

# Is There Evidence for Mandating Electrocardiogram as Part of the Pre-Participation Examination?

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**Abstract:** The risk of sudden cardiac death may be increased up to 2.8 times in competitive athletes compared with nonathletes. The majority of sudden cardiac death cases are caused by an underlying abnormality that potentially may be identified on cardiovascular screening, depending on the specific abnormality and the content of the cardiovascular screening applied. Indeed, today, cardiac screening is universally recommended by the cardiac societies [European Society of Cardiology (ESC) and American Heart Association (AHA)] and required by the sporting bodies [Fédération Internationale de Football Association (FIFA) and Union of European Football Associations (UEFA)]. Pre-participation examination is by consensus understood to include personal history and physical examination; controversy exists regarding the usefulness and appropriateness of screening using resting 12-lead electrocardiogram (ECG), with an apparent transatlantic difference. The ESC recommends screening consisting of personal history, physical examination, and 12-lead resting ECG, whereas recommendations from the AHA includes only personal history and physical examination. There is firm scientific ground to state that the sensitivity of screening with ECG is vastly superior to, and the cost-effectiveness significantly better than, screening without ECG. Cardiac screening of elite athletes with personal history, physical examination, and ECG is cost-effective also in comparison with other well-accepted procedures of modern health care, such as dialysis and implantable cardiac defibrillators. Newly published recommendations for the interpretation of the ECG in athletes (ESC) and future studies on ECGs in athletes of different ethnicity, gender, and age may further increase the specificity of ECG in cardiac screening, refining the screening procedure and lowering the costs for additional follow-up testing. Cardiac screening without ECG is not cost-effective and may be only marginally better than no screening at all and at a considerable higher cost. The difficulties in feasibility and liability issues for recommending ECGs in some countries need to be acknowledged but must be dealt with within those countries/systems. On ethical grounds, the reasons (logistical, legal, economic) for *not* screening individual athletes should be clearly stated. Alas, the current evidence, as presented here, suggests that the ECG should be mandatory in pre-participation screening of athletes.

**Key Words:** ECG screening, cardiac screening, pre-participation examination, sudden cardiac death

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## BACKGROUND

Regular physical activity (PA) is important for primary and secondary prevention of cardiovascular disease.<sup>1,2</sup> Sports activities may have specific effects, as more intensive PA has added value, and physical fitness is a predictor of mortality.<sup>3</sup> However, the risk to benefit ratio of very intensive PA may even be negative in the case of an underlying cardiovascular abnormality.<sup>4</sup>

Sudden cardiac death (SCD) increases transiently with the intensity of PA,<sup>4</sup> most often caused by coronary artery disease in individuals older than 35 years. In younger athletes, underlying cardiac abnormalities, such as hypertrophic cardiomyopathy (HCM), coronary artery anomaly, arrhythmogenic right ventricular cardiomyopathy, different ion channelopathies (long QT-syndrome and Brugada syndrome), congenital valve disease, and complications related to Marfan syndrome, remain the leading causes of death.<sup>5</sup>

The incidence of SCD is low in this population, and a recent review estimated it to be around 1 to 3 in 100 000 per year<sup>6</sup>; but the risk for SCD may be significantly increased in competitive athletes compared with nonathletes.<sup>7</sup> The noted 2.8 greater incidence was only apparent in athletes with underlying cardiovascular disease,<sup>7</sup> forming a rationale for regular cardiac screening of competitive athletes, to try to identify individuals with such an underlying predisposition for SCD.

The majority of SCD cases are indeed caused by an underlying abnormality that potentially could have been identified on cardiovascular screening, depending on the specific abnormality and the content of the cardiovascular screening applied. As a consequence, cardiac screening is universally recommended by the cardiac societies [European Society of Cardiology (ESC) and American Heart Association (AHA)]<sup>8,9</sup> and required by the major sporting bodies [Fédération Internationale de Football Association (FIFA) and Union of European Football Associations (UEFA)] today. Pre-participation examination is by consensus understood to include personal history and physical examination; controversy exists regarding the usefulness and appropriateness of screening using resting 12-lead electrocardiogram (ECG), also with an apparent transatlantic difference. The ESC recommends screening consisting of personal history, physical

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examination and 12-lead resting ECG,<sup>8</sup> whereas the US recommendations from the AHA includes only personal history and physical examination.<sup>9</sup>

