CLINICAL RESEARCH STUDY

THE AMERICAN JOURNAL of MEDICINE®

Demographics and Epidemiology of Sudden Deaths in Young Competitive Athletes: From the United States National Registry

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ABSTRACT

BACKGROUND: Sudden deaths in young competitive athletes are tragic events, with high public visibility. The importance of race and gender with respect to sport and the diagnosis and causes of sudden death in athletes has generated substantial interest.

METHODS: The US National Registry of Sudden Death in Athletes, 1980-2011, was accessed to define the epidemiology and causes of sudden deaths in competitive athletes. A total of 2406 deaths were identified in young athletes aged 19 ± 6 years engaged in 29 diverse sports.

RESULTS: Among the 842 athletes with autopsy-confirmed cardiovascular diagnoses, the incidence in males exceeded that in females by 6.5-fold (1:121; 691 vs 1:787,392 athlete-years; $P \leq .001$). Hypertrophic cardiomyopathy was the single most common cause of sudden death, occurring in 302 of 842 athletes (36%) and accounting for 39% of male sudden deaths, almost 4-fold more common than among females (11%; $P \leq .001$). More frequent among females were congenital coronary artery anomalies (33% vs 17% of males; $P \leq .001$), arrhythmogenic right ventricular cardiomyopathy (13% vs 4%; $P = .002$), and clinically diagnosed long QT syndrome (7% vs 1.5%; $P \leq .002$). The cardiovascular death rate among African Americans/other minorities exceeded whites by almost 5-fold (1:12,778 vs 1:60; 746 athlete-years; $P < .001$), and hypertrophic cardiomyopathy was more common among African Americans/other minorities (42%) than in whites (31%; $P \leq .001$). Male and female basketball players were 3-fold more likely to be African American/other minorities than white.

CONCLUSIONS: Within this large forensic registry of competitive athletes, cardiovascular sudden deaths due to genetic and/or congenital heart diseases were uncommon in females and more common in African Americans/other minorities than in whites. Hypertrophic cardiomyopathy is an under-appreciated cause of sudden death in male minority athletes.

 • *The American Journal of Medicine (2016) 129, 1170-1177*

KEYWORDS: Athletes; Congenital heart disease; Hypertrophic cardiomyopathy; Sudden death

Sudden deaths in young competitive athletes are a highly visible medical and societal issue, which has attracted considerable interest in both the physician and lay communities.[1-19] Most recently, substantial attention has been directed toward the interaction of race, gender, cardiac diagnosis, and sport on sudden death risk, and how these variables may influence implementation of the most effective and practical strategy for preparticipation screening to detect unsuspected and potentially lethal genetic and/or congenital cardiovascular diseases.[3,8-10,12-19] To that purpose, we have taken this opportunity to revisit these issues by accessing the largest available national forensic database, which represents a unique resource for insights into the epidemiology of sudden death events in young athletes and the underlying causes.

METHODS

Selection of Athletes

The US National Registry of Sudden Death in Athletes was instituted at the Minneapolis Heart Institute Foundation to

Funding: None.

Conflict of Interest: None.

Authorship: All authors had a role in the writing of the manuscript and access to all data.

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0002-9343/$ -see front matter
http://dx.doi.org/10.1016/j.amjmed.2016.02.031

prospectively assemble data on the deaths of young athletes participating in competitive athletics. Sports participants are considered for inclusion if they engaged in an organized team or individual sport requiring regular training and competition, and experienced sudden death.[1-3,8,12-20] Deaths occurring in club or intramural sports, or resulting from automobile accidents, cancer, and other systemic diseases are not included. This project was approved by the Biomedical Research Alliance of New York Institutional Review Board.

A variety of sources[7,12-14,17-19,21] were used to identify the study population by targeted searches: (1) LexisNexis archival informational database with searchable access to authoritative news, legal, and public records; (2) National Collegiate Athletic Association Memorial Resolutions List; (3) news media accounts systematically assembled through Burrelle's Information Services (Livingston, NJ); (4) internet search engines (eg, Google, Yahoo); (5) reports from the US Consumer Product Safety Commission (Washington, DC); (6) records of the National Center for Catastrophic Sports Injury Research (University of North Carolina, Chapel Hill, NC); (7) reports submitted to the Registry through personal contact with physicians, attorneys, coroners/medical examiners, schools, and patient advocacy/support organizations.

