Accuracy of the ECG for differential diagnosis between hypertrophic cardiomyopathy and athlete’s heart: comparison between the European Society of Cardiology (2010) and International (2017) criteria

Alessandro Zorzi,1 Chiara Calore,1 Riccardo Vio,1 Antonio Pelliccia,2 Domenico Corrado1

ABSTRACT

Background Interpretation of the athlete’s ECG is based on differentiation between benign ECG changes and potentially pathological abnormalities. The aim of the study was to compare the 2010 European Society of Cardiology (ESC) and the 2017 International criteria for differential diagnosis between hypertrophic cardiomyopathy (HCM) and athlete’s heart.

Methods The study populations included 200 patients with HCM and 563 athletes grouped as follows: ‘group 1’, including normal ECG and isolated increase of QRS voltages, which are considered non-pathologic according to ESC and International criteria; ‘group 2’, including left atrial enlargement or left axis deviation in isolation and Q-waves with an amplitude ≥4 mm but <25% of the ensuing R-wave and a duration <0.04 s which are considered pathologic according to the ESC but not according to the International criteria; and ‘group 3’, including abnormalities which are considered pathologic according to ESC and International criteria.

Results Overall, the 2010 ESC criteria showed a sensitivity of 95.5% and a specificity of 86.9%. Considering group 2 ECG changes as normal according to the International criteria led to a statistically significant (p<0.001) increase of specificity to 95.9%, associated with a non-significant (p=0.47) reduction of sensitivity to 93%. Among patients with HCM, there was a significant increase of maximal left ventricular wall thickness from group 1 to 3 (p=0.02).

Conclusions The use of 2017 International criteria is associated with a substantial increase in specificity and a marginal decrease in sensitivity for differential diagnosis between HCM and athlete’s heart.

INTRODUCTION

Preparticipation screening including 12-lead ECG has the potential to identify at a presymptomatic stage cardiomyopathies such as hypertrophic cardiomyopathy (HCM), which may cause sudden death (SD) during sports activity.1–4 Over the last decades, there has been much debate over the cost-effectiveness of such screening modality, due to the presumed high level of false-positive results mostly related to ECG findings of trained athletes that may mimic abnormalities seen in cardiac diseases.5–7

Modern criteria for interpretation of the athlete’s ECG were first proposed in 2010 by a task force of the Section of Sports Cardiology of the European Society of Cardiology (ESC) with the aim to improve the accuracy of preparticipation screening. In this document, the ECG changes were classified according to the prevalence, relation to exercise training, association with an increased risk of cardiovascular disease and need for further investigations into two groups: ‘common and training-related’ and ‘uncommon and training-unrelated’. Subsequently, the criteria have been refined by further documents with the main goal to improve the specificity.8

According to the recent (2017) International criteria, a number of ECG changes that were previously considered potentially pathologic (such as left atrial enlargement (LAE) and left axis deviation (LAD) in isolation, T-wave inversion confined to V1–V4 and preceded by J-point elevation in black athletes, Q-waves ≥3–4 mm but <1/4 of the R-wave and <0.04 s in duration) were reclassified as physiologic and not requiring further clinical assessment.9 The aim of this study was to compare the accuracy of the ESC (2010) versus International (2017) criteria for differential diagnosis between HCM and athlete’s heart and to assess the balance between improvement in specificity (reduction of false-positive results) and reduction in sensitivity (ability to identify affected athletes).

METHODS

Study sample

This case–control study included samples of patients with HCM and athletes of the same age range (14–65 years).

Patients with HCM

The HCM sample included 200 patients (74% males; age 40±13 years) from the database of the Division of Cardiology of the University of Padua. The diagnosis of HCM was based on the presence of a hypertrophied and non-dilated left ventricle (LV) in the absence of other diseases that could produce the same magnitude of hypertrophy. Echocardiographic criteria for diagnosis were a wall thickness ≥15 mm in adult index patients and ≥13 mm in adult relatives in the absence of other conditions that can produce a similar degree of hypertrophy.10 Patients with HCM and systolic dysfunction (ejection fraction <50%) and/or heart failure symptoms were excluded from the study to omit patients with end-stage remodelling that could influence ECG features.

