The Clinical Significance of Ventricular Arrhythmias during an Exercise Test in Non-Competitive and Competitive Athletes

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ABSTRACT: **Background:** Sudden death in athletes can occur during sport activities and is presumably related to ventricular arrhythmias. There are no guidelines concerning athletes who develop ventricular arrhythmias during an exercise test. It is unclear whether they should be allowed to continue with their competitive activity or not.

Objectives: To investigate the long-term follow-up of athletes with ventricular arrhythmias during an exercise test.

Methods: From a database of 56,462 athletes we identified 192 athletes, less than 35 years old, who had ventricular arrhythmias during an exercise test. Ninety athletes had ≥ 3 ventricular premature beats (group A) and 102 athletes had ventricular couplets or non-sustained ventricular tachycardia during an exercise test (group B). A control group of 92 athletes without ventricular arrhythmias was randomly selected from the database (group C).

Results: All athletes, except one who died from a dilated cardiomyopathy, were alive during a follow-up period of 70 ± 25 months. An abnormal echocardiogram was obtained in seven athletes from group A (10%), four from group B (5%), and one from group C (3%) (not significant). An abnormal echocardiogram was more likely to be present in competitive athletes ($P = 0.001$) and in female athletes ($P = 0.01$).

Conclusions: Our results showed that ventricular arrhythmias during exercise are more commonly associated with cardiovascular abnormalities in young competitive athletes and in female athletes. When present, they necessitate a thorough investigation and follow-up.

IMAJ 2011; 13: 735–739

KEY WORDS: arrhythmias, exercise testing, echocardiography, competitive sports

Sudden death in young athletes has a major impact on the lay and medical communities. Identifying athletes at risk of sudden death remains a major challenge. Ventricular premature beats occur among athletes with the same frequency as in the general population but they usually disappear with exercise. In contrast, complex ventricular arrhythmias should prompt a search for underlying heart disease. In the majority of cases these arrhythmias are supposedly part of the "athlete's heart syndrome" and do not increase the risk of sudden death in athletes with an apparently normal heart [1-4]. The data available in the literature deal with ventricular arrhythmias assessed mainly by 24 hour ambulatory electrocardiograms [5,6].

To date, there are no guidelines concerning athletes who develop ventricular arrhythmias during an exercise test. The aim of this retrospective study was to look at the long-term follow-up of these athletes to determine whether the development of ventricular arrhythmias during an exercise test is an indicator for future cardiovascular events or cardiovascular abnormalities.

PATIENTS AND METHODS

PATIENT SELECTION

The athletes' records at the Wingate Institute of Sports for the period January 1995 to August 2007 were reviewed. Athletes were referred by different athletic organizations for preparticipation screening before engagement in sport activities. This was not part of a prospective organized national screening program for athletes.

According to the Israeli guidelines for sports medicine, all athletes should undergo physical examination before engaging in sports activities prior to each game season. Additionally, each athlete must undergo an exercise test at age 17, 23, 27, 32, 34 and yearly thereafter. Athletes with an abnormal physical examination, an abnormal electrocardiogram and/or an abnormal exercise test are referred for further workup as needed. All the records of clinical data on the athletes in our study were kept in a database maintained by the Wingate Institute. The exercise tests were retrospectively analyzed by an electrophysiologist for the purpose of this study. All VPB,