Screening to identify individuals with increased risk for sudden death in relation to PA has many implications for society, for the individual, and for professional bodies and individual clubs. A potentially preventable case of sudden death in a young professional athlete may have tremendous impact on personal, professional, economic, and legal levels. Barring a high-risk professional athlete from personal and economic success, whose risk nevertheless is less than, say, smoking 20 cigarettes per day or riding a motorcycle without a helmet, also has obvious profound implications for that individual and for his family, club, and society. Any screening must, in addition to fulfilling the World Health Organization's classic screening criteria,<sup>10</sup> also yield a reasonable balance between sensitivity and specificity because this will ultimately determine the utility of the screening.

The aim of this article is to discuss the existing evidence for mandating resting ECG as a part of the recommended cardiac screening of athletes. Most of the ECG changes seen in athletes will be due to the cardiac physical adaptation to training (ie, athlete's heart), but abnormalities on the ECG may also be an expression of an underlying cardiovascular disease, with an increased risk for SCD during sports. We will discuss the sensitivity, specificity, cost-effectiveness, and feasibility of the 12-lead ECG as a part of the pre-participation examination of athletes.

### **SENSITIVITY OF SCREENING WITHOUT ELECTROCARDIOGRAM**

For any screening to be meaningful, the chosen method of screening must be able to detect what we want to find.<sup>10</sup> Thus, cardiac screening should be able to identify relevant underlying cardiovascular abnormalities, that is, having a high sensitivity.

The current US screening recommendations include personal history and physical examination only (see AHA). The limited data available indicate that the sensitivity of personal history and physical examination without an ECG for identification of cases of SCD is very low. In a study of 115 cases of SCD by Maron et al,<sup>11</sup> only 1 case was identified using the US screening method without mandatory ECG. Similar low figures for sensitivity of screening without the ECG has been found in Italian studies<sup>12</sup> and in a recent British study.<sup>13</sup>

Recently, the study by Baggish et al<sup>14</sup> of 510 collegiate athletes showed that a screening strategy including personal history and physical examination would identify 5 of 11 individuals with underlying cardiovascular abnormality, as determined by echocardiography, yielding a sensitivity of 46%.<sup>14</sup> However, it should be kept in mind that echocardiography will not identify all possible causes of SCD in athletes, such as nonstructural diseases like arrhythmias.

The sensitivity of cardiac screening with personal history and physical examination but without the ECG is low or very low, and the lack of sensitivity remains a major concern for recommending a screening strategy without including the ECG.

### **SENSITIVITY OF SCREENING WITH ELECTROCARDIOGRAM**

Several studies have looked at the sensitivity of a resting ECG to identify the most common cause of SCD (HCM).<sup>15</sup> In 1 study, more than 95% of cases of SCD caused by HCM, where previous ECGs were available, showed abnormal resting ECGs.<sup>16</sup> In other studies, 70% to 80% of SCD caused by arrhythmogenic right ventricular cardiomyopathy, where resting ECGs were available, showed abnormal findings.<sup>17,18</sup>

In fact, the ECG may be almost as good as, or equal to, echocardiography regarding sensitivity for detecting underlying HCM, as shown by comparing the Italian data, using the ECG,<sup>19</sup> with similar figures of discovery in the United States, using echocardiography.<sup>20</sup> Furthermore, Pelliccia et al<sup>21</sup> showed that a normal ECG has a very high negative predictive value (99.98%) for excluding HCM, in an 8-year follow-up.

In addition, resting ECG will identify the majority of cases with pre-excitation, long/short QT-interval, and Brugada syndrome, if certainly not all.<sup>22</sup> A large variety of arrhythmias could also be identified, possibly as a marker of an underlying structural disease.

A Swedish study by Wisten et al<sup>23</sup> indicated that of 66 cases of SCD in young individuals (<35 years, athletes or nonathletes), 18% had a positive family history, 76% had previous symptoms, and 82% showed earlier ECG abnormalities. In the study of Baggish et al,<sup>14</sup> >500 collegiate athletes underwent pre-participation screening with personal history and physical examination, identifying 5 of 11 cases of structural disease. The addition of an ECG made it possible to identify an additional 5 cases for a total of 10 of the overall total of 11 (sensitivity 91%).

All in all, adding the 12-lead resting ECG to the personal history and physical examination will substantially increase the sensitivity for detecting the underlying cardiac abnormalities, with a very high negative predictive value.

