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Narrative Review

Electrocardiogram Use on a Division III University Campus Population: An Update on Usage and Prevalence. A Narrative Review of Literature

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Abstract

Objectives: 12-Lead EKG use has been a heavily debated topic for screening collegiate athletes for over two decades. The purposes of this narrative review were to summarize current findings on EKG abnormalities in college athletes, revisit the current opinions on whether EKG use should be used in screening college athletes, and to provide future guidance on research in this area.

Methods: A database search was conducted using multiple databases. Eight different keywords were used in the database search. Articles were considered if they matched keywords and were no older than 12 years old. Two culls were then completed to allow for a total of 36 articles to be used in the final review.

Results: As a narrative review, no statistical analysis was carried out. However, an update on the current research was given with clear and concise analysis of the articles that were used. EKG use continues to be a debated subject with feasibility, cost, presence of false positives, and time being major factors for the argument(s) against the use of this tool [2,5,10,20,24]. Counter arguments involve a direct rebuttal to feasibility as many campuses either have 12-lead EKG machines or are near access the machines, and that other teaching and learning benefits are aspects of using 12-lead EKG machines [21].

Conclusion: 12-lead EKG analysis continues to be a debated topic. The use of 12-lead EKGs is not currently a standard pre-screening tool for collegiate athletes. This is the current position even though there is a discrepancy between universities and colleges at different athletic divisions, with a higher number of division 1 campuses utilizing 12-lead EKGs versus other division 2 or division 3 schools, suggesting that schools with more resources are more likely to use more screening tools for their athletes [21].

Keywords: *Electrocardiogram; 12-Lead EKG; Athletes; Sudden Cardiac Death (SCD)*

Introduction

The use of electrocardiograms (EKG) as a screening tool to prevent sudden cardiac death (SCD) in the athletic population [24] has been extensively debated in the past [10,20,24]. SCD has been the major driving factor behind research in college athletes with some rates reported as 2.65/100,00 in males and rates are higher still in black athletes: Rates as high as 19.2/100,000 have been reported in division I basketball players [10]. However, the mechanisms behind SCD remain unclear. Anatomical and physiological changes occur at the myocardium because of both endurance and strength training; hence these changes must result in electrical changes of the heart as well [4,9,10,22]. Adaptations of the myocardium to endurance and strength training have been discussed with elite level athletes across sports with discussion at all levels of college sports but a lacking in discussion at division III (DIII) level [3,9,18]. Therefore, although reports of incidence rates of SCD exist across multiple athletic levels (Division III, II, I, pro), EKG use as a mandatory pre-participation screening continues to be debated with many halts in the discussion as researchers have begun to try and understand the possible mechanisms behind SCD in athletes.

This literature review will focus on a concise summation of current literature regarding EKG changes in athletes, more specifically on the prevalence of EKG abnormalities in a college aged population. From this, a potential call to action for testing DII athletes due to the lack of consistent medical monitoring, and thus EKG as a prescreening tool becomes more important.

Methods

A search of 52 different sources was conducted using eight keywords as the first level of screening for articles, including: EKG, division 3 athletes, college athletes, sudden cardiac death, EKG screening, prevalence, analysis, and EKG abnormalities. All articles matching the keywords were gathered from the databases listed, and in total 165 articles were collected. The first cull was to remove any articles from 2014 or earlier to maintain a 12-year limit on the body of research. After the first cull, 113 articles were selected. The remaining article abstracts were reviewed for pertinence to the purpose of this literature review. Once the 113 abstracts were reviewed, the articles were imported into Rayyan© review software for screening assistance. This brought the number of abstracts down to 67. Upon final review, 35 articles were selected for full-text review by both authors and included in this literature review.

Discussion

Electrocardiograms in athletes: Sudden cardiac death

Athletes can be identified across multiple age ranges, ethnicities, different genders, exercise or sport modalities, fitness levels, and health statuses. For athletes in the United States of America (USA), those who compete at either a scholastic level or pro level typically will undergo a series of pre-exercise or pre-participation screening prior to being cleared for participation [20]. One topic of debate, particularly in the past 10 - 20 years, has been the inclusion of 12-lead EKGs as part of a mandatory screening process for athletes. To the knowledge of these authors, a 12-lead EKG is not a mandatory pre-participation screening tool for athletic competition. For the purposes of this review the authors will focus on examining other possible benefits from 12-lead electrocardiogram testing in a division III university campus setting versus re-visiting the conversation of whether EKG testing should be part of the mandatory pre-participation screening in college athletes.

Exercise and sports training results in a multitude of anatomical and physiological changes with the myocardium, yielding increased performance and health benefits as well [4]. Often in research the terms “athlete’s heart” and “cardiac remodeling” are used to express the specific changes to left ventricular size and function i.e. increased stroke volume and decreased heart rate, because of training [7,14]. The anatomical changes in increased left ventricular mass have often been discussed as mimicking the appearance of hypertrophic cardiomyopathy, however with positive implications instead of negative [4,24,33]. These anatomical changes often are accompanied with physiological changes as well as intrinsic electrical changes within the myocardium which are at times linked to the discussion of sudden cardiac death (SCD) in athletes [7,24].