A systematic tracking process was established to assemble detailed information on each case, including the autopsy report (with gross anatomic, histologic, and toxicologic findings) and pertinent clinical and demographic information. Postmortem findings were adjudicated by one senior investigator (BJM) with >35 years' experience/expertise in this discipline.[12-19,22] When judged necessary, autopsy findings were verified by direct communication with medical examiners, and primary pathologic materials were selectively requested and analyzed. In some cases, selected data (eg, circumstances of collapse) were derived from written accounts or telephone interviews with family members, witnesses, or coaches.

Diagnostic criteria for hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, and other cardiovascular diseases reported here have been published previously.[12-14] Diagnosis of long QT syndrome was based on, when available, 12-lead electrocardiograms, positive genotyping, and/or family history in athletes with structurally normal hearts at autopsy. Race could be reliably resolved from the record in 2380 of 2406 individual athletes (99%).

CLINICAL SIGNIFICANCE

- Sudden deaths are uncommon in females but relatively common in African Americans and other minorities.
- Overall, hypertrophic cardiomyopathy is the single most common cause of sudden death, accounting for one-third of these events.
- Among cases of hypertrophic cardiomyopathy, >50% occurred in minority males but only 1% in minority females.
- These data relate to clinical cardiovascular screening for athletes and other young people, as well as clinical evaluation of patients, including those with hypertrophic cardiomyopathy.

Study Design

There are 2406 athlete deaths reported to the Registry (Figure 1). In 214 (188 male, 26 female) it was not possible to reliably assign a cause of death, owing to a variety of factors: (1) failure to perform autopsy examination; (2) restricted access to postmortem and/or clinical findings owing to confidentiality and privacy obstacles; or (3) descriptions of gross and histopathologic findings on the autopsy report were judged particularly ambiguous, with insufficient detail to assign a reliable diagnosis.

Of the remaining 2192 athletes, 886 were judged to have a noncardiovascular cause of death; 464 other athletes experienced virtually instantaneous collapse during or immediately after physical activity, which were judged probable cardiovascular deaths but remained without a definitive clinical and/or autopsy diagnosis (given ambiguous or absent autopsy reports). The remaining 842 cases with confirmed cardiovascular diagnoses form the primary study group.

Statistics

Data are expressed as mean ± standard deviation for continuous variables. Frequency and proportions were reported for categorical variables. Proportions were compared with the χ^2 or Fisher exact tests. Continuous variables were compared with the unpaired Student's *t*-test or Mann-Whitney rank sum test, where appropriate. Trends in counts over time were assessed by Poisson regression analysis with log link and likelihood ratio tests and in binary variables by logistic regressions with likelihood ratio tests.

To calculate the number of athlete-years, stratified by gender and race, available public domain data on student participation were assembled from the National Federation of State High School Associations[23] and the National Collegiate Athletic Association.[24] In each of these analyses, the number of tabulated participations was converted to the number of athlete-years relying on the published correction factors (ie, 1.9 for high school and 1.2 for college).[13] To calculate the incidence of confirmed cardiovascular sudden deaths by gender, the database was reviewed, and deaths among athletes aged 15-24 years were selected. Similarly, to calculate the incidence rate of confirmed cardiovascular sudden deaths by race, the database was reviewed, and deaths among athletes aged 19-24 years were selected.

