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Mandatory Electrocardiographic Screening of Athletes to Reduce Their Risk for Sudden Death

Proven Fact or Wishful Thinking?

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Objectives	The purpose of this study was to determine if pre-participation screening of athletes with a strategy including resting and exercise electrocardiography (ECG) reduces their risk for sudden death.
Background	An increasing number of countries mandate pre-participation ECG screening of athletes for the prevention of sudden death. However, the evidence showing that such a strategy actually reduces the risk of sudden death in athletes is limited. We therefore analyzed the impact of the National Sport Law enacted in Israel in 1997—which mandates screening of all athletes with resting ECG and exercise testing—on the incidence of sudden death among competitive athletes.
Methods	We conducted a systematic search of the 2 main newspapers in Israel to determine the yearly number of cardiac arrest events among competitive athletes. The size of the population at risk was retrieved from the Israel Sport Authority and was extrapolated to the changes in population size over time.
Results	There were 24 documented events of sudden death or cardiac arrest events among competitive athletes during the years 1985 through 2009. Eleven occurred before the 1997 legislation and 13 occurred after it. The average yearly incidence of sudden death or cardiac arrest events was 2.6 events per 100,000 athlete-years. The respective averaged yearly incidence during the decade before and the decade after the 1997 legislation was 2.54 and 2.66 events per 100,000 person years, respectively ($p = 0.88$).
Conclusions	The incidence of sudden death of athletes in our study is within the range reported by others. However, mandatory ECG screening of athletes had no apparent effect on their risk for cardiac arrest. (J Am Coll Cardiol 2011; 57:1291-6) © 2011 by the American College of Cardiology Foundation

Sudden cardiac death in young athletes is a tragic event. Because most cases are the result of ventricular arrhythmias caused by underlying heart disease (1), an increasing number of countries now enforce medical pre-participation screening that includes recording of a baseline electrocardiography (ECG) results (2), with the aim of detecting specific cardiac pathologic features associated with sudden death in athletes (3). However, the evidence showing that such a strategy actually prevents sudden death among athletes is limited to a single, retrospective Italian study (4).

In 1997, a mandatory pre-participation screening program was implemented in Israel (5). By law, the obligatory screening tests for all athletes include a medical questionnaire, physical examination, baseline ECG, and exercise stress testing. The aim of this study was to evaluate the impact of this extensive mandatory screening on the incidence of sudden death and cardiac arrest in athletes.

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Methods

Definitions. The Israel Sport Regulations on Athletes Medical Testing, enacted in 1997, calls for the mandatory medical screening of all athletes in Israel (6). By law, to be allowed participation in sporting activities, every athlete in Israel must undergo medical screening by specifically accredited physicians. The Israel Sport Law defines athletes requiring screening as “individuals who engage in sportive activity at any level of physical endurance” (6). Only

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**Abbreviation
and Acronym**

ECG = electrocardiography

certified physicians who have participated in a specialized accreditation course can perform this screening (6).

The obligatory screening, mandated for all athletes, includes a medical questionnaire, physical examination, resting ECG, and Bruce-protocol exercise testing. Medical assessment, including resting ECG, is repeated on a yearly basis. In addition, athletes 17 to 34 years of age must undergo exercise stress testing every 4 years, whereas yearly exercise tests are required for athletes who are 35 years of age or older or for athletes of any age competing at the national level. Beginning in 1999, all exercise tests were required by law to be symptom-limited tests.

At the discretion of the certified screening physicians, athletes with abnormal screening test results are referred to expert cardiologists, cardiac electrophysiologists, or both for additional testing and consultation. The final decision regarding certification or disqualification is eventually made based on the expert consultants' opinions.