SCD in athletes has been discussed in length elsewhere; However, the authors of this paper want to review the statistics on SCD as it remains a part of the larger discussion regarding EKG changes and abnormalities that are seen with athletes and physically fit individuals [10]. Incidence rates of SCD in athletes have been recorded in the most recent literature as 1:63,682 athlete-years (95% CI, 1:54 065-1:75 010) according to some researchers [26]. The authors of this review chose to pull information from this source as the study was conducted over a 20-year time frame, done retrospectively, and included athletes that were enrolled at either a division I, II, or III level which is a similar population that the authors of this paper are interested in [26]. Current incidence rates of SCD appear low to the untrained eye yet many researchers still ask the question and in some cases are pushing for 12-lead EKGs to become a part of a mandatory pre-participation screening as other EKG abnormalities are seen in athletes yet sometimes not until an issue has arisen warranting an EKG [3]. The authors of this paper wanted to quickly review SCD and the connection to 12-lead EKGs, however, are more focused on the prevalence of other EKG abnormalities that can be seen in athletes in trained individuals that would offer further insight to health professionals and those looking to keep athletes safe while competing.

Prevalence of EKG abnormalities in athletes

The Seattle criteria versus other methods

EKGs are a simple, easy, and non-invasive method of measuring the electrical physiology of the myocardium while allowing the opportunity to infer certain mechanical implications of the electrical aspects that are seen [6,7]. Since researchers and clinicians have begun implementing EKGs in athletes as both a diagnostic and preventative tool, certain "normal changes" can be seen on an athlete's EKG that may not be present on the EKG of an untrained or physically unfit individual [9,11]. Arguably one of the largest issues that clinicians and other health professionals will face is how to distinguish between normal EKGs and abnormal EKGs. Additionally, medical professionals will face the challenge of determining whether an EKG abnormality that is seen on an athlete's EKG is one that warrants further clinical/medical evaluation, or if it is simply considered a normal variant due to training [14]. Multiple resources compiled over the years by medical professionals exist to help medical doctors and clinicians in determining if EKG abnormalities are dangerous and warrant further evaluation.

Two major resources that currently exist are the Seattle criteria and the international criteria, both of which can be used by healthcare professionals to determine if abnormal EKGs in athletes warrant further medical evaluation. The Seattle criteria and international criteria will be discussed in this review; there are however other criteria such as the European society of cardiology (ESC) and the refined criteria.

The ESC was developed initially in 2005, prior to the Seattle criteria which was developed in 2013 and prior to the refined criteria, developed in 2014 [22]. Reiteration and updates have occurred throughout the years to account for more accurate EKG specificity as practitioners develop a better understanding of the physiology that is inferred through EKGs.

Throughout the years both the Seattle and international criteria have been used to help professionals although the international criteria, being the newer of the two, does not have the body of literature behind it that the Seattle criteria does [6,22]. This is understandable as the international criteria has not been around as long as the Seattle criteria. Favorability of the international criteria, however, has begun increasing, mostly due to updated guidelines, reduction in false-positive tests, and reduction in abnormal diagnosed EKGS all while maintaining sensitivity [6]. Recently, Cosio-Lima and colleagues [8] determined rates of abnormal EKGs using both the International (n = 2 (3.6%), p = .004) and Seattle criteria (n = 12 (21.4%), p = 0.004). These values agree with other researchers who note that a decrease in expert over-read flagged EKGs with the Seattle criteria (3%) to 1.6% using the international criteria, values that were both found to be statistically significant at p = < 0.0001 [15]. Other experts who have begun researching the difference in "criteria" for analyzing EKGs have begun to determine that some of the high false-positive findings can be attributed to differences in races and ethnicities when using EKGs, particularly among African American athletes [6]. Regardless of race, the international criteria still seems to carry a higher level of specificity when compared to other criteria.

Multiple reasons exist for the continuing updates to these criteria, including a better understanding of EKGs as they relate to physiology, updates to the use of EKG in different racial populations, and the need for continuously determining which EKG abnormalities are considered dangerous or normal variant [6].

Common EKG abnormalities

As discussed earlier, an abundance of anatomical and physiological changes in the myocardium occur because of sport and fitness training, many of which to this time have been discussed with regards to SCD [4,7,14]. There is still, however, a great amount of information that is unknown about the prevalence (and analysis) of other EKG abnormalities with trained athletes. Some of the most common changes that are analyzed and discussed include QRS complex voltage changes suggesting an increase in left ventricular mass, QT interval changes and the potential for negative side effects leading to early-repolarization, and T wave disparities [3,9,18,22].

