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Visual or computer-based measurements: Which is important for the interpretation of an athlete's electrocardiography?

Ayşe Birsu Topcugil Kırık[1*], Oğuz Yüksel[1], Hüseyin Dursun[2], İnci Tuğçe Çöllüoğlu[3], Tuğba Kocahan[4], Dayimi Kaya[2]

SUMMARY

OBJECTIVE: Preparticipation screening of athletes by electrocardiography is the most crucial step in determining sudden cardiac death risk factors. Several electrocardiography interpretation software programs have been developed for physicians practicing in this field. Our study aimed to assess cardiopoint sudden death screening module by comparing its findings with two cardiologists using Seattle and International criteria.

METHODS: A total of 303 licensed national athletes (37% females) were enrolled. electrocardiographies were examined by the cardiopoint sudden death screening module using Seattle criteria and cardiologists. The consistency between cardiologists and software was compared, and the confidence assessment of the module was tested.

RESULTS: With regard to Seattle criteria, moderate consistency was found between the cardiopoint sudden death screening module and the 1st (κ=0.41) and 2nd cardiologist (κ=0.59). Consistency between two cardiologists was moderate (κ=0.55). When we applied International criteria, there was moderate consistency between the module and the 1st cardiologist (κ=0.42), and good consistency between the module and the 2nd cardiologist (κ=0.63). Consistency between the two cardiologists was good (κ=0.62).

CONCLUSION: The cardiopoint sudden death screening module had similar agreement with cardiologists based on both criteria. However, the software needs to be updated according to International criteria. Using computer-based measurements for preparticipation screening will help to save time and provide standardization of electrocardiography interpretation.

KEYWORDS: Athlete. Electrocardiography. Exercise. Cardiac sudden death.

INTRODUCTION

Sudden cardiac death (SCD) is one of the leading causes of death in sports participants[1,2]. Preparticipation screening, consisting of medical history, physical examination, and a resting 12-lead ECG, aims to identify pre-existing cardiovascular abnormalities that may lead to SCD[3].

ECG interpretation criteria, such as the European Society of Cardiology (ESC) criteria, Seattle criteria, and International criteria, have been developed for preparticipation screening[4-7]. These criteria have clearly and practically delineated normal, borderline, and pathological ECG findings in athletes aged between 12 and 35 years[7]. Each revision of ECG criteria resulted in improved specificity without compromising sensitivity.

Automated ECG interpretation is fast and time-saving; however misdiagnosis is also possible. One such software program is the cardiopoint sudden death screening (SDS) module[8]. This module examines ECGs using Seattle criteria. Slaby et al. reported that the cardiopoint SDS module has a high negative predictive value with variable levels of sensitivity and specificity[9].

The aim of our study was to compare the ECG interpretation of the cardiopoint SDS module to that of two cardiologists in the preparticipation screening of sports participants.

METHODS

Participants

We enrolled 303 licensed national athletes (37% females) from 34 sports disciplines between the ages of 13 and 35 years from October 1, 2017, to April 1, 2018. All athletes underwent cardiovascular screening, including medical histories and physical examination. Morphometric and demographic data were also obtained.

[1]Dokuz Eylül University, Faculty of Medicine, Department of Sports Medicine – İzmir, Turkey.
[2]Dokuz Eylül University, Faculty of Medicine, Department of Cardiology – İzmir, Turkey.
[3]Karabük University Education and Research Hospital, Department of Cardiology – Karabük, Turkey.
[4]University of Health Sciences Gülhane Training and Research Hospital, Department of Sports Medicine – Ankara, Turkey.
*Corresponding author: ayse_birsu@hotmail.com
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Ethical approval and consent

Athletes and, if needed, their parents gave informed consent to participate in the study. This study complied with the Declaration of Helsinki, and the research protocol was approved by the local institutional ethics committee.

Electrocardiography

We used a BTL® 08 MT Plus (BTL, United Kingdom) 12-lead ECG tool. All ECGs were automatically sent to the cardiopoint SDS module via Wi-Fi LAN network and were automatically interpreted using Seattle criteria. ECG findings were also analyzed by two cardiologists with different levels of expertise using both Seattle and International criteria.