Patients with athletes

The athletes sample included 563 athletes of the same age range (14–65 years) from the database of the Section of Sports Cardiology of the University of Padua. The diagnosis of athlete’s heart was based on the presence of abnormal ECG findings of trained athletes that may mimic abnormalities seen in cardiac diseases.12

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Athletes
The athletes’ population included 563 Caucasian athletes (77% males; age 29±11 years) including (1) a consecutive series of 438 Caucasian competitive athletes 14–65 years old engaged in ≥6 hours/week of sports activity (excluding disciplines at low static and low dynamic demand according to the Mitchell classification\(^1\)), who underwent preparticipation screening at the Centre for Sports Medicine, Public Health System, Padua, in 2015–2016 and were considered eligible and (2) 125 Caucasian top-level athletes (competing at an International level) from the database of the Institute of Sports Medicine and Science of the Italian National Olympic Committee (CONI) in Rome. All top-level athletes underwent preparticipation echocardiography that showed features of athlete’s heart with augmented LV mass but preserved LV shape and function in the absence of other cardiovascular abnormalities. In this subgroup, differential diagnosis between athlete’s heart and HCM was based on dimension of LV cavity, magnitude and distribution of LV wall thickening, type of sports and intensity of training.

ECG interpretation
The ECG tracings of both study samples were recorded at standard speed and amplification (25 mm/s, 10 mm=1 mV) and obtained at, or nearest to, the time of initial evaluation in all individuals. The ECG tracings were independently analysed by two experienced physicians (CC, AZ) who were blinded to underlying condition (HCM or athlete’s heart); in case of disagreement, a third physician was consulted (DC).

The ECG findings evaluated were relevant to a diagnosis of HCM and included (1) increased QRS voltages (voltage criteria for left ventricular hypertrophy) as SV1 + RV5 or RV6, whichever is larger, >35 mm (Sokolow-Lyon index); (2) LAE as prolonged P-wave duration of >120 ms in leads I or II with negative portion of the P-wave ≥1 mm in depth and ≥40 ms in duration in lead V1; (3) LAD from −30° to −90° on the frontal plane; (4) ST-segment depression >0.1 mV in depth in at least two adjacent leads; (5) T-wave inversion as negative T-waves>0.1 mV in at least two adjacent leads (except aVR), in the absence of conduc
tion disturbance; (7) complete left bundle branch block (LBBB) with QRS ≥0.12 s; and (8) pathological Q-waves.

The definition of pathological Q-waves was not discussed in the ESC recommendations but Pelliccia et al previously suggested that Q-waves≥4 mm in ≥2 leads should be considered as ‘distinctly abnormal’.\(^1\) According to the International criteria, the Q-waves were defined either as ‘non-pathologic’ (amplitude ≥4 mV but <25% of the ensuing R-wave and duration <0.04 s) or ‘pathologic’ (amplitude ≥25% of the ensuing R-wave and/or duration ≥0.04 s) figure 1. T-wave inversion were divided in two categories: ‘T-wave inversion confined to V1–V4 and preceded by J-point elevation ≥1 mm in at least one lead exhibiting inverted T-wave’ and ‘other T-wave inversion’ (i.e., in leads other than V1–V4 or anterior T-wave inversion with no J-point elevation).

The ECG tracings of patients with HCM and athletes were grouped as follows: ‘group 1’, including normal ECG and isolated increase of QRS voltages in the absence of group 2 and 3 abnormalities, which are considered non-pathologic according to ESC and International criteria; ‘group 2’, including LAE or LAD in isolation and Q-waves with an amplitude ≥4 mm but <25% of the ensuing R-wave and a duration <0.04 s in the absence of group 3 changes, which are considered pathologic according to ESC but non-pathologic according to International criteria; ‘group 3’, including LAE or LAD in association (occurring together), ST-segment depression, T-wave inversion, Q-waves of amplitude ≥25% of the ensuing R-wave and/or duration ≥0.04 s and LBBB, which are considered pathologic according to both ESC and International criteria.

Isolated right bundle branch block, right atrial enlargement and right axis deviation that are also listed among group 2 findings in the International criteria are not considered in this study as they are not traditional markers of HCM.

Echocardiography of patients with HCM
Two-dimensional images and M-mode echocardiograms of left atrial and LV cavity were obtained in multiple cross-sectional planes, with the transducer in standard positions according to the recommendations of the American Society of Echocardiography.\(^1\) The magnitude and distribution of LV hypertrophy were assessed prospectively with two-dimensional echocardiography according to previously published criteria, primarily from the parasternal long-axis and short-axis cross-sectional planes; apical views were used to integrate observations. Measurements were made from the parasternal views, and the greater dimension at any site in the LV wall was regarded as maximal diastolic left ventricular wall thickness (LVWT). Outflow obstruction at rest was identified by peak instantaneous LV outflow gradient ≥30 mm Hg at Doppler echocardiography.