Estimation of the number of sudden cardiac death events in athletes. The sudden death of a competitive athlete is a dramatic event that generally is covered by the media. Therefore, we limited our analysis to sudden death events in competitive athletes. As in previous studies (1), we systematically screened the general media for reports of sudden death in athletes. For that purpose, we assigned 2 professional media researchers to perform a systematic day-by-day search of the 2 leading newspapers in Israel (*Yediot Aharonot* and *Maariv*) (7). Of note, *Yediot Aharonot* reached 70% of the daily newspaper readership in Israel during the study period, whereas *Yediot Aharonot* and *Maariv* combined covered 90% of the readership (8,9). Beginning in September 2009 (and ending in December 2009), the professional media researchers scrutinized the newspapers published daily between January 1985 and December 2009. This 24-year period was targeted because we wanted to compare 2 equally long periods. Consequently, because the law mandating pre-participation ECG screening of athletes became effective 12 years previously (on November 1997) (5), we compared the 12-year period of 1985 through 1997 with that of 1998 through 2009. All the reports of deaths or dramatic medical events in competitive athletes were brought to the consideration of 3 investigators to determine (by consensus) whether the report could be considered as an athlete's sudden cardiac death or cardiac arrest. Sudden death was defined as a witnessed instantaneous death with futile resuscitation. Cardiac arrest was defined as instantaneous collapse with successful resuscitation. Sudden deaths related to trauma were excluded. As in previous studies (4), annual incidence rates were calculated by counting the events in 2-year periods and halving the result.

Estimation of the population at risk. According to the Israeli Sports Authority, the official Israeli sports organization acting under the Israeli Ministry of Sports, the number of registered athletes who engaged in competitive sports

during 2009 was 45,000. We extrapolated these data to the growth of the Israeli population who were 10 to 40 years of age during the last 24 years as available from the Israeli Central Bureau of Statistics (10). In addition, because some data suggest that the percentage of the adult population engaging in sportive activities has increased by 50% during the last decade (11), we repeated our calculations of the number of athletes at risk, assuming a gradual doubling of the percentage of athletes over the 24 years of our study.

Statistical analysis. The rate of event was calculated as the number of sudden cardiac deaths in a certain period divided by the estimated number of person-years at risk. We used the parametric bootstrap, assuming no difference between the periods, and Poisson distributions for the observed death counts to compute the p value.

Results

Overall, 36 incidents of potential sudden death events in competitive athletes were identified by the professional media researchers. Twelve of these incidents were excluded by the investigators because of the following reasons: 6 events were unequivocally the result of trauma (accidental head trauma with brain concussion, intracranial bleeding, or both in 5 and severe chest trauma during a hockey game in 1 athlete); 2 incidents occurred before the assigned study period; and 4 events involved 2 referees, 1 coach, and 1 former athlete. Thus, we identified 24 events of presumed sudden cardiac death or cardiac arrest in athletes. All of the athletes were males, their ages ranged from 12 to 44 years (mean 23.9 ± 8.8 years), and most of the athletes were football (soccer) players (Table 1). Of these 24 events, 11 events occurred during the 12 years preceding the 1997 sports legislation mandating pre-participation screening and 13 occurred during the 12 years that followed.

We estimate that the number of Israeli competitive athletes gradually increased from 28,000 in 1985 to 45,000 in 2009. Accordingly, the average yearly incidence for a sudden death or cardiac arrest event was 2.6 events per 100,000 person-years or an average of 1 event per 38,000 athletes per year. The average yearly incidence before and after the 1997 legislation was 2.54 and 2.66 events per 100,000 person-years, respectively ($p = 0.88$) (solid line in Fig. 1). Repeating our calculations assuming that the proportion of Israeli inhabitants who engage in sports doubled over the last 2 decades did not change our results significantly (there was a nonsignificant decrease in annual rate of cardiac arrest from 4.27 before 1997 to 3.13 after that, $p = 0.44$) (dotted line in Fig. 1).

Discussion

Prevention of sudden death in athletes is a universal goal. However, the optimal way to achieve this goal is still debated (12-17). Nevertheless, an increasing number of countries, as well as medical and sport organizations (2), including the International Olympic Committee (18), are

Table 1 Summary of Sudden Cardiac Death or Cardiac Arrest Events in Israel in the Years 1985 to 2009