Statistical analysis

All statistical analyses were performed using SPSS Statistics for Windows, version 22 (IBM Corporation, Armonk, NY). Continuous variables are presented as means±SD and categorical variables are presented as percentages. Values of $p<0.05$ were considered statistically significant. Cohen's kappa (κ) statistics were used to determine the consistency between the cardiopoint SDS module and observers. κ (kappa) scores between 0.01 and 0.20 were classified as none to slight, 0.21 and 0.40 as fair, 0.41 and 0.60 as moderate, 0.61 and 0.80 as good, and 0.81 and 1.00 as almost perfect agreement.

RESULTS

The baseline demographics of athletes are shown in Table 1.

Findings based on Seattle criteria

The cardiopoint SDS module detected 22 (7.3%) ECGs as abnormal. Both cardiologists found 14 (4.6%) ECGs as abnormal. There was moderate consistency between the cardiopoint SDS module and the first cardiologist (κ=0.41), as well as the second cardiologist (κ=0.59). Furthermore, moderate consistency was found between the two cardiologists (κ=0.55) (see Figure 1).

Findings based on International criteria

The ECG findings of the cardiopoint SDS module were also re-evaluated using International criteria. Further examination was suggested in 14 (4.6%) athletes. A total of 7 (2.3%) athletes were suggested for further examination by the first cardiologist, and 12 (4%) athletes were suggested by the second cardiologist. There was moderate consistency between the cardiopoint SDS module and the first cardiologist (κ=0.42), while the kappa statistic between the module and the second cardiologist showed higher consistency (κ=0.63). Likewise, there was good consistency between the two cardiologists (κ=0.62) (see Figure 1).

Table 1. Baseline demographics.

Variables	n=303
Age (years)	18.7±4.1
Height (cm)	173.2±10.0
Weight (kg)	66.9±14.0
Body mass index (kg/m²)	22.1±3.3
Heart rate (beats/min)	75±11.6

Electrocardiographic findings

The ECG parameters for which the cardiopoint SDS module had high sensitivity and specificity, as well as the parameters for which the module had low sensitivity, are shown in Figure 2.

The cardiologists detected 67 early repolarizations and 2 T wave inversions (TWIs); however, these findings were not detected by the module. The module reported one early repolarization and one TWI, which were defined as false positives by the cardiologists. The cardiopoint SDS module found five ECGs with ST segment depression. However, both cardiologists defined these ECG changes as normal findings occurring secondary to right bundle branch block (RBBB). Furthermore, five complete RBBB were detected by the cardiologists; however, none of these were defined by the cardiopoint SDS module.

The cardiopoint SDS module did not report the parameters that were not defined for this software: respiratory sinus arrhythmia and juvenile TWI. The cardiologists found 4 sports participants had juvenile TWI and 29 sports participants had respiratory sinus arrhythmia.

DISCUSSION

In this study, the cardiopoint SDS module provided ECG interpretation results similar to cardiologists. Furthermore,

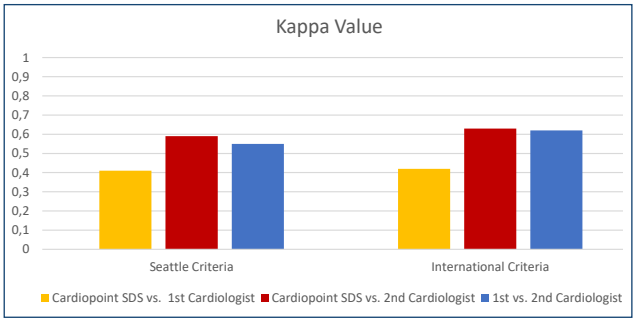

Figure 1. Consistency levels of the cardiopoint sudden death screening module and the 1st and 2nd cardiologists in the evaluation of the Seattle and International criteria.