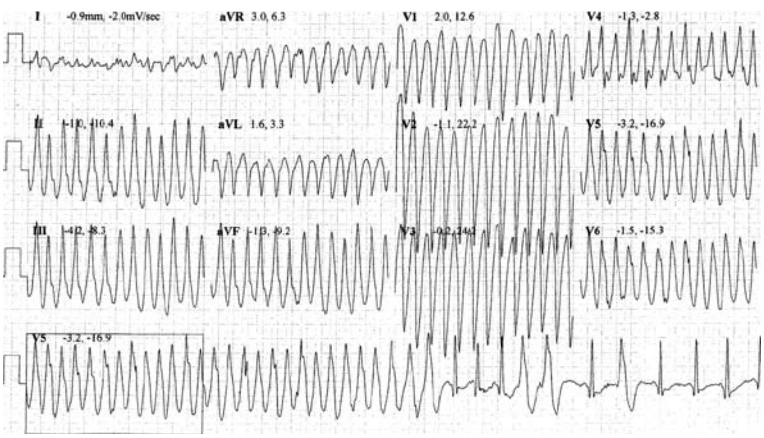
VPB = ventricular premature beats

Table 1. Classification of sports

	A: Low dynamic component	B: Moderate dynamic component	C: High dynamic component
High static component	Gymnastics, sailing, climbing, water skiing, weight lifting, windsurfing	Body building, wrestling	Boxing, canoeing, cycling, rowing, speed skating, triathlon
Moderate static component	Equestrian, motorcycling	Football, jumping, figure skating, rugby, running, surfing, swimming	Basketball, ice hockey, lacrosse, running (middle distance), swimming, handball
Low static component	Bowling, cricket, golf	Baseball, softball, fencing, table tennis, volleyball	Squash, running (long distance), soccer, tennis

Modified from the 36th Bethesda conference, task force 8 [8].

Figure 1. Ventricular arrhythmias during an exercise test in athletes. Twelve-lead ECG at peak exercise shows a very rapid ventricular tachycardia at 300 beats/min, which subsided immediately during recovery from exercise. The athlete was asymptomatic. He was a competitive weight lifter and was disqualified from competitive sports. He underwent a thorough workup that included an echocardiogram and an MRI; both were normal.



ventricular couplets and runs of non-sustained ventricular tachycardia were counted from the tracings obtained during the exercise test and during the recovery period. (NSVT was defined as three or more consecutive ventricular beats). The athletes' baseline ECG were analyzed according to the most recent recommendations for interpretation of 12-lead ECG in the athletes [7]. Athletes with ventricular premature beats only at rest before exercise were excluded from the study. Athletes older than 35 were also excluded from the study in order to decrease the likelihood of enrolling athletes with coronary artery disease.

Each of the athletes completed a detailed questionnaire and underwent a thorough physical examination by a sports physician. All athletes underwent an exercise test adhering to the Astrand protocol (maximal exercise test with change of speed and steepness of the treadmill every minute). At the time of the exercise test no athlete was taking a beta-blocker or an anti-arrhythmic drug. Athletes who developed ventricular arrythmia during the exercise tests underwent a more thorough cardiovascular workup that included a Holter monitor (n=37), echocardiogram (n=182), magnetic resonance imaging (n=3) and electrophysiologic study (n=4).

An abnormal echocardiogram was defined as follows: valve abnormalities at least moderate in severity, hypertrophy defined as > 13 mm, and dilated cardiomyopathy diagnosed based on a dilated left ventricular cavity of ≥ 60 mm in end-diastole and a left ventricular ejection fraction < 45%. Athletes who had significant arrhythmias during exercise or recovery were disqualified from competitive sports until completion of the medical workup. Fifteen athletes from Group A and 22 athletes from Group B were disqualified from sports participation because of ventricular arrythmia during exercise.

The athletes were engaged in different sport disciplines. The different sport activities were divided into three groups: low (class A), moderate (class B) and high (class C), according to the task force for the classification of sports [8]. This classification was used to simplify the data analysis [Table 1].

The study was supported in part by a grant from a medical equipment company. The sponsors had no involvement in the study design, data analysis, or manuscript preparation. The authors are responsible for the accuracy and completeness of the data and the analyses.

STUDY DESIGN

We conducted a matched case-control study that compared the long-term outcomes in athletes who had VPB, ventricular couplets and NSVT during an exercise test with the outcomes in a similar group of athletes who had no ventricular arrythmias during an exercise test [Figure 1]. The study design was approved by the institutional review boards of the Wingate Institute and the Assaf Harofeh Medical Center. Written informed consent was waived for the athletes whose records were reviewed.

STATISTICAL ANALYSISS

Statistical analysis was performed using SPSS version 13 software. Data are expressed as mean ± standard deviation. Differences between means were assessed by a paired Student's *t*-test or one-way ANOVA. Differences between proportions were assessed with the Pearson chi-square test, the Fisher exact test, McNemar test or Wilcoxon signed ranks test as appropriate. A two-tailed P value < 0.05 was considered to indicate statistical significance. Logistic-regression analysis was used to analyze the effect of several variables (age, gender, number of ventricular arrythmias, sports class, ECG abnormalities, competitiveness) on the occurrence of ECG abnormalities.