Event Date	Sex/Age (yrs)	Sport	CPR Delivered?	On-Site or Hospital Death?
01/12/1985	M/17	Football	Yes	Yes
12/21/1988	M/26	Football	Yes	Yes
01/13/1991	M/33	Handball	Yes	Yes
12/05/1992	M/16	Football	Yes	Yes
01/04/1995	M/23	Football	Yes	No
01/07/1995	M/17	Football	Yes	Yes
02/26/1995	M/17	Football	Yes	Yes
04/12/1995	M/31	Football	Yes	Yes
12/13/1995	M/28	Rugby	Yes	Yes
01/21/1996	M/15	Football	ND	Yes
04/04/1997	M/22	Football	Yes	Yes
03/01/1998	M/44	Football	ND	Yes
01/24/1999	M/14	Football	Yes	Yes
02/20/2000	M/14	Football	Yes	Yes
08/06/2000	M/18	Basketball	Yes	Yes
05/01/2001	M/12	Football	ND	No
01/15/2001	M/39	Football	ND	Yes
01/26/2002	M/21	Football	Yes	Yes
09/27/2003	M/22	Athletics	Yes	Yes
02/18/2004	M/27	Football	Yes	Yes
10/14/2005	M/40	Triathlon	Yes	Yes
12/09/2005	M/29	Basketball	Yes	Yes
09/25/2005	M/21	Football	Yes	Yes
08/29/2007	M/29	Football	Yes	Yes

CPR = cardiopulmonary resuscitation; ND = no data available.

now mandating pre-participation screening—with baseline ECG—of all athletes. Yet, there is very limited proof that such preventive strategy actually works (17). We therefore performed the present study to assess whether the enforcement of massive pre-participation screening, including not only resting ECG, but also an exercise stress test, would reduce the risk of sudden cardiac death or cardiac arrest in athletes.

Main findings. We found that the average yearly incidence for a sudden cardiac death event among Israeli competitive athletes was 2.6 events per 100,000 person-years or 1 event

per 38,000 athletes per year. These numbers are within the range reported by others (see the following text). Importantly, we found that a mandatory screening strategy including, resting ECG and exercise ECG, had no apparent influence on the incidence of sudden death in athletes.

Impact of mandatory screening on the incidence of sudden death of athletes viewed in the context of previous studies. Figure 2 shows the annual mortality per 100,000 person-years in our study and in the only 2 previous studies—from Italy (4) and from the United States (19)—that evaluated the effects of screening on the mortality of athletes over time. The Italian study (4) (pink graph in Fig. 2) analyzed the effects of a screening strategy that includes baseline ECG recording of all athletes on the mortality rates of those 35 years of age or younger. In that Italian study, the sudden death rate among athletes in the prescreening period was 3.6 per 100,000 person-years, which is similar to the 2.6 per 100,000 person-years finding in our study. The Italian investigators reported that after the onset of screening, the annual rate of sudden death among athletes decreased dramatically. Indeed, the pink graph shows an impressive reduction in the incidence of sudden cardiac death from 3.6 per 100,000 person-years in the prescreening period to 0.4 per 100,000 person-years at the end of the study (from point B to point F in Fig. 2) (4). Note that, in the Italian study, the prescreening period used as a reference value was limited to the 2 years before the enforcement of pre-participation screening (point A to point B in Fig. 2).

More recently, Maron et al. (19) reported that the sudden death rate among high school athletes over a 23-year period in Minnesota was 1 per 100,000 person-years. That study appears as a yellow graph in Figure 2. The Minnesota sudden death rate of athletes was lower than the rates reported in Italy and in our study, although the ECG examination was not part of the screening strategy used in the United States during that period.

Our study (green graph in Fig. 2) reports the effects of a screening strategy that includes resting ECG and exercise