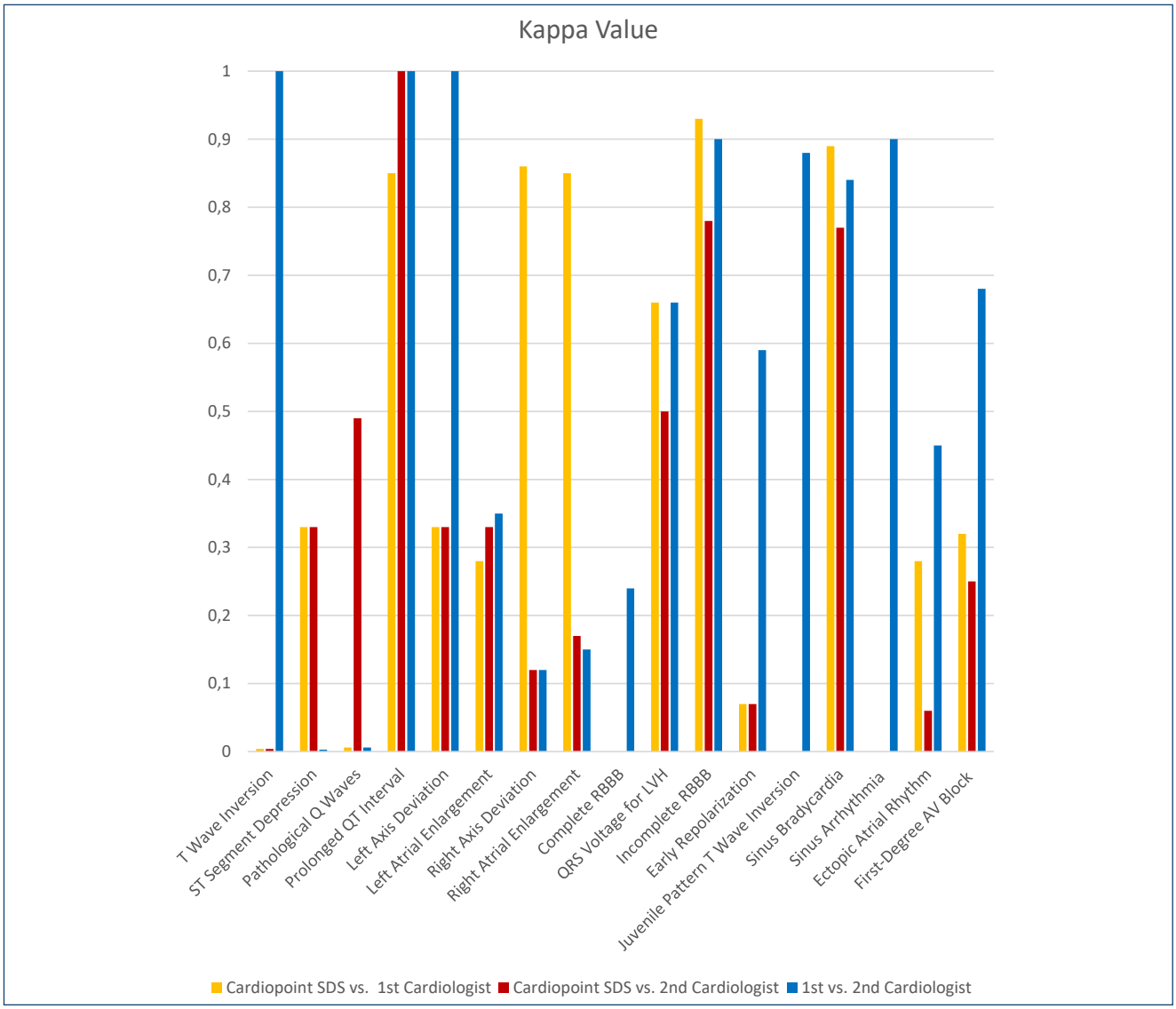

Figure 2. Consistency levels of the cardiopoint sudden death screening module and the 1st and 2nd cardiologists in the evaluation of electrocardiography findings.

when we applied International criteria to the cardiopoint SDS module, the consistency between the module and cardiologists becomes higher.

