Hypertrophic cardiomyopathy (HCM) is a leading cause of sudden cardiac death among athletes in the United States (1). The electrocardiogram (ECG) can be used for screening athletes to identify HCM (2–4); however, its routine use remains controversial due to false positives (5). We hypothesized that through systematic comparison of digital ECGs of HCM patients with those of healthy athletes, an effective set of characteristics could be identified to distinguish these 2 groups.

A cohort of 1,124 athletes from the Stanford Sports Medicine program and 255 HCM patients from the Stanford Center for Inherited Cardiovascular Diseases underwent a resting 12-lead ECG. Each digital ECG was processed using the same algorithm.

Continuous ECG characteristics were compared using Student t tests and dichotomous variables using chi-square tests. Because of differences in age, a secondary analysis with only HCM patients under 40 years of age was performed. Electrocardiographic characteristics that met the following criteria were considered the best at differentiating the 2 populations: 1) 10-fold greater prevalence in the HCM population; 2) prevalence <2% in athletes; 3) statistical significance of p < 0.001 when comparing athletes to HCM patients under 40 years of age. To determine the ability of these ECG characteristics to independently differentiate HCM patients from athletes, multivariate logistic regression analysis was performed.

Athletes were on average 20 years of age, 65% male, and 24% African American. Patients with HCM were on average 51 years of age, 56% male, and 5.8% African American. Compared to athletes, patients with HCM had a higher resting heart rate (71 vs. 62 beats/min; p < 0.001), were more likely to have QRS duration >140 ms (12.5% vs. 0.09%; p < 0.001), a QTc interval >480 ms (14.6% vs. 0.4%; p < 0.001), left or right axis deviation, right bundle branch block, and right or left atrial abnormality. While 5.9% of patients with HCM had a left bundle branch block, none of the athletes had this finding. Any degree of T-wave inversion in leads V4, V5, or V6 were more pronounced in the patients with HCM compared to athletes (38% vs. 0.8%; p < 0.001).

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Optimal Electrocardiography Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>Hypertrophic Cardiomyopathy % With Characteristic</td>
</tr>
<tr>
<td>TWI &lt;0 mV in V4, V5, V6</td>
<td>1</td>
</tr>
<tr>
<td>TWI &lt;0.5 mV in V4, V5, V6 (major)</td>
<td>2</td>
</tr>
<tr>
<td>QTc &gt;480 ms</td>
<td>1</td>
</tr>
<tr>
<td>Q-wave &gt;40 ms in V5 or aVF</td>
<td>1</td>
</tr>
<tr>
<td>ST-segment depression &lt;-0.05 mV V5 or V6</td>
<td>1</td>
</tr>
<tr>
<td>ST-segment depression &lt;-0.1 mV V5 or V6 (major)</td>
<td>2</td>
</tr>
<tr>
<td>Left atrial abnormality</td>
<td>1</td>
</tr>
<tr>
<td>Left axis deviation</td>
<td>1</td>
</tr>
<tr>
<td>Right axis deviation</td>
<td>1</td>
</tr>
<tr>
<td>QRS duration &gt;140 ms</td>
<td>1</td>
</tr>
<tr>
<td>Left bundle branch block (major)</td>
<td>2</td>
</tr>
</tbody>
</table>

The multivariate regression model was adjusted for age, sex, ethnicity, heart rate, and all of the other electrocardiography characteristics in the first column.

TWI = T-wave inversion.
In contrast, large voltages did not differentiate the 2 populations (15.3% of athletes vs. 12.9% of HCM; p = 0.35). Early repolarization with ST-segment elevation >0.1 mV in V2 was too common in athletes (33.7%) to serve as a helpful marker.

Characteristics that best differentiated the 2 populations as described previously were designated minor ECG criteria and assigned 1 point, whereas characteristics not present in any athlete were designated major ECG criteria and assigned 2 points. Major ECG criteria included T-wave inversions deeper than 0.5 mV, ST-segment depressions deeper than 0.1 mV, and left bundle branch block. The final list of optimal HCM ECG characteristics, their frequencies, and examples of each abnormality are presented in Table 1. Many of the characteristics contributed independently on multivariate analysis.

Using the optimal ECG characteristic scores, 4.0% of athletes and 72.2% of all HCM patients received 1 or more points, while 47.1% of all HCM patients and only 1 athlete (0.09%) received 2 or more points. A score of 1 (1 minor ECG abnormality) distinguished HCM patients from athletes with 72% sensitivity and 96% specificity; while a score of 2 (1 major or 2 minor ECG abnormalities) distinguished the 2 groups with 47% sensitivity, 99.9% specificity, and a false positive rate of <1 of 1,000.

Although these findings need validation, ideally using a young athletic HCM cohort, we have identified criteria that result in a low false positive and maintain reasonable sensitivity, which we believe supports the use of the digital 12-lead ECG in athletic screening.

Please note: Dr. Hadley and Dr. Froelicher are co-owners of Cardea Associates, Inc. (Palo Alto, California), which provides an electrocardiography system that is used to screen athletes. Dr. Ashley is founder of Personalis, Inc. Dr. Perez has received grant support to conduct this study from the Steven M. Gooter Foundation. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

REFERENCES


Effects of Weight and Weight Change on Cardiac Remodeling Over 20 Years

The CARDIA (Coronary Artery Risk Development in Young Adults) Study

Relative weight, often characterized as body mass index (BMI), is a factor associated with left ventricular (LV) mass and geometry. Cross-sectional studies in middle-aged adults showed higher BMI was associated with higher LV mass and volumes (1). Longitudinal data in another middle-aged cohort showed higher initial BMI was associated with greater increase in LV mass (2).

The goal of this study was to determine whether BMI was associated with changing cardiac structure and function over the next 20 years and whether maintaining a stable BMI was associated with less change in cardiac structure and function.

The CARDIA (Coronary Artery Risk Development in Young Adults Study) study recruited 5,115 Caucasian and African American men and women, 18 to 30 years of age, in 4 U.S. centers in 1985 (year 1). We stratified participants by year 5 (initial) BMI (kg/m²): 18.5 to 24.9, 25 to 29.9, 30 to 34.9, ≥35. We further stratified participants by BMI change between years 5 and 25: increasing BMI (≥2), stable BMI (≤2), and fluctuating

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