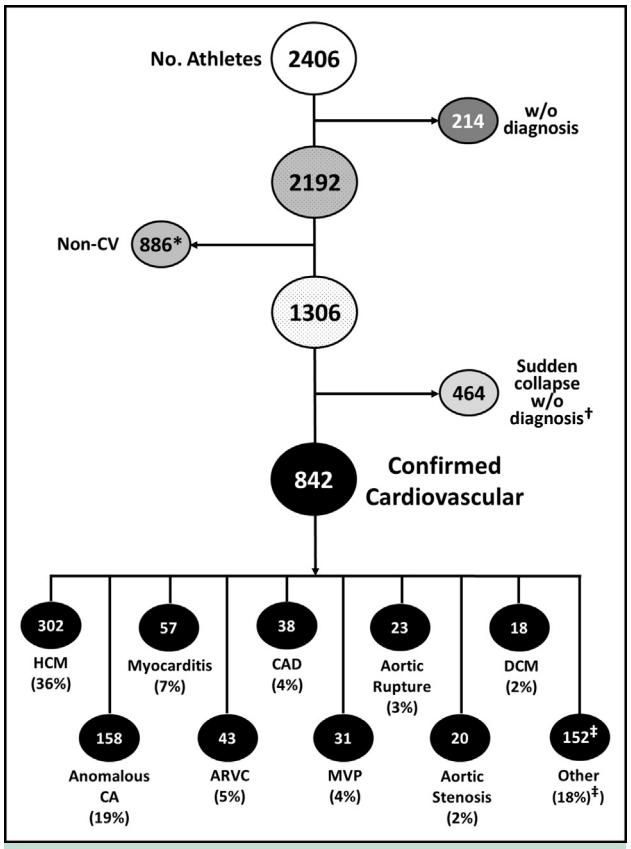

Figure 1 Flow diagram showing entries into the US National Registry of Sudden Death in Athletes, 1980-2011. *Includes blunt trauma (n = 488); drugs (n = 81); suicide (n = 66); commotio cordis (n = 58); heat stroke (n = 56); pulmonary disease (n = 41), sickle cell trait (n = 31); other noncardiac causes (n = 65). †Includes 26 athletes (without clinical evaluations) with structurally normal hearts; heart weight 352 ± 71 g, 16 ± 2 years of age, and 23 (90%) male. ‡Bridged left anterior descending (n = 23); long QT syndrome (n = 18); congenital heart defect (n = 8); Wolff-Parkinson-White (n = 8); myocardial infarction (n = 4); sarcoidosis (n = 4); stroke (n = 3); conduction system abnormality (n = 2) and 1 each for cardiac rupture, cardiac tumor, tetralogy of Fallot, electrolyte abnormality, ruptured cerebral arteriovenous aneurysm; left ventricular hypertrophy of unresolved etiology (n = 77). ARVC = arrhythmogenic right ventricular cardiomyopathy; CA = coronary artery; CAD = coronary artery disease; CV = cardiovascular; DCM = dilated cardiomyopathy; HCM = hypertrophic cardiomyopathy; MVP = mitral valve prolapse; w/o = without.

RESULTS

Registry Study Population

Demographics. Over a 32-year study period, 1980-2011, a total of 2406 athletes with sudden death were enrolled in the Registry, mean age 19 ± 6 years. Of the 2406 Registry deaths, 1931 (80%) occurred in high school/middle school or in college student-athletes; the other 475 athletes (20%) were engaged in organized youth, postgraduate, Masters, or professional sports (Table 1); 74% occurred during competition or practice, and the other 26% while sedentary or engaged in mild physical exertion or recreational activities.

Reports to the Registry of sudden deaths have increased at 4.4%/year ($P < .001$; 95% confidence interval [CI] 3.9%-4.8%), 1.5%/year for males ($P < .001$; 95% CI 1.4%-1.7%), and 5.7%/year for females ($P < .001$; 95% CI 5.1%-6.2%). Deaths are reported from all 50 states and the District of Columbia, most commonly California (n = 226), Florida (n = 154), and Texas (n = 153).

Gender/Race. Within the overall Registry cohort, 2153 deaths from all causes (89%) occurred in males, and 253 deaths (11%) were in females (Table 1). With respect to incidence, the mortality rate in males exceeded that in females by 8-fold (1:62; 439 and 1:523,093 athlete-years, respectively; $P < .001$).

The number of sudden deaths from all-causes in whites was 1464 (62%) and in African Americans and other minorities 891 (38%) (Table 1). With respect to incidence, the mortality rate in African Americans and other minorities exceeded that in whites (1:6314 and 1:20,096 athlete-years, respectively; $P \leq .001$) by 3.2-fold.