Follow-up
Follow-up data were obtained during regular outpatient visits at 6 to 12-month intervals. Major arrhythmic events occurring during follow-up were defined as sudden cardiac death, cardiac arrest due to ventricular fibrillation, sustained ventricular tachycardia and appropriate intervention of implantable cardioverter defibrillator (ICD).

Statistical analysis
Data are expressed as mean ± SD for continues variables and as N (%) for categorical variables. Differences between means were tested with the unpaired Student’s t-test or with the rank-sum test for normally and non-normally distributed variables, respectively. Normality was assessed with the Shapiro-Wilk test. Categorical frequencies were compared with the X² test or with the Fisher’s exact test, as appropriate. Differences among three subgroups were assessed with the Kruskal-Wallis test for continuous variables and with the X² test for dichotomous variables. Post hoc pairwise comparisons were performed using the Bonferroni correction. The probability of true positives and

Figure 1 Examples of ‘non-pathological’ and ‘pathological’ Q-waves according to the 2017 International criteria. (A) A 5 mm deep non-pathological Q-wave. Note that it is <25% of the following R-wave and <0.04 s in duration. (B) A 5 mm deep pathological Q-wave. Note that it is ≥25% of the following R-wave. (C) A 1.5 mm deep pathological Q-wave. Note that it is ≥0.04 s in duration.
false negatives using the ESC versus International criteria in the setting of preparticipation screening were calculated with the Bayes theorem according to an estimated prevalence of HCM among athletes undergoing preparticipation screening of 0.06%. Ninety-five per cent confidence intervals of sensitivity, specificity, true and false positives were calculated based on the binomial distribution. Probability values reported are two sided, and values < 0.05 were considered statistically significant. SPSS Statistics V. 18.0 (SPSS) was used for analysis.

RESULTS

ECG abnormalities in patients with HCM and athletes

Details of ECG abnormalities of patients with HCM and athletes are reported in table 1.

Group 1 ECG was found in 9 (4.5%) patients with HCM and 489 (86.9%) athletes (p < 0.001); group 2 abnormalities in 5 (2.5%) patients with HCM and 51 (9.1%) athletes (p < 0.001) and group 3 in 186 (93.0%) patients with HCM and 23 (4.1%) (2.5%) patients with HCM and 51 (9.1%) athletes (p < 0.001).

Q-waves characteristics

The Q-waves characteristics are summarised in table 2. ‘Pathological’ Q-waves were observed in 57 (28.5%) patients with HCM and 0 athletes (p < 0.001), while ‘non-pathological Q-waves’ were observed in 2 (1.0%) patients with HCM and 23 (4.1%) athletes (p = 0.06). One (0.5%) patient with HCM showed ‘non-pathological Q-waves’ in isolation compared with 22 (3.9%) athletes (p = 0.01). The prevalence of pathological Q-waves was highest (32%–33%) in patients with HCM with hypertrophy of the entire left ventricular septum with or without hypertrophy of the anterolateral free wall (type II or type III according to the Maron classification15) and it was lowest (12.5%) in patients with apical hypertrophy (type IV) although the difference did not reach statistical significance (online supplementary table 1).

Diagnostic accuracy of different ECG interpretation criteria

Overall, the 2010 ESC criteria showed a sensitivity of 95.5% and a specificity of 86.9% in identifying patients with HCM. Considering group 2 ECG changes as normal according to the International criteria led to a statistically significant (p < 0.001) increase of specificity to 95.9%, associated with a non-significant reduction of sensitivity to 93.0% (p = 0.47). On a simulated model of preparticipation evaluation, compared with the 2010 ESC criteria, the use of the 2017 International criteria to screen athletes for HCM reduced the estimated number of unnecessary further investigations from 1 in 8 athletes to 1 in 24 athletes, a 68.9% reduction, and potentially decreased the sensitivity to detect HCM by 2.5% (table 3).