### **SPECIFICITY OF SCREENING WITH ELECTROCARDIOGRAM**

The physiologic adaptation to regular intensive PA includes structural and electrical remodeling, also resulting in electrocardiographic changes, which is all a part of the "athlete's heart." Most ECG abnormalities found in athletes will therefore not be due to an underlying cardiac abnormality. The presence of undefined ECG abnormalities may have a low specificity for cardiac disease in the athletic population. For example, coronary artery disease and coronary artery anomaly may be difficult to identify by ECG alone, although they may well be suspected by the combination of symptoms and family history.

Up to 40% of athletes, depending on type of sport, duration of regular activity, ethnicity, age, and gender, may show some kind of abnormalities on standard 12-lead ECG.<sup>24</sup> Clearly, the cutoff values chosen to define abnormalities on the athlete ECG will greatly influence the specificity achieved. Previously given cutoff values for ECG interpretation<sup>25</sup> yielded a high number of "false-positives" in cardiac screening. Larger studies examining different athletes of

different age and gender and in a variety of sports showed that 60% of the ECGs defined as abnormal were in fact showing isolated QRS amplitude signs of left ventricular hypertrophy and/or repolarization abnormalities only.<sup>24,26</sup>

Newer studies have shown that some ECG changes seen in athletes, such as repolarization changes, are not associated with an increased risk in the long term but instead may be the expression of autonomic adaptations secondary to long-term training.<sup>26,27</sup>

Electrocardiographic changes are dependent also on ethnicity.<sup>28,29</sup> For example, echocardiographic studies showed that 20% of black athletes compared with 4% of white athletes will have an increased left ventricular wall thickness >12 mm, which is also associated with a higher degree of ECG changes.<sup>28</sup>

The ESC section of Sports Cardiology recently proposed<sup>26</sup> to classify ECG changes in athletes into 2 groups:

1. Common and training-related ECG changes, such as sinus bradycardia, first-degree atrioventricular block, incomplete right bundle branch block (RBBB), early repolarization, and isolated QRS voltage criteria for left ventricular hypertrophy.
2. Uncommon and training-unrelated ECG changes, such as widespread T-wave inversion, complete RBBB/left bundle branch block, and Brugada-like early repolarization.<sup>26</sup>

Indeed, the common and training-related ECG changes are much more common, constituting more than 80% of ECG changes found in athletes. The training-unrelated ECG changes typically constitute only 5% to 10% of ECG changes seen in athletes.<sup>26,27</sup> However, this figure can be expected to vary in respect of ethnicity and gender, and more studies are therefore needed in different ethnic groups and genders.

When Corrado et al<sup>26</sup> applied this new classification to the previously reported data from Pelliccia et al<sup>24</sup> on 1005 highly trained athletes without structural or other heart disease, 292 of the 402 athletes previously described as having ECG abnormalities showed either an isolated increase of QRS voltage ( $n = 233$ ) or early repolarization patterns ( $n = 59$ ). Only 11% ( $n = 110$ ) were classified as “uncommon and training-unrelated” according to the new criteria,<sup>26</sup> thus showing the potential efficacy of the new classification to increase the specificity of the ECG as a part of cardiac screening.

In summary, although the specificity of any abnormal ECG is limited, new criteria suggest that, if appropriate consideration is given to gender, level of training, and ethnicity, the specificity of screening with the ECG are greatly improved.

## COST-EFFECTIVENESS

Up to now, one of the most common reasons for not advocating ECG as part of the routine pre-participation cardiac screening of athletes has been the purportedly high cost of follow-up examinations due to the low specificity of the ECG in screening. The actual cost of the ECG itself has not been considered to be the main problem,<sup>9</sup> nor the cost of physical examination and personal history taking by a physician, because this has been advocated by the AHA/American College of Sports Medicine for competitive athletes.<sup>9</sup>