Sports. Sudden deaths occurred in a wide variety of 29 competitive sports; in males, most commonly football (n = 723; 34%); basketball (n = 437; 20%); baseball (n = 144; 7%); and cross-country/track (n = 143; 7%) (Table 1). Females most commonly participated in basketball (n = 47; 19%); cross-country/track (n = 41; 16%); soccer (n = 26; 10%); and cheerleading (n = 22; 9%).

Confirmed Cardiovascular Causes of Sudden Death

Gender. Of the 842 sudden deaths that could be reliably attributed largely to genetic and/or congenital cardiovascular diseases, males (747 of 842; 89%) exceeded females (95 of 842; 11%), an 8:1 ratio (Figure 1, Table 2). With respect to incidence, the mortality rate in males exceeded that in females by 6.5-fold (1:121,691 and 1:787,392 athlete-years, respectively; $P < .001$).

The single most common cause of sudden death was hypertrophic cardiomyopathy (302; 36%), occurring in 292 males and only 10 females. Hypertrophic cardiomyopathy was 3.5-fold more common among males (292 of 747; 39%) than among females (10 of 95; 11%) ($P \leq .001$) (Table 3). Congenital coronary anomalies, arrhythmogenic right ventricular cardiomyopathy, and long QT syndrome were significantly more common among females than among males (Table 3).

Race. Of the 842 athletes, most (452 [54%]) were white, 350 (42%) were African American, and 40 (5%) were other minorities. With respect to incidence, cardiovascular mortality in African Americans and other minorities exceeded

Table 1 Sports Participation by Gender in 2406 Competitive Athletes with Sudden Death

Sport	Males	Whites	AA-M*	Females	Whites	AA-M†
No. (%)	2153 (89)	1273	834	253 (11)	191	57
Baseball	144 (7)	119	23	0	0	0
Basketball	437 (20)	132	296	47 (19)	23	23
Boxing	62 (3)	21	40	1 (0.4)	1	0
Cheerleading	0	0	0	22 (9)	12	10
Cross-country/track	143 (7)	97	41	41 (16)	32	8
Equestrian	18 (1)	12	6	10 (4)	10	0
Field hockey/ice hockey	35 (2)	34	1	5 (2)	4	0
Football	723 (34)	358	345	1 (0.4)	1	0
Gymnastics	5 (0.2)	4	1	7 (3)	5	2
Lacrosse	29 (1)	25	3	2 (1)	2	0
Marathon	29 (1)	25	3	10 (4)	8	2
Martial arts	15 (0.7)	11	4	1 (0.4)	1	0
Motor vehicle sports	115 (5)	113	2	1 (0.4)	1	0
Rowing	6 (0.3)	6	0	3 (1)	2	1
Rugby	20 (1)	17	3	0	0	0
Skiing/snowboarding	20 (1)	20	0	6 (2)	6	0
Soccer	132 (6)	97	31	26 (10)	21	4
Softball	7 (0.3)	4	3	20 (8)	19	1
Surfing	10 (0.5)	8	2	0	0	0
Swimming/water polo	42 (2)	40	2	20 (8)	18	2
Tennis	14 (0.6)	10	3	3 (1)	3	0
Triathlon	23 (1)	20	2	5 (2)	4	0
Volleyball	2 (0)	1	1	16 (6)	12	4
Wrestling	90 (4)	72	17	0	0	0
Miscellaneous/other	32 (1.5)†	27	5	6 (2)	6	0

AA-M = African Americans and other minorities.
*Race not available in 46 athletes.
†Race not available in 5 athletes.

that in whites by a factor of 4.8 (1:12,778 and 1:60,746 athlete-years, respectively; $P < .001$). Hypertrophic cardiomyopathy was more common among African Americans and other minorities (164 of 390; 42%) than among white athletes (138 of 452; 31%) ($P < .001$). Arrhythmogenic right ventricular cardiomyopathy and long QT syndrome were more common among white athletes (Table 3).