Table 2 Comparison of Q-waves in hypertrophic cardiomyopathy (HCM) and athletes

<table>
<thead>
<tr>
<th>Q-waves definition</th>
<th>HCM (n=200)</th>
<th>Athletes (n=563)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥4 mm in depth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Isolated*</td>
<td>9 (4.5)</td>
<td>23 (4.1)</td>
<td>0.72</td>
</tr>
<tr>
<td>- Isolated</td>
<td>1 (0.5)</td>
<td>22 (3.9)</td>
<td>0.01</td>
</tr>
<tr>
<td>≥25% of the following R-wave</td>
<td>57 (28.5)</td>
<td>0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>- Isolated*</td>
<td>8 (4.0)</td>
<td>0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>≥0.04 s in duration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Isolated*</td>
<td>16 (8)</td>
<td>0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>- Isolated</td>
<td>3 (1.5)</td>
<td>0</td>
<td>0.03</td>
</tr>
<tr>
<td>Non-pathological Q-waves†</td>
<td>2 (1.0)</td>
<td>23 (4.1)</td>
<td>0.05</td>
</tr>
<tr>
<td>- Isolated*</td>
<td>1 (0.5)</td>
<td>22 (3.9)</td>
<td>0.01</td>
</tr>
<tr>
<td>Pathological Q-waves†</td>
<td>57 (28.5)</td>
<td>0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>- Isolated*</td>
<td>8 (4.0)</td>
<td>0</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

* Q-waves in isolation or associated with increased QRS voltages.
† t=4 mm but <25% of the following R-wave and <0.04 s in duration.
‡ ≥25% of the following R-wave and/or ≥0.04 s in duration.
Clinical characteristics, echocardiographic findings and outcome of HCM according to ECG features

Correlation of clinical and echocardiographic findings among patients with HCM from different ECG groups is reported in table 4. Maximal LVWT in HCM population ranged from 13 to 46 mm (mean 22±6); it was ≤15 mm in 28 patients (14%); age 33±13 years, 16–19 mm in 47 (24%); age 40±12 years, 20–24 mm in 69 (35%); age 45±14 years, 25–29 in 34 (17%); age 36±11 years and ≥30 mm in 22 (11%); age 37±13 years. Resting outflow tract obstruction was found in 53 (27%) patients. Mean LV end-diastolic diastolic dimension was 45±6 mm (range 30–68 mm), shortening fraction 44±10% (range 24%–71%) and parasternal left atrium diameter 44±8 mm (range 27–70 mm).

There was no statistically significant difference in the maximal LVWT between group 1 and 2 (17±2 mm vs 18±3 mm; p=0.38), while group 3 patients showed a statistically significant higher LVWT (22±6 mm than both group 2 (p=0.03) and group 1 (p=0.01) patients figure 2.

During a mean follow-up period of 8±7 years, among patients with HCM, 36 (19%) group 3 patients received an ICD and 9 (5%) experienced major arrhythmic events, including sudden cardiac death (SCD) (n=3), aborted SCD (n=1), appropriate ICD intervention on ventricular fibrillation (n=2) and sustained ventricular tachycardia (n=3). The remaining patients with HCM of group 1 and 2 had an uneventful outcome. Compared with patients with HCM, all athletes had an uneventful outcome during a mean follow-up period of 7±2 years, regardless from the ECG group.

DISCUSSION

HCM is one of the leading causes of SD in athletes.18,19 The estimated prevalence of this genetic heart muscle disease in the general population of screened athletes is 0.06%.16 Conventionally, clinical diagnosis of HCM relies on echocardiographic demonstration of otherwise unexplained LV hypertrophy. Twelve-lead ECG has traditionally been an integral part of non-invasive evaluation of patients with HCM. ECG abnormalities are commonly observed in affected athletes with a reported prevalence >90%.20 Previous studies have shown that athletic cardiovascular evaluation including an ECG is effective in identifying HCM at a presymptomatic stage;14–21 however, the cost-effectiveness of the screening remains controversial because of its presumed low specificity.22 The main limitation of the use of the ECG for screening trained athletes for HCM is considered to be the high rate of false-positive findings, mostly due to the

Table 4  Clinical and echocardiographic profile of patients with hypertrophic cardiomyopathy (HCM) according to the ECG pattern

