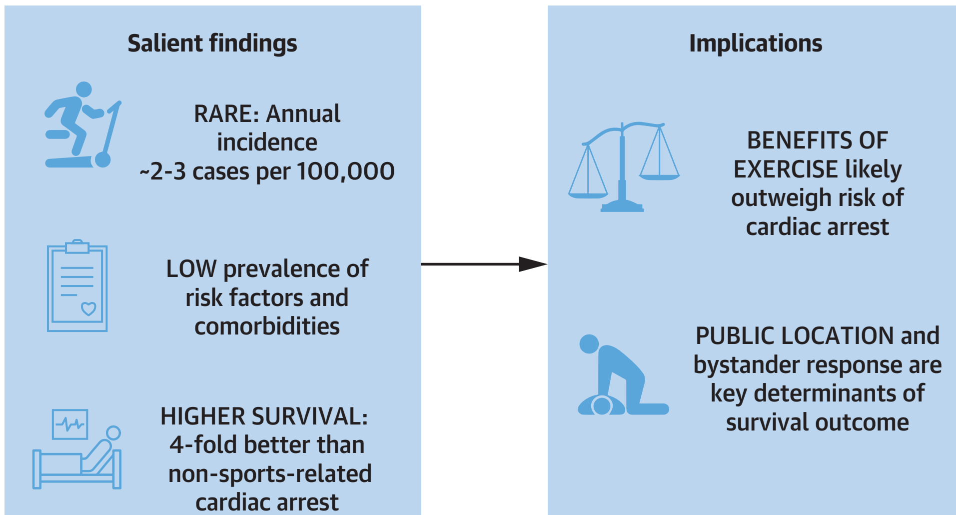
## METHODS

**STUDY POPULATION.** Study subjects were ascertained from 2 community-based studies in the United States that have an identical design: the Oregon SUDS (Sudden Unexpected Death Study) (since 2002) and the Ventura PRESTO (Prediction of Sudden Death in Multi-ethnic Communities) (since 2015). Both are prospective and ascertain all out-of-hospital SCAs from the Portland, Oregon, USA, metro area (population ∼1 million), and Ventura County, California, USA (population ∼850,000), respectively. Out-of-hospital SCAs are ascertained from the region's 2-tiered emergency medical services (EMS) system. In-house SCA adjudication and entry of detailed information was performed by trained researchers using all available medical records for each potential SCA case: EMS prehospital care report, complete medical records from the region's hospital systems, medical examiner's report, and death certificates from Oregon and California state vital statistics records. SCA was defined as a sudden loss of pulse of likely cardiac etiology that occurred with a rapid witnessed collapse, or if unwitnessed, the subject should have been seen alive within 24 hours. We excluded cases with likely noncardiac etiology (eg, trauma/violent death, overdose/substance abuse) or chronic terminal illness. Consequently, the Oregon SUDS and Ventura PRESTO include all out-of-hospital SCAs of likely cardiac origin in both communities.

**CURRENT SUBSTUDY.** For this substudy, we included all SCA cases ≥65 years of age with resuscitation attempted by EMS. For the Oregon SUDS, we ascertained SCA cases between 2002 and 2017, whereas for the Ventura PRESTO study, we ascertained SCA cases between 2015 and 2021. The details of case ascertainment and selection of study subjects are presented in **Figure 1**. Information on arrest circumstances and resuscitation measures were obtained by evaluation of EMS reports from all SCA cases. Data on warning symptoms was obtained from EMS reports, medical records, and postarrest interviews if the subject survived. Information on prearrest clinical characteristics was included if the patient provided a written consent or was deceased, in which case consent was waived. Medical records were obtained from regional health care systems and used to characterize the detailed clinical profile. Diabetes, hyperlipidemia, or chronic obstructive pulmonary disease (COPD)/asthma were defined by diagnosis or medication listed in the clinical record. For other comorbidities, a corresponding diagnosis was required. Information on survival to hospital discharge was obtained from EMS case records and medical records.

Sports activity was defined as any physical activity conducted with the goal of recreation or maintenance of physical fitness or skill. SrSCA was defined as SCA during sports activity or within 1 hour of cessation of sports activity. When SCA events occurred during physical activity that was not considered sports

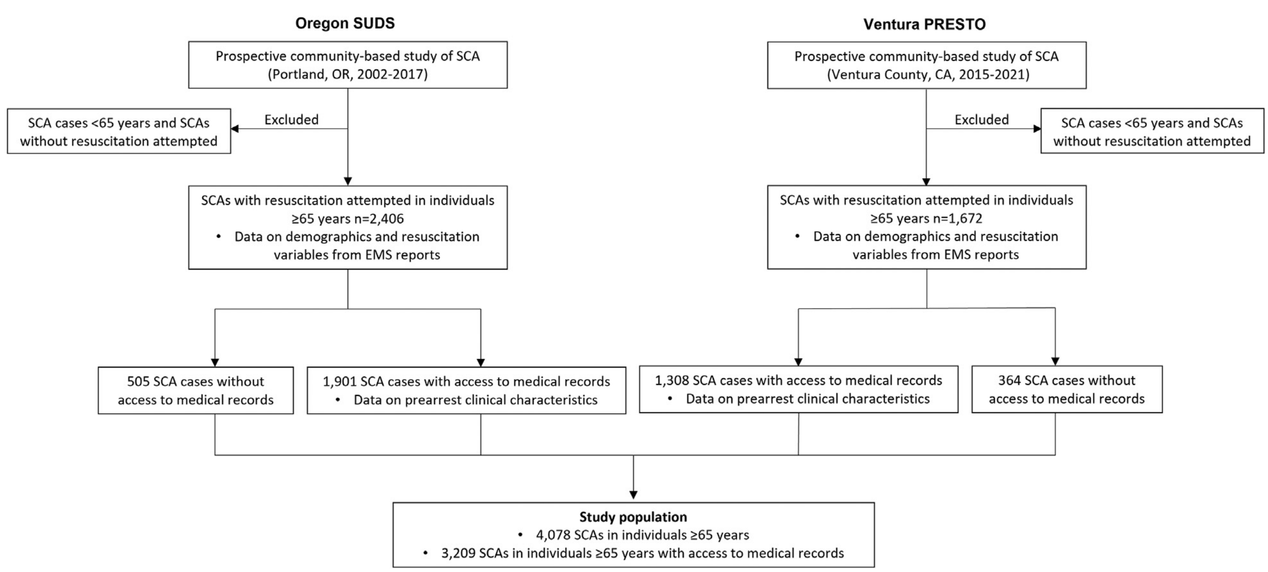
**CENTRAL ILLUSTRATION Sports-Related Sudden Cardiac Arrest in Older Adults**




