Comparison of Frequency of Significant Electrocardiographic Abnormalities in Endurance Versus Nonendurance Athletes

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Most data assessing the accuracy of electrocardiographic (ECG) screening in identifying cardiac pathology in athletes are derived from relatively unselected cohorts of subjects involved in competitive sports. We hypothesized that the prevalence of ECG abnormalities may be greater in athletes performing the greatest combination of exercise intensity and duration, namely professional endurance athletes. A total of 1,007 male and 254 female elite adult athletes underwent cardiovascular screening inclusive of an electrocardiogram, interpreted using the 2010 European Society of Cardiology guidelines. Training-related ECG changes (group 1) were more common in endurance athletes (EAs) than non-endurance athletes (NEAs; 90.8% vs 86.0%, p = 0.04), as were multiple (≥2) training-related changes (78.9% vs 53.5%, p <0.0001). Group 2 ECG changes (previously considered uncommon and training unrelated) were seen in 18.1% of subjects and were twice as prevalent in EAs compared with NEAs (29.9% vs 15.1%, p <0.0001). Right ventricular hypertrophy (4.4% EAs vs 1.5% NEAs, p <0.005) and deep right precordial T-wave inversion (14.3% EAs vs 4.7% NEAs, p <0.0001) were 3 times as common in EAs. Both group 1 and group 2 changes were similarly prevalent among elite male and female athletes and were more common in EAs regardless of gender. In conclusion, ECG abnormalities are very common in elite athletes and are more common in EAs than NEAs. Right ventricular hypertrophy and deep right precordial T-wave inversion are particularly common in EAs, possibly because of increased structural and/or electrical right ventricular remodeling in this subgroup. The predictive value of ECG screening and criteria for abnormal findings in elite EAs requires specific appraisal. **(Am J Cardiol 2014;113:1567−1573)**

Current European Society of Cardiology (ESC) athlete electrocardiographic (ECG) interpretation guidelines classify ECG changes as either those which are common in athletes and thought to be training related (group 1) or those thought to be uncommon, training unrelated, and which warrant further investigation to exclude cardiac pathology (group 2).[1] These guidelines are derived from studies of unselected cohorts of young subjects involved in competitive sports without a defined threshold for the quantity or quality of athletic conditioning. In fact, most studies assessing the prevalence of abnormal ECG patterns have predominantly comprised male subelite nonendurance athletes (NEAs).[2−5] Thus, all "athletes" are considered equal in regard to ECG criteria, although there are abundant data demonstrating that cardiac remodeling ("athlete's heart") is determined by the volume and intensity of exercise exposure, with pure endurance−trained athletes demonstrating larger cardiac dimensions than NEAs, and those competing at the highest level showing the most marked adaptations.[6−8] Therefore, we hypothesized that ECG changes, especially group 2 changes, would be more common in those performing the greatest combination of exercise intensity and duration, namely professional endurance athletes (EAs). Furthermore, we sought to test whether this hypothesis also applied to elite female athletes given that experience is even more limited for this group.

Methods

In 2011, the investigators contacted a variety of Australian sporting organizations currently undertaking, or wishing to undertake, ECG screening and invited athletes to participate in this study. From June 2011 to June 2013, a total of 1,381 elite athletes underwent cardiovascular screening inclusive of a 12-lead electrocardiography at rest, clinical history and examination, and collection of morphometric and demographic data. Athletes aged from 16 to 35 years were included. In 23 athletes who underwent repeated screening during this period, only data from the first collection were considered, and 1 athlete with a known history of cardiac disease was excluded.

A total of 228 athletes demonstrating group 2 ECG changes underwent a thorough repeat history analysis and examination and were referred for follow-up investigations as appropriate, most commonly transthoracic echocardiography.

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See page 1572 for disclosure information.

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Elite athletes were defined as professional athletes whose main source of income was derived from their sport, athletes competing at an international level, for example, Olympic Games and world championships, and/or nationally competitive athletes. Endurance sports were defined as those events requiring sustained efforts at >70% VO_2 max (e.g., cycling, swimming, and rowing), in which a large volume of endurance exercise forms the basis of training, as opposed to nonendurance sports where intermittent bursts of effort are required and training is a mix of skill-based and aerobic and/or anaerobic exercise (e.g., football, basketball, and alpine skiing).

Ethical approval was obtained from the Human Research Ethics Committee at both St Vincent's Hospital, Melbourne, Australia and The Australian Institute of Sport, Canberra, Australia. Written, informed consent was obtained from all athletes, outlining the fact that if an abnormality was identified on initial testing (history, examination, or electrocardiography), further investigation would be suggested, and that ultimately this could result in a recommendation of athletic restriction.

A standard 12-lead electrocardiogram was recorded at 25 mm/s and 10 mm/mV in all subjects. All electrocardiograms were interpreted by 2 experienced cardiologists, using the 2010 ESC recommendations,[1] and classified as having group 1 or group 2 changes, in which case further investigation was recommended.