Cardiovascular sudden deaths in male basketball players were 3-fold more common among African Americans and other minorities (188 of 361; 52%) than whites (71 of 386; 18%) ($P = .001$). Cardiovascular deaths in female basketball players were similarly more common among African Americans and other minorities (13 of 29; 45%) than whites (10 of 66; 15%) ($P = .002$) (Table 2).

In 26 athletes without clinical evaluation, 16 ± 2 years of age, the heart was judged structurally normal at autopsy (heart weight 352 ± 71 g); 23 were male, and 20 were white.

Race and Gender

Incorporating race with gender for confirmed cardiovascular sudden deaths yielded these frequencies: white males (n = 386; 46%); African Americans and other minority males (n = 361; 43%); white females (n = 66; 8%); African American and other minority females (n = 29; 3%) (Figure 2, Table 2). Hypertrophic cardiomyopathy was more common in African American and other minority males (160 of 302; 53%) than in white males (132 of 302; 44%) and least common in white females (6 of 302; 2%) and African American and other minority females (4 of 302; 1%) (Figure 2, Table 3).

Noncardiovascular Causes of Sudden Death

Of the 2406 deaths, 886 were unrelated to cardiovascular causes (37%) (Figure 1, Table 3), more common among male athletes than females: 809 of 2153 (38%) vs 77 of 253 (30%) ($P = .026$), and more common among whites than African Americans and other minorities (608 of 1464; 42%, vs 273 of 891; 31%) ($P = .001$ (Table 3)). Of these 886 deaths, 488 were directly attributable to blunt trauma causing profound bodily injury, most commonly to the head and neck, and often with structural damage to other critical organs.[25]

Similarly, blunt precordial blows causing cardiac arrest (commotio cordis),[26] occurred in 58 athletes, with a striking male predominance (57 vs 1). Suicide (n = 66) was more common among females (13 of 253; 5.1%) compared with males (53 of 2153; 2.5%) ($P = .023$). Deaths attributable to

Table 2 Gender and Race Comparisons for Demographic Variables in 842 Confirmed Cardiovascular Deaths

Parameter	Males	White	AA-M	Females	White	AA-M
No. of deaths (%)	747 (89)	386 (46)	361 (43)	95 (11)	66 (8)	29 (3)
Age (y), mean ± SD	17.8 ± 4.7	17.7 ± 5.2	17.8 ± 4.1	16.8 ± 5.2	17.1 ± 5.6	16.1 ± 3.9
Circumstance						
During competition	190 (25)	95	950	31 (33)	17	14
During practice	291 (39)	158	133	37 (39)	28	9
During recreational activity	139 (19)	54	85	7 (7)	6	1
Unassociated with physical activity	127 (17)	79	48	20 (21)	14	6
Level of competition						
Youth	25 (3)	16	9	4 (4)	3	1
High school/JHS	494 (66)	263	231	68 (72)	47	21
College	142 (19)	57	85	13 (14)	7	6
Professional/postgraduate/amateur/Masters	86 (11)	50	36	10 (11)	9	1
Sports						
Basketball	259 (35)	71	188	23 (24)	10	13
Football	226 (30)	102	124	0 (0)	0	0
Soccer	57 (8)	45	12	12 (13)	9	3
Cross country/track	54 (7)	39	15	16 (17)	12	4
Baseball	47 (6)	38	9	0 (0)	0	0
Wrestling	23 (3)	19	4	0 (0)	0	0
Swimming/water polo	17 (2)	17	0	7 (7)	6	1
Marathon	10 (1.3)	10	0	4 (4)	4	0
Field hockey/ice hockey	9 (1.2)	8	1	1 (1)	1	0
Boxing	7 (0.9)	3	4	0 (0)	0	0
Lacrosse	6 (0.8)	4	2	0 (0)	0	0
Rugby	5 (0.7)	5	0	0 (0)	0	0
Triathlon	4 (0.6)	4	0	2 (2.2)	2	0
Motor vehicle sports	3 (0.4)	3	0	0 (0)	0	0
Rowing	3 (0.4)	3	0	3 (3.2)	2	1
Tennis	3 (0.4)	3	0	0 (0)	0	0
Gymnastics	2 (0.3)	2	0	2 (2)	2	0
Equestrian	1 (0.1)	1	0	1 (1.1)	1	0
Softball	1 (0.1)	1	0	9 (9)	8	1
Cheerleading	0 (0)	0	0	10 (10)	6	4
Volleyball	0 (0)	0	0	5 (5)	3	2
Other*	10 (1.3)	8	2	0 (0)	0	0