In preparticipation screening of athletes, strong correlations have been observed between the clinicians and automatic ECG analysis using the Cardea software program with the detailed descriptions of ECG findings[10]. Hyde et al. explained that the difference in pathologic Q wave definition between Seattle criteria and International criteria decreased false positive rates[10]. A new and detailed definition of ECG findings may allow automatic ECG interpretation devices to give more consistent results.

One of the major differences between the Seattle and the International criteria is that some abnormal findings based on the Seattle criteria shifted to the borderline class in the International criteria. Left axis deviation, left atrial enlargement, and complete RBBB were defined as abnormal findings based on the Seattle criteria, while all of these appeared in the borderline class in the International criteria[6,7].

Although previous studies showed no relationship between these abnormal findings in ECG and morphological changes of left or right heart structures[11], these findings may still be abnormal ECG findings as assessed by more sensitive imaging modalities including cardiac magnetic resonance imaging (MRI) due to showing tissue characterization. Therefore, if two or more borderline ECG findings are seen on the surface ECG, it can be useful to lead further evaluation and close follow-up[7]. The other possible factor supporting our

findings was that the age group in which TWI was considered as an abnormal ECG finding. In International criteria, TWI is accepted as a normal ECG finding in athletes below 16 years of age whereas TWI is considered an abnormal ECG finding irrespective of age according to Seattle criteria[6,7]. In our study, athletes below 16 years of age comprised 33% of the study population. So, we can conclude that using International criteria instead of Seattle criteria reduces the rate of abnormal ECG findings.

Importantly, the cardiopoint SDS module had a high sensitivity and specificity for the correct calculation of corrected QT (QTc). Long or short QT is associated with an increased risk of fatal ventricular arrhythmias in young sports participants[12,13], and unfortunately, the QT interval cannot be accurately calculated by clinicians, including experienced cardiologists[14]. Therefore, the evaluation of ECG by clinicians and software together can give more reliable results.

Beyond this accuracy, our study showed that the cardiopoint SDS module did not have the same power as that in a retrospective study by Slaby et al.[9] for the determination of pathological Q wave and left axis deviation. Pathological Q wave and left axis deviation were seen commonly in hypertrophic cardiomyopathy (HCM) subjects[15-17]. HCM is one of the leading causes of SCD in sport participants in the USA[18]. Additionally, silent myocardial infarction can lead to the development of Q wave[19]. Moreover, the software has difficulty identifying myocardial infarction related ECG findings[20]. When all these findings are evaluated together, the cardiopoint SDS module may be insufficient in subjects with a high risk of developing SCD such as HCM. This finding once again demonstrates the importance of ECG analysis with clinicians.

The study by Hyde et al. showed that the Cardea software program had a trend of being more useful in clinical practice with the technological development and standardization of measurements[10]. With more clearly defined ECG parameters, each update of ECG interpretation criteria provided improvement in specificity and decreased false positive results compared to the previous criteria[7]. These findings coupled with the fact that using the International criteria may lead to better consistency between the clinicians in preparticipation screening for young athletes. More consistent results may provide a reduced risk of SCD during exercise and unnecessary disqualification of athletes who do not have cardiovascular disease. In the future, the cardiopoint SDS module may be the recommended software to analyze ECG in sports participants.

LIMITATIONS

Our study included only a small number of athletes. Additional diagnostic tests have not been performed in athletes with ECG changes. Another limitation is that in the evaluation of software-physician consistency, physicians should not be compared with a standard ECG device other than the cardiopoint SDS module.

CONCLUSION

Modern ECG interpretation software analyzes ECGs in a short time with high accuracy. In particular, the cardiopoint SDS module coupled with International criteria may provide more consistent results, and its clinical use may help provide the standardization preparticipation screening for the determination of SCD risk in sports participants.

AUTHORS' CONTRIBUTIONS

ABTK: Data curation, Investigation, Visualization, Writing – original draft. **OY:** Conceptualization, Writing – review & editing. **HD:** Project administration, Writing – review & editing. **İTÇ:** Formal Analysis, Visualization. **TK:** Investigation, Methodology. **DK:** Supervision.

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