**Holmstrom L, et al. J Am Coll Cardiol EP. 2023;9(7):893-903.**

Sudden cardiac arrest in the setting of sports activity was evaluated in a catchment population of 1.8 million. Subjects with sudden cardiac arrest during or within 1 hour of cessation of sports activity were categorized as sports-related. Detailed information was obtained regarding warning symptoms, resuscitation profile, and lifetime clinical history.

**FIGURE 1 Flow Chart Showing Details of Case Ascertainment and Selection of Study Subjects**




EMS = emergency medical services; PRESTO = Prediction of Sudden Death in Multi-ethnic communities; SCA = sudden cardiac arrest; SUDS = Sudden Unexpected Death Study.

(n = 75, most commonly during gardening or walking), these were not considered SrSCA. Additionally, 13 SCAs occurred during sexual intercourse (0.3%) and were not categorized as SrSCA.

The Institutional Review Boards of Ventura County Medical Center, Oregon Health and Science University, Cedars-Sinai Health System, and all other relevant health systems and participating hospitals approved the study protocol.

**STATISTICAL ANALYSIS.** Information on demographics and resuscitation variables was obtained and analyzed in all study subjects using EMS clinical reports, and analysis of the lifetime clinical history was restricted to those with clinical records available (n = 3,209; 79%). All continuous variables are presented as mean ± SD. Between-group differences were analyzed with the chi-square test and Student's *t*-test/Mann-Whitney *U* test for categorical and continuous variables, respectively. We considered continuous variables to be normally distributed after visual inspection and data skewness calculation (between −1 and 1), after which between-group differences were calculated using Student's *t*-test. If the criteria were not met (age, ejection fraction), between-group differences were calculated using nonparametric Mann-Whitney *U* test. For calculation of incidence rates, we used data from the U.S. Census Bureau. The annual number of all residents ≥65 years of age in Multnomah County and Ventura County were considered as the denominator for incidence calculation in the Oregon SUDS and Ventura PRESTO studies, respectively. For incidence trend calculations, we divided the number of SrSCA in each 4-year period by the mean annual number of all individuals ≥65 years of age. We calculated crude estimates of the number of individuals >65 years of age participating in sport activity in each of the 2 communities based on published findings from the Cardiovascular Health Study, which reported that 11.4% of study subjects >65 years of age were participating in high-intensity exercise.[13] We calculated the SrSCA incidence per sport participation years by dividing the number of SrSCA by the number of older adults that participate in sports activity. Predictors of survival to hospital discharge were evaluated using multivariable logistic regression including all variables with a *P* value <0.10 in a univariate analysis. Univariate and multivariable logistic regression were used to calculate adjusted ORs with 95% CIs for survival to hospital discharge variables. *P* values for trends were calculated using linear regression. Statistical analyses were performed with the IBM Statistical Package for Social Studies (SPSS) version 24.0. All reported *P* values are 2-sided, and *P* values <0.05 were considered significant.

**TABLE 1** Type and Prevalence of Sports Activities Associated With Sudden Cardiac Arrest ≥65 Years

| | |
|---|---|
| Cycling | **13/77 (16.9)** |
| Gym activity | 13/77 (16.9) |
| Running | 12/77 (15.6) |
| Golf | 9/77 (11.7) |
| Tennis | 8/77 (10.4) |
| Swimming | 5/77 (6.5) |
| Bowling | 5/77 (6.5) |
| Dancing | 4/77 (5.2) |
| Racquetball | 3/77 (3.9) |
| Basketball | 2/77 (2.6) |
| Hiking | 1/77 (1.3) |
| Kayaking | 1/77 (1.3) |
| Volleyball | 1/77 (1.3) |

Values are n (%).

## RESULTS

**PREVALENCE, EVENT CIRCUMSTANCES, AND WARNING SYMPTOMS.** Of 4,078 total SCA cases in subjects ≥65 years of age, 77 (1.9%) occurred in the setting of sports activity. The most common sports activities at the time of SCA were cycling (n = 13; 17%), gym activity (n = 13; 17%), running (n = 12; 16%), golf (n = 9; 12%), and tennis (n = 8; 10%) (Table 1). The majority (77%) of SrSCAs occurred during sports activity and 17% within 1 hour after cessation (6% could not be classified in either category). In total, 20 SrSCA cases (26%) had warning symptoms during the 24 hours preceding the SCA event. The most common warning symptom was chest pain in 11 of 20 cases (55%), and 3 subjects had seizures (15%). The remainder had nonspecific symptoms, eg, dizziness, nausea, or complaints of not feeling well.

