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Letters

Global Incidence of Sports-Related Sudden Cardiac Death

Sports-related sudden cardiac death (SrSCD) is a catastrophic event and a leading medical cause of death in athletes (1). The incidence of SrSCD is debated with estimates ranging from 0.12 to 13 per 100,000 person-years (PY) (1–3). However, there is a wide variation in methodology of the studies, accuracy of SCD identification and estimation of at-risk population. Accurate estimates of SrSCD are essential not only in estimating the burden of this problem but also in drafting policy regarding pre-participation screening. We performed a systematic review and meta-analysis to determine the incidence of SrSCD.

A computerized search of English language literature was made in the PubMed and EMBASE databases that studied the incidence of SrSCD obtained through any means (including autopsy, media reports, and prospective registries). Search terms included "SCD," "athletes," and "sport." This was last assessed as up-to-date on October 1, 2016. Studies including noncardiac death and sports-related sudden cardiac arrest (SrSCA) were included only if the number of SrSCD could be abstracted. Unsuccessful resuscitations, death prior to hospital arrival, and in-hospital death were considered SCD. We excluded SrSCD studies where the at-risk population were participants during a single sporting event and data were unavailable for calculation of PY incidence. Incidence rates were entered if available and represented as event rate per 100,000 PY with 95% confidence intervals (CIs). For studies where SrSCD incidence was unavailable, we calculated it by dividing the number of events of SrSCD by PY of the study. If PY of study was not available, it was calculated by multiplying the mean number of persons studied in 1 year by the total duration of study in years. Only the population actively involved in sports or vigorous physical activity was considered in this calculation. We evaluated heterogeneity of effects using the Higgins's I^2 statistic. As the heterogeneity for all our analysis was significant (defined as $I^2 > 40$), random effects models were used.

There were 21 studies with 1,994 SCD over 437,156,081 PY of study (**Table 1**). The incidence of SrSCD was 0.72 (95% CI: 0.58 to 0.86) per 100,000 PY. When considering only high-quality studies, the pooled incidence did not change ([0.72; 95% CI: 0.58 to 0.86] per 100,000 PY). Whereas the incidence of SrSCD was slightly higher in the United States (0.70; 95% CI: 0.47 to 0.93) than in Europe (0.68; 95% CI: 0.51 to 0.86), there was no significant difference ($Q = 0.011$; $p = 0.92$). The incidence when considering only high school/college athletes was 0.67 (95% CI: 0.34 to 1.00) per 100,000 PY. The difference in incidence was of borderline significance ($Q = 0.905$; $p = 0.09$) between prospective (0.83; 95% CI: 0.64 to 1.03) and retrospective studies (0.60; 95% CI: 0.43 to 0.78).

There was considerable heterogeneity in our analyses given the significant methodological differences. We dealt with each of these systematically. First, case detection methods were different across the studies ranging from autopsy reports and media searches to systematic prospective data. However, our subgroup analysis showed that pooled estimates obtained from retrospective and prospective data were not significantly different. Another source of variability in estimates of SrSCD is inclusion of SrSCA. While some studies in our analysis included SrSCA, we used only SrSCD for incidence analysis. SrSCA is "witnessed" in ≤87% cases and has ~31% survival to hospital admission and 16% survival at hospital discharge with >82% individuals having a neurological status compatible with normal life (4,5). Given this, SrSCA should potentially be treated as a separate entity.

Our study has several limitations. All data are observational and subject to selection bias. Many studies did not report cause of death; as a result, it was not analyzed. There are key differences in study methodology resulting in significant heterogeneity in the analyses. However, the large size of our data and consistency of results after multiple sensitivity and subgroup analyses provide robustness to the results. Evidence of publication bias was observed on Eggers test ($p = 0.007$) for incidence of SrSCD, likely from variable methodological designs of studies. Another

TABLE 1 Description of Included Studies

Study	Design	PY of Study	Rate per 100,000 PY (95% CI)
Thompson et al. JAMA 1982;247:2535–8	Retrospective	76,368	13.09 (4.98 to 21.21)
Waller et al. Clin Cardiol 1992;15:851–8	Prospective	829,089	1.69 (0.80 to 2.57)
Fuller et al. Med Sci Sports Exerc 1997;29:1131–8	Prospective	16,845	0.33 (0.27 to 0.40)
Maron et al. J Am Coll Cardiol 1998;32:1881–4	Retrospective	651,695	0.75 (-1.33 to 2.82)
Van Camp et al. Med Sci Sports Exerc 1995;27:641–7	Retrospective	30,093,579	0.46 (-0.06 to 0.98)
Durakovic et al. J Sports Med Phys Fitness 2005;45:532–6	Retrospective	3,930,000	0.15 (0.03 to 0.27)
Corrado et al. JAMA 2006;296:1593–601	Prospective	1,954,382	1.87 (1.38 to 2.37)
Chevalier et al. Eur J Cardiovasc Prev Rehabil 2009;16:365–70	Prospective	317,205	1.26 (0.03 to 2.50)
Drezner et al. Circulation 2009;120:518–25	Prospective	64,200,000	1.59 (1.03 to 2.14)
Maron et al. Circulation 2009;119:1085–92	Prospective	1,239,112	0.61 (0.55 to 0.67)
Holst et al. Heart Rhythm 2010;7:1365–71	Retrospective	1,239,112	1.21 (0.60 to 1.82)
Solberg et al. Eur J Cardiovasc Prev Rehabil 2010;17:337–41	Retrospective	2,597,204	0.85 (0.49 to 1.20)
Marijon et al. Circulation 2011;124:672–81	Prospective	169,742,000	0.33 (0.31 to 0.36)
Steinvil et al. J Am Coll Cardiol 2011;57:1291–6	Retrospective	923,076	2.38 (1.39 to 3.38)
Roberts and Stovitz. J Am Coll Cardiol 2013;62:1298–301	Retrospective	1,666,509	0.24 (0.00 to 0.48)
Toresdahl et al. Heart Rhythm 2014;11:1190–4	Prospective	1,577,366	0.13 (-0.05 to 0.30)
Risgaard et al. Heart Rhythm 2014;11:1673–81	Prospective	3,035,521	1.45 (1.02 to 1.88)
Harmon et al. Circulation 2015;132:10–9	Prospective	4,242,519	1.86 (1.45 to 2.27)
Grani et al. Eur J Prev Cardiol 2016;23:1228–36	Retrospective	24,392,760	0.59 (0.50 to 0.69)
Bohm et al. Eur J Prev Cardiol 2016;23:649–56	Prospective	120,000,000	0.09 (0.07 to 0.11)
Harmon et al. Mayo Clin Proc 2016;91:1493–502	Retrospective	6,974,640	0.99 (0.76 to 1.22)
Overall		437,156,081	0.72 (0.58 to 0.86)

Test for heterogeneity: $I^2 = 97.4\%$; $Q = 791.88$; $p < 0.001$.
CI = confidence intervals; PY = person years.

possible explanation for this is our inclusion of only English language literature (i.e., mainly from North America and Europe).

In conclusion, in a meta-analysis of observational studies incorporating 1,994 SrSCD over >430 million PY, the incidence of SrSCD is low at 0.72 per 100,000 PY (1 death per 138,889 PY).

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Appropriate Referrals of Angiography Despite High Prevalence of Normal Coronary Arteries or Nonobstructive CAD

National registry data indicate that approximately 60% of patients referred for invasive coronary angiography (ICA) have normal coronary arteries (NCA) or non-obstructive coronary artery disease (CAD) (1). Some have suggested that the rather low prevalence of