NSVT = non-sustained ventricular tachycardia

RESULTS

A total of 56,462 athletes underwent an exercise test for preparticipation screening at the Wingate Sports Institute between January 1995 and August 2007. From this database we identified 192 athletes who were under the age of 35 and had ventricular arrythmia during an exercise test. Ninety athletes had three or more VPB (group A) and 102 athletes had VPB and ventricular couplets or NSVT (range 3–30 consecutive beats) during an exercise test (group B) [Figure 1]. The control group comprised 92 athletes who were randomly selected from the group of athletes who had no ventricular arrythmias during their exercise test (group C).

DEMOGRAPHIC CHARACTERISTICS

Group A included 70 males (78%), Group B 83 males (81%) and Group C 77 males (84%). The mean age during their initial assessment was 25 ± 5 years for Group A (range 12–35, median 25), 25 ± 5 years for Group B (range 15–34, median 25) and 24 ± 5 years for Group C (range 14–35, median 24) [Table 2]. The athletes were engaged in different sport disciplines, most commonly running (98 athletes), followed by gymnastics (n=41), basketball (n=25), swimming (n=19), soccer (n=18), cycling (n=13), tennis (n=9), judo (n=7), horse riding (n=4), and miscellaneous disciplines (surfing, boxing, ice skating, water ball, netball, handball, volleyball, triathlon, fencing and weight lifting). The competitive athletes in this cohort took part in national or international Olympic events (Group A 27% competitive, Group B 19% competitive, Group C 21% competitive) (not significant). The remaining athletes were non-competitive.

ELECTROCARDIOGRAM

Eight athletes (9%) from Group A, 11 (11%) from Group B and 6 (6.5%) from Group C had an abnormal ECG (not significant). The ECG abnormalities included complete right bundle branch block (1 in group A, 2 in group B), negative T waves (3 in group A, 4 in group B, 3 in group C), right axis deviation (4 in group A, 3 in group B, 3 in group C), ST segment depression (1 in group B), q waves in the inferior leads (1 in group B). None were significant.

HOLTER MONITORING

Eight athletes from Group A had a Holter monitor, which showed VPB in three subjects and supraventricular arrhythmia in two subjects. Twenty athletes from Group B had a Holter monitor, showing VPB in 6 subjects and atrial premature beats in 2. Ten athletes from group C had a Holter monitor, showing VPB in 2 subjects and atrial premature beats in 2.

ECHOCARDIOGRAM

Echocardiogram was normal in 170 (93%) athletes and abnormal in 12 (7%). Sixty-eight athletes from Group A had an echocardiogram, which was abnormal in 7 (10%) [Table 2]. In Group B 79 athletes had an echocardiogram and in 4 of them it was abnormal (5%). Thirty-five athletes from Group C had an echocardiogram and in 1 of them it was abnormal (3%) (P = 0.27).

There was no significant difference in age, sports class, hours of training, peak heart rate during exercise, arrhythmia morphology, and ECG abnormalities between the group of athletes with a normal echocardiogram and the group with an abnormal echocardiogram. There was no statistically significant difference in the amount of ventricular arrhythmia during exercise in the athletes with an abnormal echocardiogram compared to those with a normal echocardiogram (P = 0.27).

Logistic-regression analysis was used to analyze the effect of several variables (age, gender, amount of ventricular arrythmia, sports class, ECG abnormalities and competitiveness) on the occurrence of echocardiographic abnormalities. According to our data, athletes who were competitive were six times more likely to have an abnormal echocardiographic finding than those who were not non-competitive (P = 0.001) and female athletes were four times more likely than male athletes to have an abnormal echocardiographic finding (P = 0.019).