**DEMOGRAPHICS AND DIURNAL VARIANCE.** SrSCA cases were more often men (90.9% vs 62.4%; *P* < 0.001) and were younger on average (74.1 ± 7.5 years vs 78.3 ± 8.6 years; *P* < 0.001) compared with non-SrSCA cases, and there was no statistically significant difference in race/ethnicity distribution (Table 2). Women who experienced SrSCA were older than men (79.6 ± 11.7 years vs 73.5 ± 6.9 years; *P* = 0.04) (Figure 2). There were 2 diurnal variation peaks for SrSCAs, 8: 00 AM to 12:00 PM and 4:00 PM to 6:00 PM, whereas no distinct peaks were identified for non-SrSCA (Figure 3). A likely reason is that our study subjects were probably most likely to exercise during these hours. There were no statistically significant

**TABLE 2 Demographic Comparisons of Sports-Related SCA and Nonsports-Related SCA**

| | Sports-Related SCA (n = 77) | Nonsports-Related SCA (n = 4,001) | P Value |
|---|---|---|---|
| Demographics | | | |
| Age, y | 74.1 ± 7.5 | 78.3 ± 8.6 | <0.001 |
| Female | 7/77 (9.1) | 1,503/4,001 (37.6) | <0.001 |
| Race/ethnicity | | | 0.27 |
| White | 64/72 (88.9) | 3,030/3,889 (77.9) | |
| Hispanic | 3/72 (4.2) | 407/3,889 (10.5) | |
| Black | 2/72 (2.8) | 191/3,889 (4.9) | |
| Asian | 2/72 (2.8) | 194/3,889 (5.0) | |
| Other | 1/72 (1.4) | 67/3,889 (1.7) | |

Values are mean ± SD or n/N (%).
SCA = sudden cardiac arrest.

septadian or seasonal differences between SrSCAs and non-SrSCAs.

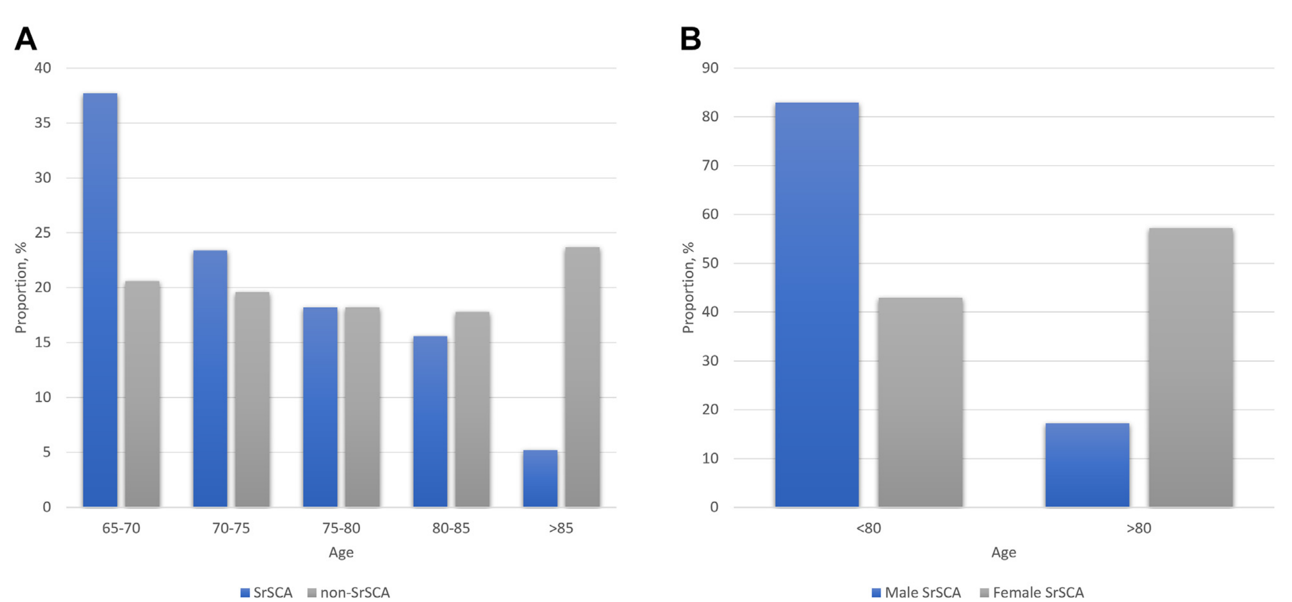
**CLINICAL CHARACTERISTICS.** We were able to evaluate clinical characteristics for cases with medical records available (47 SrSCA and 3,162 non-SrSCA). In general, SrSCA cases had lower prevalence of clinical comorbidities compared with non-SrSCA cases, including heart failure (17.0% vs 38.0%; $P$ = 0.003), COPD/asthma (15.6% vs 35.8%; $P$ = 0.004), and hypertension (57.8% vs 80.1%; $P$ = 0.001). However, history of previously diagnosed coronary artery disease (CAD) (48.9% vs 48.1%; $P$ = 0.91) and myocardial infarction (MI) (27.7% vs 25.4%; $P$ = 0.74) was equal in SrSCA and non-SrSCA cases (Table 3). The most common clinical substrate for SCA identified in SrSCA cases was CAD without heart failure (Figure 4).

Additionally, SrSCA cases had a significantly lower burden of cardiovascular risk factors (hypertension, diabetes, hyperlipidemia, smoking, obesity) than non-SrSCA cases ($P$ for trend = 0.03): 0 risk factors in 17% (SrSCA) vs 9% (non-SrSCA); 1 risk factor in 32% (SrSCA) vs 17% (non-SrSCA); 2 risk factors in 23% (SrSCA) vs 29% (non-SrSCA); 3 risk factors in 19% (SrSCA) vs 29% (non-SrSCA); 4 risk factors in 9% (SrSCA) vs 15% (non-SrSCA); and 5 risk factors in 0% (SrSCA) vs 1% (non-SrSCA).