Several cost-effect analyses of screening with ECG have been performed; in Japan,<sup>30</sup> in Italy (unpublished data), and in the United States.<sup>31,32</sup> The Fuller<sup>32</sup> study estimated that adding the ECG to personal history and physical examination was more cost-effective (USD 44 000 per life-year saved as compared with USD 84 000 per life-year saved without the ECG screening). The Japanese study by Tanaka et al<sup>30</sup> concluded that ECG screening was cost-effective. Still, a more strict and formal cost-effect analysis fully accounting for costs and benefits of screening has been needed.<sup>33</sup> Recently, such an analysis was published from Stanford University.<sup>34</sup> The authors used a decision model to project the costs and survival rates for 14-year-old to 22-year-old US athletes undergoing a cardiac screening session, either by personal history and physical examination alone or with an added 12-lead resting ECG. The data were compared with no screening at all, using Italian data of survival and adjusting the figures to US standards. The analysis estimated that adding the ECG to history and physical examination saves 2.06 life-years per 1000 athletes screened, costing USD 42 000 per life-year saved, compared with screening without ECG.<sup>34</sup> The addition of the ECG was considered cost-effective. In fact, screening with added ECG is cost-effective also compared with other well-known and widely accepted procedures in health care, such as giving dialysis to patients with chronic kidney disease (USD 20-80 000 per quality-adjusted life-year saved) or application of an implanted cardioverter defibrillator for the prevention of sudden death (USD 34-70 000 per quality-adjusted life-year saved). In a final comment, the authors concluded that cardiovascular screening with history and physical examination without the ECG was substantially more costly and marginally more effective than no screening at all.<sup>34</sup>

The continuous development of new even stricter ECG criteria for abnormality has the potential to further decrease the number of athletes falsely classified as abnormal, potentially improving the cost-effectiveness even more.

## FEASIBILITY AND LIABILITY

What is the rationale for leaving out the ECG? Given the superior sensitivity of cardiac screening with ECG, the limited but steadily improving specificity, and that the cost-effectiveness of including the ECG also seems superior to screening without ECG, why is the ECG not universally recommended to be a part of the regular pre-participation screening of athletes?

As the scientific reasons for including the ECG in pre-participation screening look clear and undisputable, we probably have to look elsewhere for the reasons for excluding the ECG.<sup>9</sup> Different health care systems in general and different legal systems regarding liability in particular may play a major role in the different approaches of different countries. In Italy, cardiac screening including ECG has been mandated by law since 1971,<sup>35</sup> and it has also been mandatory in other countries, such as Hungary. In the United States, however, the complex legal system with high liability charges against a physician allegedly missing a diagnosis (eg, in the case of SCD in an athlete) could be disastrous for the individual physician. The presence of any kind of pathology on the pre-participation ECGs will have tremendous impact

in any liability case. In Europe, such liability is rarely an important issue in relation to cardiovascular screening.

The opposite angle is perhaps equally important: the consequences for the athlete's career if a benign ECG abnormality is wrongly interpreted as indicating a serious underlying disease may also be vast. To the club and its members, or owners, the disqualification of a highly competent, and very costly(!), athlete may have profound economic impact in a judicial system focused on liability.

However, from a societal perspective, it is important to adequately identify individuals at increased risk for sudden death, not only to prevent unnecessary deaths in young individuals but also to prevent the public impression that PA is dangerous and should best be avoided. This being said, an intensive and vigorous screening procedure with a large number of false-positive cases may also confer the notion that PA is, in general, dangerous. The impact on public health of decreased PA among the population is difficult to calculate but potentially highly negative and very costly.

These differences in health care/legal systems have to be acknowledged and respected. They may also partly explain the somewhat differing approaches to screening in different countries and by different sporting bodies (FIFA and UEFA mandate cardiac screening by ECG, whereas the International Olympic Committee is somewhat more cautious in their latest recommendations<sup>36</sup>).

## SUMMARY

Cardiac pre-participation screening of elite athletes is universally recommended for several reasons, including ethical (AHA/American College of Sports Medicine) and employer/employee relations, ultimately to prevent SCD during sports.

The sensitivity of screening with ECG, in addition to personal history and physical examination, is superior, and the cost-effectiveness is clearly better than screening without ECG.<sup>34</sup> Screening including the ECG is cost-effective also in comparison with other well-accepted procedures of modern health care.

Thus, cardiac pre-participation screening without ECG cannot be recommended given our current knowledge. The difficulties in feasibility and liability issues for recommending ECGs in some countries need to be acknowledged but must be dealt with within those countries/systems. On ethical grounds, the reasons (logistical, legal, economic) for *not* screening individual athletes should be clearly stated.

Alas, the current evidence, as presented here, suggests that the ECG should be mandatory in pre-participation screening of athletes.

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