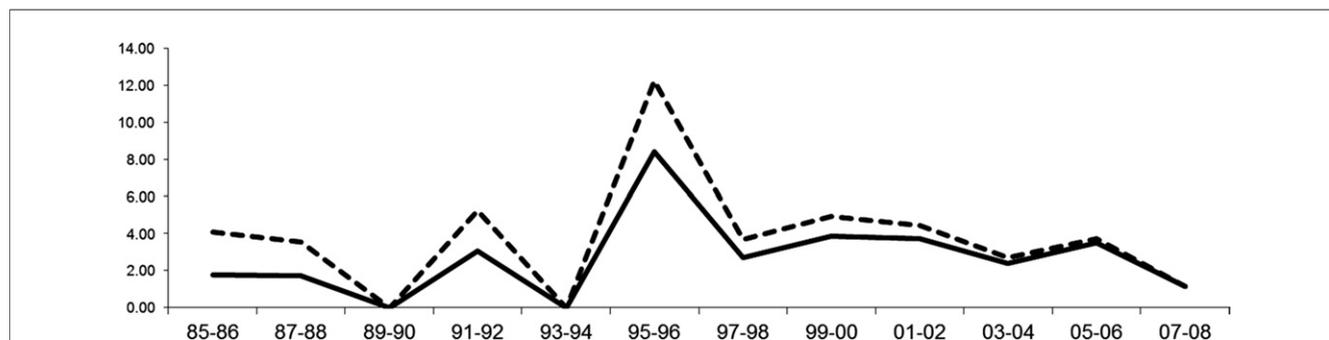


Figure 1 Sudden Death or Cardiac Arrest Events Rates per 100,000 Athlete-Years From 1985 to 2008

The crude rates are depicted by the solid line. The dotted line depicts our results after assuming that the percentage of the population actively participating in competitive sport doubled during the last 2 decades.

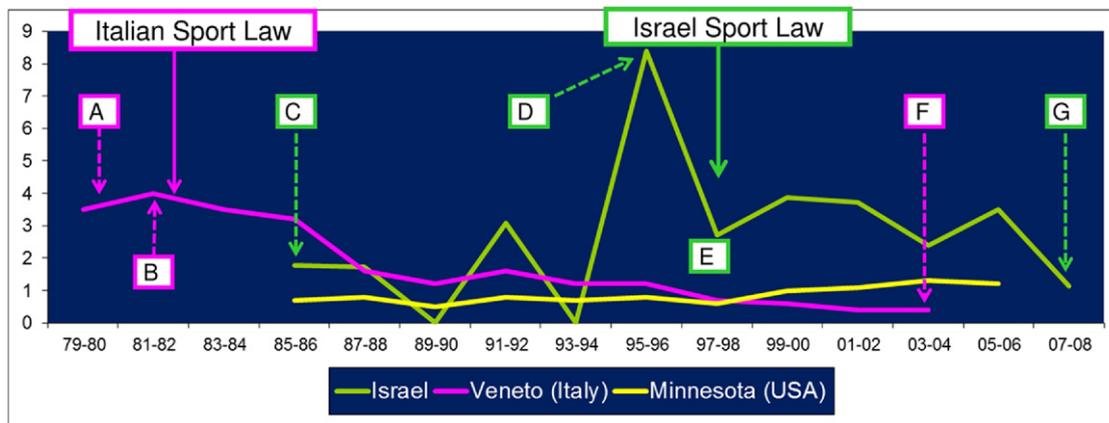


Figure 2 Annual Incidence of Sudden Cardiac Death Expressed per 100,000 Person-Years in the 3 Studies Evaluating the Effects of Screening on the Mortality of Athletes Over Time

The Italian study (4) (pink graph) concluded that electrocardiography (ECG) screening (started in 1982) significantly reduced the incidence of sudden cardiac death by comparing the sudden death in the 2-year pre-screening period (A to B) with the post-screening period (B to F). The present study is depicted by the green graph. We compared the 12 years before screening (C to E) with the 12 years after the onset of mandatory ECG screening (E to G). Had we limited our comparison of the post-screening period to the 2-year period preceding the enforcement of screening in Israel (D to E vs. E to G, as performed in the Italian study), we would have concluded erroneously that screening saved lives of athletes in Israel. The study from Minnesota (19) (yellow graph) shows a low mortality rate in a population of athletes not undergoing systematic ECG screening.

stress testing and started at the end of 1997. There is marked variation in the sudden cardiac death rates that peaks at 8.4 per 100,000 person-years 2 years before the enforcement of screening (point D in Fig. 2). Note that if one compares the sudden death rates during the 2 years preceding the enforcement of screening with the mortality at the end of the study—as was done in the Italian study—one would conclude that our screening strategy is extremely effective for preventing sudden death among athletes because the sudden death rate decreased from 8.4 to 1.1 per 100,000 person-years ($p < 0.001$) (D to G in Fig. 2). It is only when one reviews the entire study period and compares the 12-year period before screening with the 12-year period after screening (from point C to G in Fig. 2) that it becomes obvious that this apparent mortality reduction is most likely related to a large year-to-year variation.