**SCA OUTCOMES.** Survival to hospital discharge was 43.8% among SrSCA and 11.1% among non-SrSCA cases. Rates of public location (72.7% vs 9.2%; $P < 0.001$), witnessed arrest (88.0% vs 57.0%; $P < 0.001$), shockable rhythm (81.8% vs 28.7%; $P < 0.001$), and bystander cardiopulmonary resuscitation (CPR) (71.4% vs 42.1%; $P < 0.001$) were significantly higher among SrSCA cases than non-SrSCA cases. SCA event characteristics are presented in Table 4.

In the univariate models, the following variables were associated with survival from SCA events ($P < 0.10$): age, sex, diabetes, hypertension, hyperlipidemia, COPD/asthma, prior MI, prior percutaneous coronary intervention, prior coronary artery bypass

**FIGURE 2 Comparisons of Age Distribution**




Comparison of age distribution between **(A)** sports-related sudden cardiac arrest (SrSCA) and non-SrSCA, and **(B)** male SrSCA and female SrSCA.

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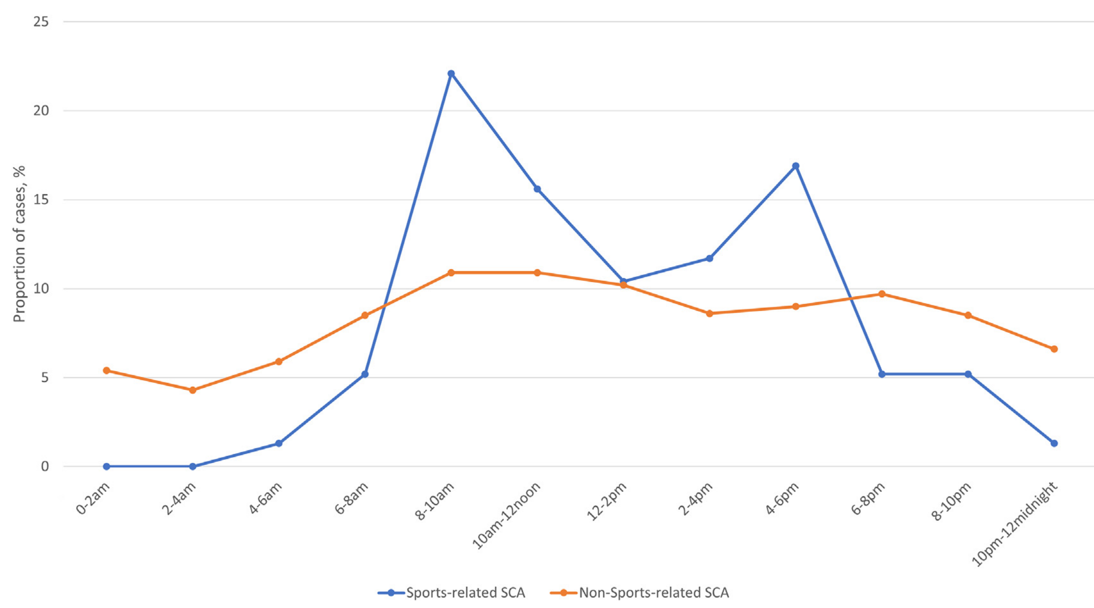
**FIGURE 3 Diurnal Variation in SrSCA and Non-SrSCA**




*P* < 0.001 for sports-related sudden cardiac arrest (SrSCA) vs non-SrSCA. Two distinct peaks were identified for SrSCA, but no significant variation was observed in non-SrSCA.

**TABLE 3 Clinical Characteristics of All Study Subjects With Available Medical Records**

| | Sports-Related SCA (n = 47) | Nonsupport-Related SCA (n = 3,162) | *P* Value |
|---|---|---|---|
| Clinical characteristics | | | |
| Coronary artery disease | 23/47 (48.9) | 1,520/3,162 (48.1) | 0.91 |
| Heart failure | 8/47 (17.0) | 1,201/3,162 (38.0) | 0.003 |
| Atrial fibrillation | 8/46 (17.4) | 580/3,146 (18.4) | 0.86 |
| Diabetes | 15/45 (33.3) | 1,397/3,141 (44.5) | 0.17 |
| Hypertension | 26/45 (57.8) | 2,515/3,141 (80.1) | 0.001 |
| Hyperlipidemia | 27/45 (60.0) | 2,042/3,141 (65.0) | 0.53 |
| COPD/asthma | 7/45 (15.6) | 1,126/3,141 (35.8) | 0.004 |
| Smoker | 2/32 (6.3) | 355/2,442 (14.5) | 0.31 |
| BMI, kg/m$^2$[a] | 27.9 ± 4.8 | 29.0 ± 8.2 | 0.19 |
| Obesity (BMI ≥30 kg/m$^2$) | 10/33 (30.3) | 855/2,375 (36.0) | 0.50 |
| SCA history | 0/47 (0) | 37/3,162 (1.2) | 0.45 |
| Myocardial infarction | 13/47 (27.7) | 802/3,162 (25.4) | 0.74 |
| ICD | 0/47 (0) | 73/3,162 (2.3) | 0.63 |
| Pacemaker | 2/47 (4.3) | 121/3,162 (3.8) | 0.70 |
| PCI | 3/47 (6.4) | 282/3,162 (8.9) | 0.80 |
| CABG | 9/47 (19.1) | 374/3,162 (11.8) | 0.17 |
| EF ≤35% | 2/14 (14.3) | 318/1,498 (21.2) | 0.75 |
| Mean EF, %[b] | 53.7 ± 20.2 | 50.1 ± 15.4 | 0.53 |
| SCA caused by acute coronary event[c] | 10/28 (35.7) | 239/820 (29.1) | 0.53 |

Values are n/N (%) or mean ± SD. [a]Data available from 2,408 subjects. [b]Data available from 1,512 subjects. [c]Data available from 848 subjects with autopsy or postarrest clinical evaluation.