Group 1 ECG changes as outlined by the 2010 ESC criteria were defined as follows. Sinus bradycardia was defined as a heart rate at rest of <60 beats/min; first-degree atrioventricular (AV) block as a PR interval of >200 ms; left ventricular (LV) hypertrophy on voltage criteria as the sum of the S wave in V_1 and the R wave in V_5 or V_6 >35 mm; and incomplete right bundle branch block (RBBB) as an rsR' pattern in V_1 with QRS duration <120 ms, including those with a QRS duration of >100 ms but <120 ms, which was also separately defined as partial RBBB. Early repolarization was defined as elevation of the J point (offset of QRS complex) or J wave of at least 0.1 mV in ≥2 leads in any territory, including anterior leads V_1 to V_3. Rohmilt-Estes score for LV hypertrophy was also calculated.

Group 2 ECG changes as per 2010 ESC criteria were defined and calculated as follows. Long QTc, QTc >440 ms for men or >460 ms for women, and short QTc <360 ms. QTc was calculated by hand, using the "teach-the-tangent" method.[9] The QT interval was measured in lead II or V_5 (whichever provided best delineation of the T wave), the preceding RR interval was measured, and Bazett's formula was used to calculate QTc. In cases of significant sinus arrhythmia, the averages of 3 QT and RR intervals were calculated. A PR interval of <120 ms with or without evidence of preexcitation was defined as abnormal. Left and right axis deviations (RADs) were defined as a QRS axis more negative than −30° or more positive than +110°, respectively; left atrial abnormality as a negative P wave in V_1 or V_2 ≥1 mm deep and wide and/or total P duration in lead II >120 ms; right atrial abnormality as a P wave >2.5 mm tall in II, III, or aVF; nonspecific intraventricular conduction delay as any QRS of >120 ms; right ventricular hypertrophy (RVH) as the sum of RV_1 + SV_5 or V_6 >10.5 mm; ST-segment depression was considered significant if ≥0.5 mm deep in ≥2 leads and Q waves significant if ≥4 mm deep in any lead except III or aVR. A Brugada type 1 ECG pattern was defined as high takeoff and downsloping ST-segment elevation followed by a negative T wave in ≥2 leads in V_1 to V_3. Deep T-wave inversion was defined as a negative T wave of ≥−2 mm in ≥2 leads in the same territory (right precordial [V_1 to V_3], lateral [V_4 to V_6, I, aVL], or inferior [II, III, aVF]). Biphasic or bifid T waves were considered significant if the negative component was ≥−2 mm in depth in ≥2 leads. ECG changes not classified in the ESC recommendations were documented as indeterminate findings, with further investigation undertaken as believed clinically appropriate.

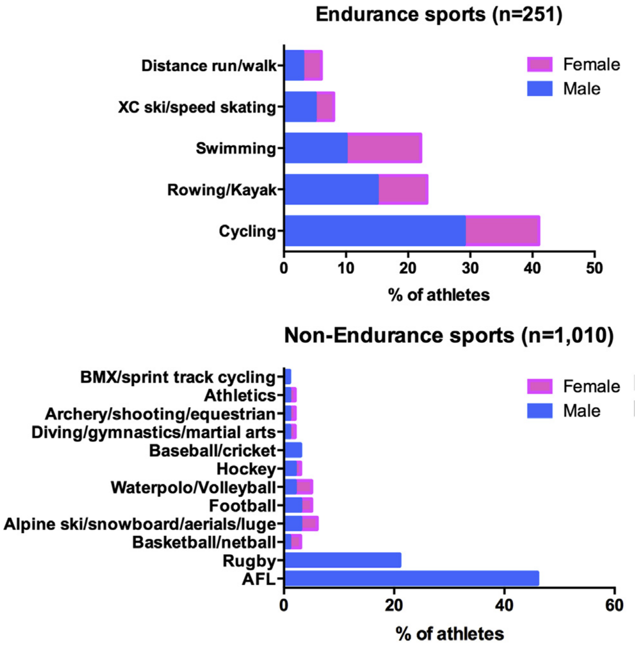

Figure 1. Sporting disciplines classified as endurance and nonendurance. *Bars* represent the percentage of athletes from each group (EA or NEA) participating in each discipline. Male athletes are represented in *blue* and female athletes in *pink*. AFL = Australian Rules Football; BMX = bicycle motocross; XC = cross country.

Table 1
Demographics of endurance and nonendurance athletes

Variable	Athletes		p Value
	Endurance (n = 251)	Nonendurance (n = 1,010)	
Age (yrs)	22.4 ± 4.8	20.1 ± 3.9	<0.0001
Male sex	156 (62)	851 (84)	<0.0001
Caucasian	243 (97)	834 (83)	<0.0001
Hours training/week	25.3 ± 5	13.3 ± 5.6	<0.0001
Height (cm)	179.1 ± 8.9	182.6 ± 8.9	<0.0001
Weight (kg)	71.5 ± 10.9	82 ± 13.6	<0.0001
Body surface area (m^2)	1.88 ± 0.2	2.04 ± 0.2	<0.0001
Heart rate (beats/min)	56 ± 10.8	60.3 ± 10.5	<0.0001

Data are presented as mean ± SD or n (%).