Table 2. Baseline characteristics of the 284 athletes

	Group A (N=90)	Group B (N=102)	Group C (N=92)	*P* value
Mean age (yrs, mean ± SD)	25 ± 6	25 ± 5	24 ± 5	0.19
Male gender	78% (70)	81% (83)	84% (77)	0.59
Sports class				
A	6% (5)	7% (7)	3% (3)	
B	45% (38)	36% (35)	28% (25)	
C	49% (41)	57% (55)	69% (61)	0.10
Competitive	27% (24)	19% (19)	21% (18)	0.39
Hours of training per week	7.3 ± 5.4	7.8 ± 9.1	7.1 ± 4.4	0.80
VA ex+recovery*				
No arrythmias	0	0	100% (92)	
› 3 VPB	53% (58)	46% (47)	0	
› 20 VPB	47% (42)	16% (16)	0	
Couplets	0	75% (76)	0	
NSVT	0	26% (26)	0	0.001
Arrhythmia morphology				
None	0	0	100% (92)	
RBBB	46% (41)	57% (56)	0	
LBBB	54% (49)	43% (42)	0	0.14
Arrhythmia axis				
None	0	0	100% (92)	
Right	56% (49)	43% (40)	0	
Left	44% (38)	57% (53)	0	0.10
Peak heart rate (bpm)	190 ± 10	190 ± 8	192 ± 8	0.13
VT-CL (msec)	0	287 ± 72	0	
Coupling interval (msec)	335 ± 77	319 ± 67	0	0.13
Abnormal ECG	9% (8)	11% (11)	6.5% (6)	0.57
Abnormal echocardiogram	10% (7)	5% (4)	3% (1)	0.27

Values are given as percentages, with number in parentheses

Sports class A,B,C according to the Bethesda classification of sports

* Ventricular arrythmia during exercise and or recovery.

VT-CL = ventricular tachycardia cycle length, VPB = ventricular premature beat, NSVT = non-sustained ventricular tachycardia, RBBB = right bundle branch block, LBBB = left bundle branch block

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The structural cardiovascular abnormalities in the 284 athletes included mitral valve prolapse (4 in group A, 2 in group B, 1 in group C), myxoma (1 in group A), dilated aorta (1 in group A and 1 in group B), atrial septal defect (1 in group B), dilated cardiomyopathy (1 in group B), a small aneurysm in the right ventricular outflow tract (1 in group B), low right ventricular ejection fraction (1 in group A), and an enlarged left ventricle (1 in group A). Two athletes from group A underwent surgery (one for coarctation of the aorta and one for an atrial septal defect).

ELECTROPHYSIOLOGIC STUDIES

Four athletes from Group B underwent an electrophysiologic study in different local hospitals. The information on the protocol used is not available. Two athletes had a normal study, one athlete was inducible to atrial fibrillation, and one athlete was inducible to polymorphic ventricular tachycardia.

MAGNETIC RESONANCE IMAGING

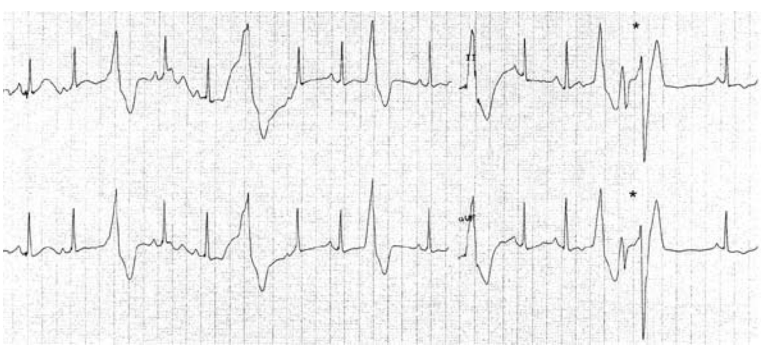
Three athletes from Group B had a cardiac MRI. The findings were normal in two athletes and one athlete had a small aneurysm in the right ventricular outflow tract.

FOLLOW-UP

The athletes were contacted by phone after a mean follow-up period of 70 ± 25 months. According to the Ministry of Interior database, the athletes who were lost to follow-up were alive in June 2009 except for one athlete from Group A, one athlete from Group B and 5 athletes from Group C about whom we could not obtain information.

One athlete from group B died during the follow-up period. He was 24 years old at his initial exercise test. This athlete played tennis and trained for about 7 hours weekly as a tennis coach and was not engaged in competitive sports. His exercise test showed frequent VPBs and ventricular couplets. The VPBs had a left bundle branch block and right axis morphology. The coupling interval was 300 msec and the cycle length of the ventricular couplets was 220 msec [Figure 2]. The VPB had a bizarre shape and were wide (QRS width 140–400 msec). His ECG showed deep negative T waves. The initial echocardiogram was normal and he was authorized to continue playing tennis. After 3 years he was diagnosed with a dilated cardiomyopathy and had an implantable defibrillator inserted. He subsequently underwent a left ventricular assist device implantation. He died one year after the diagnosis of dilated cardiomyopathy (3 years after the initial exercise test).