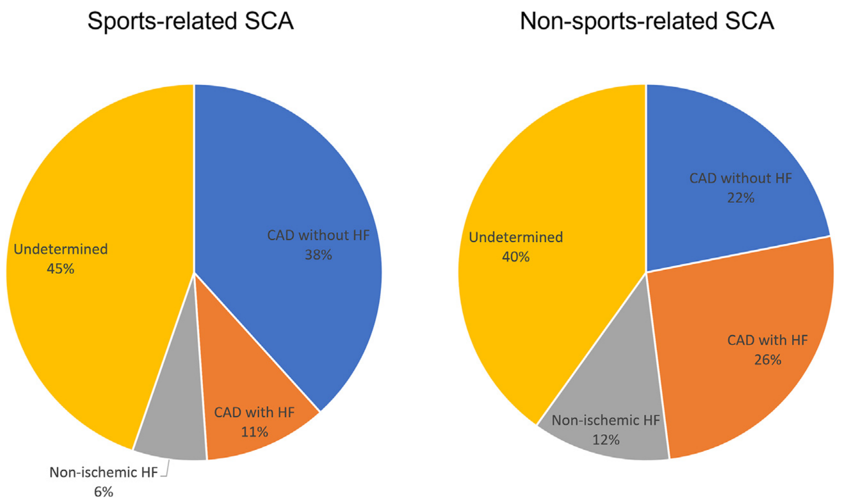
CABG = coronary artery bypass graft surgery; EF = ejection fraction; ICD = implantable cardioverter-defibrillator; PCI = percutaneous coronary intervention; SCA = sudden cardiac arrest.

graft surgery, smoking, SCA location, witness status, shockable rhythm, and SrSCA (Table 5). These variables were included in a multivariable model, in which age (OR: 0.97; 95% CI: 0.96-0.99), public location (OR: 2.49; 95% CI: 1.67-3.72), SCA in emergency department/ambulance/outpatient clinic (OR: 1.84; 95% CI: 1.09-3.09), bystander witness (OR: 4.03; 95% CI: 2.48-6.56), EMS witnessed (OR: 10.71; 95% CI: 6.07-18.91), and shockable rhythm (OR: 5.20; 95% CI: 3.69-7.33) remained independently associated with survival to hospital discharge. ORs and 95% CIs for each variable are presented in Table 5 and Figure 5.

**ANNUAL INCIDENCE AND TEMPORAL TRENDS.** In Oregon SUDS during 2002 to 2017, the mean annual crude incidence for overall SCA ≥65 years was 149/100,000, and was 3.29/100,000 for SrSCA ≥65 years. Similarly, in Ventura PRESTO 2015 to 2021, the mean annual crude incidence for overall SCA was 182/100,000 and was 2.10/100,000 for SrSCA ≥65 years. SCAs in Ventura PRESTO had a higher mean age (79.6 ± 8.8 years vs 77.3 ± 8.3 years; *P* < 0.001) which may explain the higher incidence of all SCAs and lower incidence of SrSCAs. There was no statistically significant difference in sex distribution between overall Oregon SUDS and Ventura PRESTO SCA cases.

Due to the relatively short data collection period in Ventura PRESTO, we calculated temporal trends for

**FIGURE 4** The Main Clinical Substrates of SCA in Sports-Related and Nonsports-Related SCAs




*P* = 0.01. CAD = coronary artery disease; HF = heart failure; SCA = sudden cardiac arrest.

overall SCA and SrSCA incidence only in Oregon SUDS. The ascertainment time (2002-2017) was divided into 4-year periods. The incidence of overall SCA in subjects >65 years of age remained relatively stable: 172 of 100,000 in 2002 to 2005, 141 of 100,000 in 2006 to 2009, 132 of 100,000 in 2010 to 2013, and 151 of 100,000 in 2014 to 2017 (*P* for trend = 0.46). In contrast, the incidence of SrSCA slightly increased during the same period but did not reach statistical significance: 2.65/100,000 in 2002 to 2005, 2.59/100,000 in 2006 to 2009, 3.62/100,000 in 2010 to 2013, and 4.06/100,000 in 2014 to 2017 (*P* for trend = 0.07) (Figure 6). The mean age of SrSCA cases increased slightly but did not reach statistical significance (data not shown).

When using the estimated number of individuals >65 years of age who participate in sport activity as a reference population, the incidence of SrSCA in Portland, Oregon, USA, was 28.9/100,000 sport participation years and 18.4/100,000 sport participation years in Ventura, California, USA.