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Group 1 (n=9)</th>
<th>Group 2 (n=5)</th>
<th>Group 3 (n=186)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (males), n (%)</td>
<td>46±8</td>
<td>36±20</td>
<td>40±13</td>
<td>0.27</td>
</tr>
<tr>
<td>Familial HCM, n (%)</td>
<td>7 (77)</td>
<td>5 (100)</td>
<td>135 (73)</td>
<td>0.55</td>
</tr>
<tr>
<td>Obstruction, n (%)</td>
<td>1 (11)</td>
<td>2 (40)</td>
<td>50 (27)</td>
<td>0.49</td>
</tr>
<tr>
<td>Maximal LVWT (mm)</td>
<td>17±2</td>
<td>18±3</td>
<td>22±6</td>
<td>0.02</td>
</tr>
<tr>
<td>LVIDD (mm)</td>
<td>46±5</td>
<td>46±5</td>
<td>45±6</td>
<td>0.88</td>
</tr>
<tr>
<td>LVWT (mm)</td>
<td>41±4</td>
<td>40±10</td>
<td>44±8</td>
<td>0.32</td>
</tr>
<tr>
<td>Shortening fraction (%)</td>
<td>46±13</td>
<td>50±6</td>
<td>44±10</td>
<td>0.30</td>
</tr>
<tr>
<td>Syncope, n (%)</td>
<td>1 (11)</td>
<td>0</td>
<td>27 (15)</td>
<td>1.00</td>
</tr>
<tr>
<td>Major arrhythmic events during follow-up, n (%)</td>
<td>0</td>
<td>0</td>
<td>9 (5)</td>
<td>1.00</td>
</tr>
<tr>
<td>ICD, n(%)</td>
<td>0</td>
<td>0</td>
<td>36 (19)</td>
<td>0.26</td>
</tr>
</tbody>
</table>

HCM, hypertrophic cardiomyopathy; ICD, implantable cardioverter defibrillator; LVIDD, left ventricular diastolic diameter; LVWT, left ventricular wall thickness.
overlap between the ECG changes that develop as a consequence of exercise-induced adaptation (in particular, physiological LV hypertrophy) of the cardiovascular system and those that reflect underlying HCM.

In 2010, the ESC endorsed the first recommendations for interpretation of the athlete’s ECG. In this document, the athlete’s ECG changes were classified as ‘common and training-related’, which usually reflect cardiac adaptation to exercise and do not require systematic further examination, and ‘uncommon and training-unrelated’, which may be the sign of an underlying cardiac disease that must be excluded by second-line investigations. The aim of this classification was to increase the specificity of preparticipation ECG screening, without compromising the sensitivity for potentially lethal heart diseases. Investigation on different athletic populations confirmed that application of the 2010 ESC criteria led to a substantial reduction in the rate of false positives.

Particularly, these modern ECG criteria were tested in a group of 1005 ECGs of highly trained athletes previously reported by Pelliccia et al and resulted in the improvement of ECG specificity for athlete’s heart by 70% (ie, reduction of false positives from 40% to 11%), but maintaining sensitivity for detection of cardiovascular diseases.

This stem document enabled subsequent recommendations which provided a more accurate definition of ECG criteria, including the International criteria which were published in 2017. The International criteria differed from previous recommendations excluding some borderline ECG patterns from those deemed suggestive of pathology with the aim to provide better specificity but maintain the original sensitivity. Specifically considering the ECG criteria that may be useful for differential diagnosis between HCM and athlete’s heart also in the growing population of older athletes, as the diagnostic accuracy of the new criteria was similar between the subgroups of 12–35 years old and the >35 years old. In addition, according to current International criteria, T-wave inversion confined to V1–V4 and preceded by J-point elevation is considered normal only in black athletes. According to the present and a previous study, such ECG finding can also be found in white athletes while it is never observed in patients with HCM. These findings, if confirmed by other studies from different groups, may lead to further refinement of the criteria for interpretation of the ECG of Caucasian athletes.

Previous studies suggested that a normal ECG may predict a less severe HCM phenotype and a better cardiovascular outcome. Data from McLeod et al showed that the 6% subset of patients with HCM with a normal ECG at the time of diagnosis had lower values of LVWT, LV outflow tract gradient, complications and cardiac-related mortality, compared with the other patients with HCM with an abnormal ECG, resulting in a more favourable prognosis.

Different definitions of abnormal Q-waves in athletes have been proposed: (1) ≥4 mm in depth in ≥2 leads; (2) ≥3 mm in depth or >40 ms in duration in ≥2 leads except III and aVR; (3) ≥40 ms in duration or ≥25% of the height of the ensuing R-wave in depth. The most recent International criteria adopted the last definition, based on the consideration that many healthy athletes show Q-waves ≥3–4 mm thus reducing the specificity of this criterion; however, this recommendation relied on expert consensus as scientific data were lacking. In this study, we conducted a specific subanalysis to assess the diagnostic accuracy of different Q-wave definitions. We found that Q-waves ≥4 mm but <1/4 of the R-wave and <0.04 s were recorded in as many as 4.1% of athletes versus 1.0% of patients with HCM. Moreover, only one patient with HCM (0.5%) showed isolated non-pathological Q-waves while no athletes met the new criteria for pathological Q-waves. These findings suggest that the definition of pathological Q-waves proposed by the 2017 International criteria leads to a significant improvement in specificity and a negligible reduction in sensitivity for HCM.