AA-M = African American and other minorities; JHS = junior high school (middle school).
*Surfing (2); golf (2); cycling (1); figure skating (1); martial arts (1); sailing (1); skateboarding (1); weightlifting (1).

drug abuse had similar frequency in males and females (73 of 2153; 3.4%, vs 8 of 253; 3.2%) ($P = 1.0$). Sickle cell trait was the likely cause of death in 31 of 711 African American athletes (4.4%), aged 18 ± 3 years.[27]

DISCUSSION

The risk for sudden death due largely to genetic and/or congenital heart diseases in athlete populations has been related to a number of demographic variables, including race and gender, with implications for the design of cardiovascular screening strategies.[2-6,8,9,28-30] Therefore, we have taken this opportunity to interrogate after 8 years our unique 35-year-old national forensic Registry, now with >2400 sudden death events, to revisit the circumstances surrounding deaths occurring in young athletes.[13]

We found cardiovascular sudden death incidence to be strikingly lower in female athletes, >6-fold less than in males.[13] This infrequency of female sudden deaths in our population is consistent with that reported in a French national study of recreational and competitive sports participants (in which female deaths were up to 30-fold less than in males),[11] as well as in marathon running (6-fold).[31]

Specific cardiovascular causes of death were also strongly associated with gender. For example, of the 302 athletes in the Registry who died related to hypertrophic cardiomyopathy, only 3% were female. In autosomal dominant genetic diseases (such as hypertrophic cardiomyopathy), for which males and females are expected to be affected equally,[32] disproportionate numbers of one gender over the other are notable and can be considered evidence in our population of lower sudden death risk due to hypertrophic cardiomyopathy in females. On the other hand, females predominated with respect to congenital coronary artery anomalies, arrhythmogenic right ventricular cardiomyopathy, and long QT syndrome.

Table 3 Cardiovascular and Noncardiovascular Causes of Sudden Death in Competitive Athletes According to Age, Gender, and Race

Cause of Death	No. (%)	Age (y), Mean ± SD	Males	Females	Race		
					A-A	Other Minorities*	Whites
Cardiovascular							
HCM†	302 (36)	18 ± 4	292	10	152	12	138
Congenital coronary anomalies	158 (19)	16 ± 3	127	31	77	9	72
Indeterminant with LVH (possible HCM)‡	77 (9)	18 ± 5	73	4	31	6	40
Myocarditis	57 (7)	17 ± 5	46	11	24	3	30
ARVC	43 (5)	18 ± 6	31	12	8	0	35
Atherosclerotic CAD	38 (4.5)	24 ± 7	37	1	13	1	24
MVP	31 (3.7)	18 ± 7	24	7	8	1	22
Aortic rupture	23 (2.7)	18 ± 4	18	5	9	0	14
Bridged LAD	23 (2.7)	17 ± 3	21	2	8	1	14
Aortic valve stenosis	20 (2.4)	17 ± 4	20	0	1	4	15
DCM	18 (2.1)	19 ± 3	15	3	8	0	10
LQTS§	18 (2.1)	16 ± 6	11	7	1	1	16
Congenital heart defect/disease	8 (1.0)	13 ± 3	7	1	1	2	5
WPW	8 (1.0)	18 ± 3	8	0	2	0	6
Myocardial infarction	4 (0.5)	20 ± 8	4	0	1	0	3
Sarcoidosis	4 (0.5)	26 ± 10	4	0	3	0	1
Conduction system abnormality	2 (0.2)	14 ± 2	1	1	0	0	2
Other cardiovascular‖	8 (1.0)	17 ± 6	8	0	3	0	5
Totals	842	17.7 ± 4.8	747	95	350	40	452
Noncardiovascular							
Trauma	488 (55)	21 ± 7	452	36	63	68	354
Drugs	81 (9)	23 ± 7	73	8	13	6	62
Suicide	66 (7)	21 ± 5	53	13	10	1	54
Commotio cordis	58 (6.5)	15 ± 3	57	1	7	5	46
Heat stroke	56 (6)	18 ± 5	55	1	20	1	35
Pulmonary¶	41 (5)	19 ± 6	32	9	21	3	17
Sickle cell trait	31 (3.5)	18 ± 3	29	2	30	1	0
Other noncardiovascular#	65 (7)	20 ± 6	58	7	18	6	40
Totals	886	20.4 ± 6.7	809	77	182	91	608