## DISCUSSION

To our knowledge, this is the first prospective population-based study to investigate the burden and characteristics of SrSCA in older adults, among free-living residents of 2 large communities. Our main findings include the following: 1) only a small proportion of SCAs in the elderly occurred across a spectrum of sports activities, with cycling, gym activity, and running being most common; 2) typical male predominance was exaggerated in SrSCA; 3) SrSCA cases were overall healthier than non-SrSCA cases; and 4) SrSCA was more likely to be associated with public locations, bystander-witnessed

**TABLE 4** Comparison of Resuscitation-Related Characteristics Between Sports-Related SCA and Nonsports-Related SCA

| | Sports-Related SCA (n = 77) | Nonsports-Related SCA (n = 4,001) | *P* Value |
|---|---|---|---|
| Witness status | | | <0.001 |
| Unwitnessed | 9/75 (12.0) | 1,715/3,986 (43.0) | |
| Bystander witnessed | 65/75 (86.7) | 1,877/3,986 (47.1) | |
| EMS-witnessed | 1/75 (1.3) | 394/3,986 (9.9) | |
| Arrest characteristics | | | |
| Bystander CPR | 55/77 (71.4) | 1,683/4,001 (42.1) | <0.001 |
| Return of spontaneous circulation | 52/77 (67.5) | 1,462/3,971 (36.8) | <0.001 |
| Survival to hospital discharge | 32/73 (43.8) | 437/3,954 (11.1) | <0.001 |
| Initial rhythm | | | <0.001 |
| VF/VT | 63/77 (81.8) | 1,149/4,001 (28.7) | |
| Pulseless electrical activity | 6/77 (7.8) | 1,149/4,001 (28.7) | |
| Asystole | 6/77 (7.8) | 1,579/4,001 (39.5) | |
| Bradycardia | 1/77 (1.3) | 22/4,001 (0.5) | |
| Other/unknown | 1/77 (1.3) | 102/4,001 (2.6) | |
| Location | | | <0.001 |
| Home | 12/77 (15.5) | 2,629/4,001 (65.7) | |
| Care facility | 0/77 (0) | 606/4,001 (15.1) | |
| Public location | 56/77 (72.7) | 370/4,001 (9.2) | |
| ED/ambulance/outpatient clinic | 4/77 (5.2) | 150/4,001 (3.7) | |
| Moving vehicle | 2/77 (2.6) | 66/4,001 (1.6) | |
| Other/unknown | 3/77 (3.9) | 180/4,001 (4.5) | |
| EMS response time[a] | 6.8 ± 3.3 | 6.8 ± 3.0 | 0.79 |

Values are n/N (%) or mean ± SD. [a]Data available from 3,991 subjects.

CPR = cardiopulmonary resuscitation; ED = emergency department; EMS = emergency medical services; SCA = sudden cardiac arrest; VF = ventricular fibrillation; VT = ventricular tachycardia.

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**TABLE 5 Univariate and Multivariable Models for Factors Associated With Survival**

| | Univariate Model | | Multivariable Model | |
|---|---|---|---|---|
| | OR (95% CI) | *P* Value | OR (95% CI) | *P* Value |
| Age | 0.95 (0.94-0.97) | <0.001 | 0.97 (0.96-0.99) | 0.01 |
| Female sex | 0.80 (0.65-0.98) | 0.03 | 1.31 (0.94-1.83) | 0.12 |
| Clinical characteristics | | | | |
| Diabetes | 0.66 (0.53-0.82) | <0.001 | 0.78 (0.57-1.07) | 0.13 |
| Hypertension | 0.54 (0.44-0.66) | <0.001 | 0.78 (0.52-1.18) | 0.24 |
| Hyperlipidemia | 0.84 (0.69-1.02) | 0.08 | 1.08 (0.74-1.57) | 0.69 |
| COPD/asthma | 0.65 (0.52-0.83) | <0.001 | 0.96 (0.69-1.34) | 0.82 |
| Prior myocardial infarction | 1.27 (1.01-1.59) | 0.04 | 1.19 (0.85-1.66) | 0.31 |
| Prior PCI | 1.76 (1.28-2.41) | 0.001 | 1.45 (0.94-2.24) | 0.10 |
| Prior CABG | 1.57 (1.18-2.09) | 0.002 | 1.10 (0.73-1.65) | 0.66 |
| Smoker | 1.33 (0.95-1.87) | 0.10 | 1.00 (0.66-1.52) | 1.00 |
| Location | | | | |
| Home | Ref | Ref | Ref | Ref |
| Public | 3.99 (3.11-5.12) | <0.001 | 2.49 (1.67-3.72) | <0.001 |
| ED/ambulance/outpatient clinic | 4.88 (3.39-7.03) | <0.001 | 1.84 (1.09-3.09) | 0.02 |
| Care facility | 0.38 (0.24-0.59) | <0.001 | 0.65 (0.34-1.22) | 0.18 |
| Moving vehicle | 1.95 (1.01-3.77) | 0.05 | 0.76 (0.25-2.29) | 0.63 |
| Witness status | | | | |
| Unwitnessed | Ref | Ref | Ref | Ref |
| Bystander-witnessed | 5.95 (4.43-7.98) | <0.001 | 4.03 (2.48-6.56) | <0.001 |
| EMS-witnessed | 10.04 (7.05-14.30) | <0.001 | 10.71 (6.07-18.91) | <0.001 |
| Shockable rhythm | 8.86 (7.11-11.06) | <0.001 | 5.20 (3.69-7.33) | <0.001 |
| Sport-SCA | 6.28 (3.92-10.08) | <0.001 | 1.51 (0.65-3.52) | 0.34 |