On a simulated screening model of 1000 athletes, application of the 2017 International criteria instead of the 2010 ESC criteria would lead to a substantial and highly significant reduction in the number of athletes undergoing unnecessary second-line investigations (from 1:8 to 1:24 athletes) and a non-significant reduction in sensitivity for HCM from 95.5% to 93%. Similar results were obtained in a subanalysis including only young patients with HCM (14–39 years old) and top-level athletes of the same age range with echocardiographic evidence of physiological LV hypertrophy.

Of note, the 2017 International criteria were developed for athletes aged 12–35 years old. Our study suggests that the International criteria may be useful for differential diagnosis between HCM and athlete’s heart also in the growing population of older athletes, as the diagnostic accuracy of the new criteria was similar between the subgroups of 12–35 years old and the >35 years old. In addition, according to current International criteria, T-wave inversion confined to V1–V4 and preceded by J-point elevation is considered normal only in black athletes. According to the present and a previous study, such ECG finding can also be found in white athletes while it is never observed in patients with HCM. These findings, if confirmed by other studies from different groups, may lead to further refinement of the criteria for interpretation of the ECG of Caucasian athletes.

Figure 2 Mean maximal left ventricular wall thickness according to ECG pattern in patients with hypertrophic cardiomyopathy. Patients with group 1 and group 2 ECG patterns showed significantly lower maximal left ventricular wall thickness compared with group 3 patients. On the other hand, there was no statistically significant differences between group 1 and 2 patients.
changes (considered normal by the International criteria) might express a less severe phenotype and a lower arrhythmic risk than patients with group 3 abnormalities (which require further evaluation by the International criteria).

Our study did not include athletes affected by HCM who might exhibit a milder phenotype with less prominent ECG abnormalities. However, it is noteworthy that in the study by Sheikh et al., among 103 athletes with HCM identified at preparticipation screening, 98% had group 3 ECG abnormalities; moreover, in the same study, among 3210 athletes who underwent systematic echocardiographic evaluation, those who fulfilled morphological criteria for HCM had group 3 ECG abnormalities (no athletes with HCM with group 1 or 2 ECG abnormalities in isolation).

CONCLUSIONS
A screening test is not intended to be diagnostic, but it separates persons who may have a disease from those who probably do not. Those with positive or suspicious findings will be subsequently referred for further clinical evaluation to achieve a definitive diagnosis. This study showed that the 2017 International ECG criteria provides excellent accuracy for screening athletes for HCM and helps to successfully select candidates for echocardiography as second-level examination. According to our study results, defining as normal group 2 ECG changes offers the potential to lower the traditional high number of false positives, thus reducing unnecessary and expensive investigations, while substantially preserving the ECG sensitivity for detection of HCM. False-negative ECGs might be associated with a less severe HCM phenotype, but whether athletes with such a milder phenotypic expression of HCM have a lower risk of SCD during competitive sports activity remains to be proven.

What are the findings?

► The study aimed to compare the accuracy of the European Society of Cardiology (2010) and the refined 2017 International recommendations for differentiating between hypertrophic cardiomyopathy (HCM) and athlete’s heart.

► Compared with the European Society of Cardiology criteria, the use of the 2017 International criteria to screen athletes for HCM reduced the estimated number of unnecessary further investigations from 1:8 athletes to 1:24 athletes, that is, by 69%, with a slight reduction of sensitivity (from 95.5% to 93%).

► The definition of pathological Q-waves varies in different recommendations with some considering abnormal Q-waves as ≥4 or ≥3 mm independently from the height of the ensuing R-wave. We found that the definition of pathological Q-waves (>1/4 of the R-wave and/or >0.04 s) proposed by the 2017 International criteria is associated with a higher accuracy for differentiating between HCM patients and healthy athletes.

How might it impact on clinical practice in the near feature?

► The use of the International criteria might significantly reduce the traditionally high number of false negatives ECG findings in the setting of athletes preparticipation screening, thus reducing unnecessary further investigations.

► At the same time, the use of the International criteria ECG criteria might slightly reduce the sensitivity for HCM.

► Although they were developed for young athletes (12–35 years old), the International criteria might be also useful for differential diagnosis between athlete’s heart and HCM in the growing population of older athletes.
Competing interests None declared.

Ethics approval The study was approved by the Ethical committee. Consent form was not received as data are completely anonymised.

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