A-A = African American; ARVC = arrhythmogenic right ventricular cardiomyopathy; CAD = coronary artery disease; DCM = dilated cardiomyopathy; HCM = hypertrophic cardiomyopathy; LAD = left anterior descending coronary artery; LQTS = long QT syndrome; LVH = left ventricular hypertrophy; MVP = mitral valve prolapse; WPW = Wolff-Parkinson-White.

*Hispanic (n = 92); Asian (n = 21); Pacific Islander (n = 8); mixed (n = 4); Native American (n = 5); Middle Eastern (n = 1); unknown (n = 5).

†Heart weights were 520 ± 111 g; maximum LV wall thickness was 22.6 ± 5 mm (range to 40).

‡Hearts with autopsy findings regarded as abnormal and potentially consistent with HCM, but insufficient to be diagnostic of the disease[14]; heart weight 400-500 g in males and 350-450 g in females and mild LV thickening (15-19 mm), but without compelling supporting diagnostic features of HCM.

§Identified clinically by 12-lead electrocardiogram, genotyping, and/or by family history, in presence of structurally normal heart at autopsy.

‖Cardiac rupture (n = 1); cardiac tumor (n = 1); tetralogy of Fallot (n = 1); stroke (n = 3); electrolyte abnormality (n = 1); ruptured cerebral arteriovenous aneurysm (n = 1).

¶Asphyxia (n = 2); aspiration (n = 2); pulmonary embolism (n = 15); sarcoidosis (n = 1); status asthmaticus (n = 20); unresolved (n = 1).

#Anaphylaxis (n = 2); anesthesia-related (n = 1); blood dyscrasia (n = 2); cerebral aneurysm/embolism (n = 12); dermatomyositis (n = 1); drowning (n = 27); epilepsy (n = 2); lightning strike (n = 14); rhabdomyolysis (n = 1); septicemia/encephalitis (n = 3).

Other potential determinants of gender disproportionality include intensity of training, which can be greater in males, who are generally capable of more demanding conditioning regimens, a fact that could also make them more susceptible to lethal ventricular tachyarrhythmias given underlying cardiovascular disease.[1,12,15] A second possibility is the absence of females from contact sports such as football, boxing, wrestling, and rugby, which are associated with vigorous training demands and also account for a significant proportion of sudden deaths in males. Third, it is plausible that certain as-yet undocumented protective metabolic mechanisms could suppress arrhythmic risk during intense physical exertion (eg, in females with hypertrophic cardiomyopathy or in males with arrhythmogenic right ventricular cardiomyopathy or ion channelopathies).[33] The infrequency of sudden deaths in young female athletes is unlikely to be related solely to participation rates, given that currently approximately 40% of high school and college athletes are in fact female.[34,35] However, it would be imprudent and probably unethical to use our mortality data to selectively exclude female athletes from preparticipation screening, given that hypertrophic cardiomyopathy-related sudden deaths did occur in a small