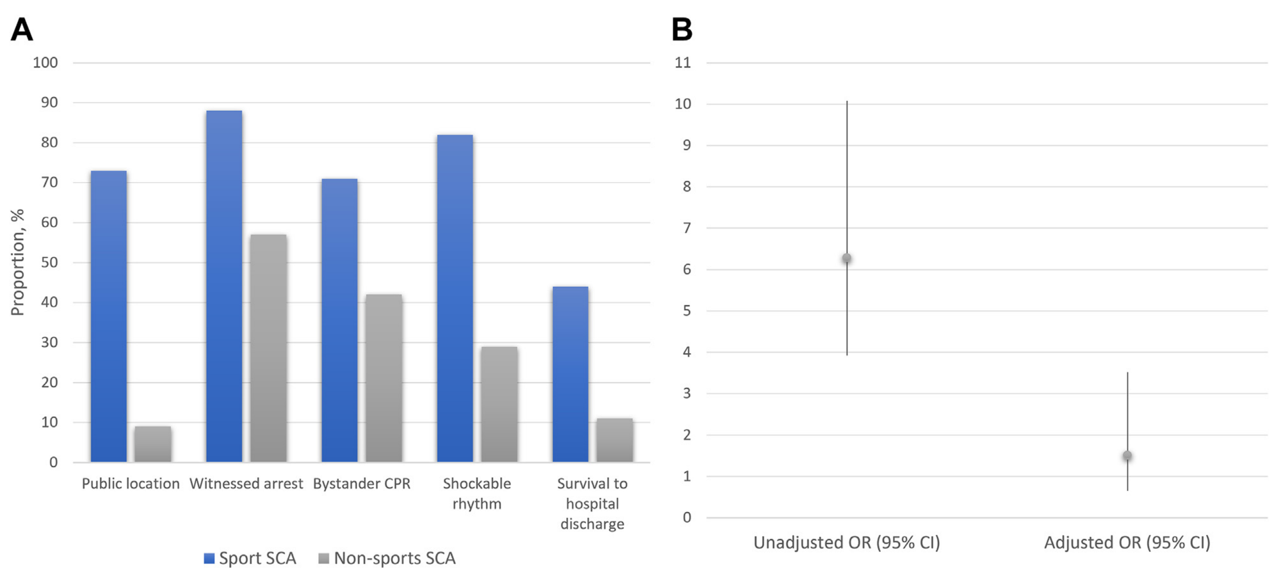
CABG = coronary artery bypass graft surgery; COPD = chronic obstructive pulmonary disease; ED = emergency department; PCI = percutaneous coronary intervention; SCA = sudden cardiac arrest.

status, and present with shockable rhythms, which contributed to a 4-fold higher rate of survival from SCA.

Although overall SCA increases with age, SrSCAs were rare and were significantly lower in prevalence compared with middle-aged and younger subgroups.[5,6,9] Individuals that had SCA in the setting of sports activity were apparently healthier than those who had non-SrSCA based on lower prevalence of cardiovascular risk factors and comorbid conditions. This could be related to the overall healthier lifestyle of individuals who participate in sports activity.[12] However, even though SrSCA cases were younger on average, the prevalence of previously diagnosed CAD and MI was similar in both groups. There may be differences in the extent and severity of CAD between SrSCA and non-SrSCA cases,[14] which we were not able to determine.

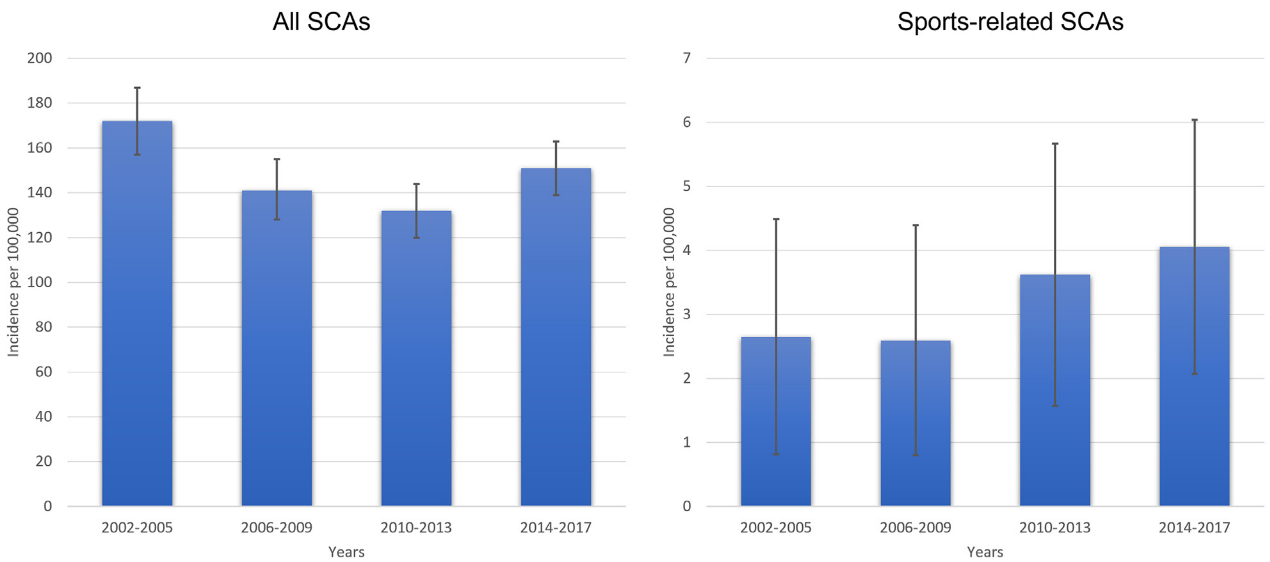
Interestingly, the prevalence of CAD related heart failure was lower in SrSCA cases, suggesting that SrSCA may have been associated with less severe CAD. Given the established beneficial effects on cardiovascular health and overall well-being among the elderly,[12] the low incidence of SrSCA in the community suggests that the benefits of exercise probably outweigh any associated risks.