Figure 2. Rhythm strip of leads II, aVF, V5 during the initial exercise test. Note the wide and bizarre ventricular premature beats and the polymorphic non-sustained ventricular tachycardia of three consecutive beats as indicated by the asterisk.



DISCUSSION

Sudden death in young and healthy-appearing athletes is a rare event but its occurrence creates an immense impact on the lay and medical communities [9-13]. According to a study by Corrado et al. [14], sports activity in adolescents and young adults is associated with an approximately three times greater risk of sudden cardiovascular death. The same investigators showed that there was a decline in sudden cardiovascular death in young competitive athletes after the implementation of preparticipation cardiovascular screening in Italy [15].

The mechanism of ventricular arrythmia in athletes is unclear [16-18]. Some arrhythmias may be secondary to the high sympathetic tone during exercise and others may be secondary to structural heart disease. Heidbuchel and coauthors [19] studied the role of an electrophysiologic study for risk stratification in athletes with ventricular arrythmia, with induction of sustained ventricular tachycardia or ventricular fibrillation and a re-entry mechanism implicating a worse prognosis [19].

Since sudden death occurs in most cases during sports activities, what is the significance of ventricular arrythmia during a preparticipation screening exercise test in an athlete? Clinicians are faced with the dilemma of either considering these arrhythmias as a benign finding that is part of the 'athlete's heart' or considering them as potentially life threatening. A similar dilemma arises when faced with an abnormal ECG in an athlete. Some of these ECG changes may be part of the 'athlete's heart' and some may represent the initial expression of a cardiovascular disease [20].

In the present study, ventricular arrythmia during an exercise test occurred in 11% of the athletes (192/1712) who were less than 35 years old. Our data are similar to the findings of Biffi et al. [5,6] who studied the long-term significance of ventricular arrythmia in 24 hour Holter monitoring in trained athletes. According to their study, ventricular arrythmias are common in trained athletes and are usually not associated with underlying cardiovascular abnormalities. When ventricular arrythmias are associated with cardiovascular abnormalities, disqualification from competitive sports is recommended.

Another interesting finding in our study was the higher likelihood of an abnormal echocardiogram in female athletes and in competitive athletes with ventricular arrhythmias during exercise. The high incidence in female athletes is probably related to the higher occurrence of mitral valve prolapse in women, whereas it can be speculated that the higher incidence of echocardiographic abnormalities in competitive athletes may be secondary to cardiac anatomical changes as a result of very strenuous physical activity.

The athletes with the more severe forms of ventricular arrythmia were automatically disqualified from competitive athletic activities and therefore we do not know if disqualification reduced the incidence of cardiovascular events in these athletes. Except for one athlete who died from a dilated cardiomyopathy, all athletes were alive and were doing well during the follow-up period. On the basis of our data it seems reasonable that in the setting of a large-scale preparticipation screening program, the occurrence of ventricular arrythmia during an exercise test may be useful in identifying athletes with structural heart disease or athletes at risk for the development of heart disease.

In a recent publication Sofi and collaborators [21] studied 30,065 athletes who underwent an exercise test before participation in competitive sports. They found that age > 30 years was significantly associated with an increased risk of being disqualified for cardiac findings during exercise testing. They also found that exercise testing can show pathological findings in athletes with innocent findings at physical examination and resting ECG [21]. A discussion on the cost-effectiveness of such an approach and its application worldwide is beyond the scope of this article [22]. Nevertheless, the findings of the present study provide useful information for the cardiology consultant faced with the challenging management of an athlete with ventricular arrythmia in countries that mandate exercise testing before engaging in competitive sports.

Our study has several limitations due to the fact that a small percentage of athletes were engaged in competitive sports. Additionally, not all athletes had an echocardiogram and athletes with ventricular arrythmia were more likely to undergo a workup. It is possible that disqualification from intensive training and competition could have favorably influenced the outcome and prevented cardiac events in athletes with severe forms of ventricular arrythmia. Therefore, the risk of engaging in competitive sports with such arrhythmias cannot be assessed from our data.

In conclusion, we investigated the clinical significance of ventricular arrythmia occurring during an exercise test in non-competitive athletes and competitive athletes. Ventricular arrythmia during exercise is more commonly associated with cardiovascular abnormalities in young competitive athletes and in female athletes. When present, they necessitate a thorough investigation and follow-up.

Acknowledgments

The study was supported in part by a grant from Gamida Mediquip Inc. Israel.

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