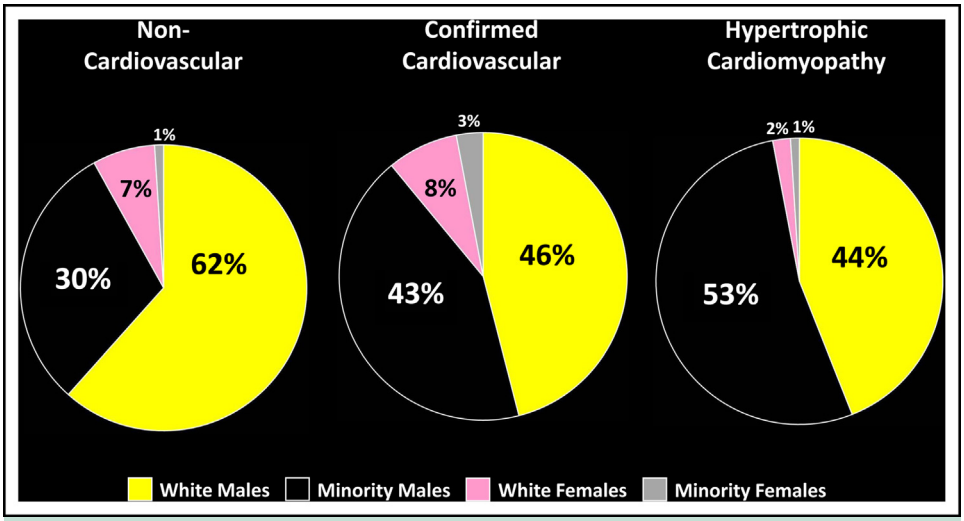

Figure 2 Race and gender with respect to sudden deaths in competitive athletes due to confirmed cardiovascular disease (*middle*); hypertrophic cardiomyopathy only (*right*); and noncardiovascular causes (*left*).

number of female athletes, and also females predominated with other diseases, including congenital coronary anomalies.

We also report a notable relationship between race and sudden death.[14] When race is incorporated into our demographic analysis, African Americans and other minority athletes combined accounted for almost 50% of confirmed cardiovascular deaths, as well as >50% of deaths due to hypertrophic cardiomyopathy. Notably, with respect to incidence, cardiovascular sudden deaths in minority athletes exceeded those in white athletes by almost 5-fold (3-fold in basketball). These observations that hypertrophic cardiomyopathy is an important, but probably under-recognized, disease in minority communities, underscore the potential for greater numbers of hypertrophic cardiomyopathy diagnoses in young people using the American Heart Association/American College of Cardiology[3] preparticipation recommendations.

Notably, in our substantial Registry experience, hypertrophic cardiomyopathy persists as the single most common cause of nontraumatic sudden death in young athletes, responsible for approximately one-third of these events. These data are based on long-standing diagnostic criteria for hypertrophic cardiomyopathy[36-38] and also by taking into account its diverse morphologic spectrum.[39-41] The frequency with which hypertrophic cardiomyopathy and other cardiomyopathies cause sudden death in young people and athletes reported here is consistent with other forensic data[42] but contrast sharply with observations from the primary care, sports, and family medicine sectors in small series offering a contrasting and challenging view that structurally normal hearts without evidence of cardiac disease are the predominant cause of sudden death in athletes.[10,43,44] As reported here, we have consistently found structurally normal hearts to constitute only <5% of athlete deaths.[12-14]

A number of potential study limitations justify mention here. First, it is possible that our race- and gender-related data have been subjected to a variety of unpredictable selection biases based on case referral patterns to the Registry. However, the substantial size of the Registry cohort (n >2400), constituting the most robust such resource available, represents an advantage that can potentially compensate for possible limitations related to the referral of cases. Furthermore, the internet-based public domain methodology used in part by this Registry has been shown to be accurate in identifying cases of sudden cardiovascular death.[21] Owing largely to limitations implicit in medical examiner autopsy reports,[45] a confirmed cardiovascular diagnosis could be made in only 65% of all cases considered likely to represent cardiovascular events.

In conclusion, interrogation of our national Registry, which has assembled more than 2400 cases of sudden deaths in young competitive athletes, demonstrated relevant principles in the epidemiology and demographics of these events. For example, although hypertrophic cardiomyopathy was a rare cause of sudden death in female athletes, it was relatively common in African American and other minority male athletes. These observations underscore the potential value of American Heart Association/American College of Cardiology-recommended preparticipation screening in minority and other communities, particularly for the identification of hypertrophic cardiomyopathy.

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