**FIGURE 5 Comparison of Resuscitation Profiles**




**(A)** Resuscitation characteristics of sudden cardiac arrest (SCA) occurring during sport or not during sport. **(B)** Unadjusted and adjusted OR for survival to hospital discharge in sports-SCA vs non-sports-SCA (reference). Adjusted model included age, sex, diabetes, hypertension, hyperlipidemia, chronic obstructive pulmonary disease/asthma, prior myocardial infarction, prior percutaneous coronary intervention, prior coronary artery bypass graft surgery, smoking, cardiac arrest location, witness status, and shockable rhythm.

**FIGURE 6** Temporal Incidence (95% CI) of All SCA and Sports-Related SCA Among Individuals ≥65 Years of Age in the Oregon SUDS Study




For all sudden cardiac arrests (SCAs), *P* value for trend is 0.46; for sports-related SCAs, *P* value for trend is 0.07.

Although our study provides comprehensive community-based information on the incidence and characteristics of SrSCA in the elderly, the effectiveness of preparticipation screening remains unclear. The incidence of SrSCA was only 18.4/100,000 sport participation years in Ventuar and 28.9/100,000 sport participation years in Portland, which is significantly lower than the overall SCA incidence in this age group.[15] Given that the estimated number of individuals >65 years of age participating sports activity is on the Cardiovascular Health Study (participants >65 years of age, project started in 1988) and that the rate of sport participation has increased in recent decades among the elderly, the actual incidence rate may be even lower. However, we were not able to evaluate the rates of screening and consequent cardiovascular care that may have been conducted in the denominator population. Given that 49% of our SrSCA cases had 0 to 1 cardiovascular risk factors and 72% had 0 to 2 risk factors, a relatively low-risk profile in SrSCA cases may restrict the sensitivity of preparticipation screening tools for asymptomatic patients. However, more work needs to be done to determine whether preparticipation screening may be beneficial in selected patient groups.

Over 90% of SrSCA cases were men. Previous studies have highlighted male predominance in young and middle-aged SrSCAs,[5,6,9,10,16,17] and these differences appear exaggerated in SrSCA over age 65 years. However, we could not estimate the possible difference in sports participation rate between men and women, and therefore, we are not able to draw any definitive conclusions regarding the contribution of gender differences to SrSCA risk.

Preparticipation exercise testing is currently not recommended for low-risk asymptomatic patients.[18,19] Given that a significant proportion of SrSCA cases may experience warning symptoms before the SCA event[6] and that the risk of SCA during sports activity is inversely correlated to habitual physical activity,[20-22] clinical assessment of symptoms and habitual physical activity is an important approach to risk stratification and guidance for the optimal exercise program to reduce the risk of SrSCA.[4] Of note, recent prospective studies of CAD patients found that symptoms and low physical activity levels have strong predictive value for sudden cardiac death.[23,24]

The survival rate following SrSCA was 4-fold higher compared with non-SrSCA, a striking difference. The high survival rate is consistent with prior studies of middle-aged and younger SrSCA.[5,6,9,25] The most important determinants for the high survival rate were public location, bystander/EMS witnessed SCA, and shockable rhythm at presentation. Although bystander CPR, prompt recognition of shockable rhythm, and immediate defibrillation are established determinants of survival following SCA, substantial regional differences in acute SCA management and survival rates have been reported.[26,27] This suggests that there is still room to improve community involvement in resuscitation. A recent study from the Paris Sudden Death Expertise Center reported that the rate of bystander CPR and automated external defibrillator use increased significantly in a 12-year period, leading to a significantly improved survival rate.[28] The same group also reported that SrSCA cases occurring in sports facilities had a better prognosis than cases that occurred outside sports facilities,[29] and the difference was mainly driven by more beneficial SCA circumstances. Altogether, these findings highlight the importance of bystander awareness and CPR skills as well as public-access automated external defibrillator deployment in improving SCA survival.

**STUDY LIMITATIONS.** There are several strengths of this work, including prospective ascertainment in 2 large U.S. communities, with comprehensive data collection and analysis. However, this study has some potential limitations that should be considered while interpreting these findings. We did not have access to medical records for all SCA cases because a proportion of SCA cases may not have had a detailed medical work-up before their cardiac arrest event. Although we attempted to contact all SCA survivors, a subgroup could not be contacted and therefore we could not obtain informed consent for analysis of their clinical records. We were not able to assess the intensity of SCA-related sports activities. Autopsy data was not universally available for all SCA cases. We were not able to evaluate possible differences in sports participation rates between the 2 separate communities, which may have affected overall SrSCA incidence. However, based on increased participation in the past 2 decades, we are likely to be overestimating SrSCA incidence. Last, collection of data on warning symptoms may be prone to recall bias.

## CONCLUSIONS

SCA in the setting of sports activity is rare in older adults, comprising only 1.9% of all SCAs in the ≥65 years age group. The vast majority of SrSCA cases occurred in men, with extremely low incidence among women. There was a lower burden of cardiovascular risk factors and clinical comorbidities in SrSCA compared with non-SrSCA. Additionally, SrSCA was associated with public location as well as higher rates of bystander-witnessed and shockable rhythms, resulting in survival outcomes that were 4-fold higher than non-SrSCA. These findings reinforce the low risk and potentially high benefit of exercise habituation in older adults.

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### PERSPECTIVES

**COMPETENCY IN MEDICAL KNOWLEDGE:** These community-based findings in a large population highlight the low burden of SrSCA in older adults. Prevalence of risk factors and comorbidity burden were significantly lower compared with non-SrSCA, rates of successful resuscitation were 4-fold higher.

**TRANSLATIONAL OUTLOOK:** These findings suggests that sports activity is associated with low SCA risk in older adults. Given the widespread beneficial effects of exercise, the overall benefit of sports activity likely outweighs the low risk of SCA in older adults.

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