What is the evidence that mandatory pre-participation ECG screening of athletes prevents sudden death in athletes? The only evidence that a mandatory screening strategy that includes a resting ECG reduces the sudden cardiac death risk in athletes comes from Italy (4). This Italian study is the basis for current guidelines from the European Heart Society advocating mandatory ECG screening of athletes (2). It is important to note that the conclusions of the Italian study are based on the comparison of sudden death rates of athletes recorded during the 2 years preceding the enforcement of ECG screening with the mortality rates 2 decades later (point A to B vs. B to F in Fig. 2). Had we adopted a similar strategy, we would have reached similar conclusions simply because the sudden cardiac death rates during the 2-year period preceding the enforcement of screening in Israel were unusually high

(point D in Fig. 2). In reality, it is likely that this unusually high sudden-death rate observed among Israeli athletes in 1995 and 1996—and the public outcry that followed—led to the legislation mandating ECG screening of athletes in Israel in 1997. Only when one extends the comparison of sudden death rates to include the decade that preceded the enforcement of screening in Israel (and not only the last 2 years) with the decade that followed it does one realize that this mortality reduction is the result of a large variation in mortality rates over longer periods of observation. A similar phenomenon could have occurred in Italy. In other words, it is possible that high mortality rates in Italy in 1980 and 1981 led to the Italian legislation in 1982 and allowed for subsequent mortality reduction. Furthermore, immortal-time bias (20), a methodology flaw frequently encountered in observational studies (21), probably skewed the findings of the Italian study toward concluding that screening improves survival. Studies with time-dependent outcomes in which the test of interest (ECG screening, in this case) and the outcome analyzed (in this case, sudden death) occur during the same period are susceptible to time-dependent bias, also termed immortality bias. All the athletes who died suddenly during the prescreening period never made it to the first screening; consequently, the population of athletes who made it alive to the first screening already represented a selected lower-risk population—and their lower-risk characteristics contributed to the lower mortality rates in the post-screening period.

Study limitations. Data on the effects of ECG screening on mortality rates among athletes are observational and retrospective. This is true for our study and for the Italian and Minnesota studies (4,19). Because of the small

number of events, it is possible that the observed non-significant difference is the result of a beta-type error. Although the Israel Sport Law mandated ECG screening of competitive as well as noncompetitive athletes, we limited our analysis to competitive athletes because sudden death in the latter is a highly visible event reported in the lay press (the sole source of our study). Although unlikely, we cannot exclude the possibility that screening reduced the mortality rate of noncompetitive athletes. It is also possible that under-reporting of sudden deaths among competitive athletes in leading newspapers led to underestimation of the sudden death risk for athletes. However, there is no reason to believe that the degree of under-reporting varied significantly during the different years of the study period. Moreover, except for the peak observed in 1995 and 1996, the sudden death rates in Israel are within the range reported by others. In addition, the number of athletes was known for the end of the study period, but was estimated for the preceding years on the premise that the fraction of the population engaging in competitive sports remained constant. This assumption could have led to serious errors when estimating the population at risk. However, repeating our calculations after assuming that the fraction of inhabitants practicing sports actually doubled over the years led to similar results. Finally, because of possible inherent shortcomings of the screening process in Israel, our results cannot be extrapolated to other countries.

Conclusions

Prevention of sudden death among athletes is indisputably a desirable goal. However, mandatory ECG screening of athletes comes with a price. The Italian model of enforced ECG screening (4), now endorsed by the European Heart Association (2), quotes a cost of US \$40 per athlete. Accepting the mortality reduction of the Italian study at face value (i.e., ignoring its limitations mentioned above) implies that 33,000 athletes must be screened to save 1 life, at a cost of \$1,320,000 per life saved (17). That is before adding the price of advanced additional testing that will be required for the 5% to 16% of athletes with ECG abnormalities (22–24). Of note, sudden death among athletes is a very rare phenomenon (approximately 1:28,000 in Italy and 1:39,000 in Israel before screening). When the prevalence (or pretest probability) is so low, it is inevitable that many people with abnormal test results (abnormal ECG results) will represent false positive results (25). Of note, disqualification from participation in sports because of abnormal ECG results obtained during an obligatory (often unsolicited) screening has profound implications for the asymptomatic athlete. Therefore, before mandatory ECG screening is endorsed universally, it is reasonable to request additional proof that such a strategy actually saves lives.

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