The use of EKGs in athletes as preventative measures in athletes, if nothing else, allows for the ability to establish a baseline EKG that can be compared to EKGs that can or need to be done after athletic training or in the presence of a cardiac issue during competition. Furthermore, when (or if) a compassionate and kind connection exists between the athletes and the individuals performing the EKGs, then an aspect of education could help to reduce worry and anxiety, particularly if an athlete produces a false positive. EKG use in athletes at different points during their training age, allows for practitioners to safely identify normal variants and common EKG abnormalities. Among the most common EKG abnormalities found in athletes are sinus bradycardia and arrhythmia, changes in QRS voltages resulting in left ventricular hypertrophy (LVH) and right ventricular hypertrophy (RVH), and early repolarization [22].

Many other abnormalities such as T wave inversion and other T wave abnormalities can be seen, as well as changes in conduction through the atrioventricular node (AV node) leading to heart blocks [18]. One study of 360 participants which included an even split of athletes to controls, was conducted in Nigeria and the authors noticed a significant difference ($p < .05$) in athletes to the control population in heart rate (control: 84.12 ± 14.100, athletes: 80.16 ± 147.021, $p = .008$) PR interval (control: M = 148.72, SD = 24.33, athletes: M = 158.17 SD = 34.68, $p = .003$), T wave amplitude (control: M = 4.09 SD = 1.55, athletes: M = 4.52 SD = 2.21, $p = .034$), and R wave amplitude (control: M = 13.4167 SD = 4.53, athletes: M = 14.77 SD = 5.73, $p = .013$) (29). Jacob and colleagues [18] discovered the prevalence of isolated T wave inversion to be roughly 1.3% when sampling collegiate athletes (N = 1755) over a span of 10 years, with no correlation or association to hypertrophic cardiomyopathy in these athletes. These findings are similar to others who have examined the prevalence of abnormalities as well and are in fact almost identical to those of Dores and colleagues [9] who discovered a T wave inversion prevalence of 1.2% in athletes. Both sets of authors admit that the use of different criteria, such as Seattle versus international, intensity level of the sport, race, and gender all can play a role in T wave inversion abnormalities [9,18]. Other researchers have found T wave inversion prevalence to be as high as 20% [33]. Still, other EKG abnormalities prove to be more prevalent, such as enlargement of the chambers or myocardial tissue.

Enlargement within the myocardium can occur as either concentric or eccentric, where concentric enlargement (hypertrophy) refers to a thickening of the myocardial muscle tissue and eccentric enlargement (hypertrophy) refers to the ability of the chambers to dilate further and accept a higher volume of blood [14,19]. Left atrial enlargement (LAE) has recently been seen to be prevalent in as much as 2.1% of athletes [9]. These values still are as high as LVH, which has been noted to be 13% of those without low voltage QRS [35]. Some authors have noted left ventricular hypertrophy (via Sokolow-Lyon index) to be as high as 67.6% in Nigerian athletes [16]. Another common EKG abnormality in the athletic population is the presence of low-voltage QRS complexes.

Low voltage QRS (LQRSV) is defined elsewhere by Zorzi and colleagues [35], who also succinctly explain how low voltage QRS has been linked both to cardiac and non-cardiac conditions. LQRSV can easily be seen in obese individuals due to increased impedance of the electrical current due to increased mass and tissue between the myocardium and the electrodes [35]. What hasn't been fully explained yet is if and how LQRSV is seen in athletes. Authors in Italy noted that in a sample of N = 2229 athletes, 1.1% of the total sample were seen to have LQRSV with the percentage increasing (2.2%) in elite level athletes, which was significantly different ($p < 0.001$) when compared to non-athletes [35]. Although the authors note that the prevalence of LQRSV is low in athletes, the need to further exclude the presence of underlying cardiomyopathy is suggested [35]. Additional abnormalities on the EKG at the level of the QRS can be seen in the form of a widened QRS complex, suggesting slowing of conduction through the ventricles and more recently the note of a fragmented QRS complex in athletes [14,25]. Currently a fragmented QRS complex is seen solely as a frequent EKG change seen in 22% of healthy athletes as a right ventricular modeling aspect, mostly due to exercise training [25]. Most EKG abnormalities in athletes and ones discussed to this point are most thought to be associated with SCD due to a link in the physiological changes that are seen in conditions such as hypertrophic cardiomyopathy [2,4,8,10]. One final EKG abnormality that these authors believe deserves discussion is early repolarization pattern (ERp).

ERp is a common EKG change that is seen in both male and female athletes as mostly benign physiological adaptation to exercise training [1]. ERp warrants discussion because as with many EKG changes seen with athletes, these changes often mimic those that are not always benign [31]. The exact definition and detailed characteristics of ERp have been discussed by Aagaard and colleagues [1] and won't be elaborated on in detail in this review. The authors of this review are specifically interested in what the prevalence of ERp is, and even more so, the prevalence within a college-aged setting. Recently authors have noted a prevalence of anywhere between 13.2% and 27% [13,32]. Both Halasz., *et al*. [13] and Vecchiato., *et al*. [32] utilized a population below the age of 18. This is important to note because it strengthens these authors' discussion that more needs to be researched in the college athletic population. Furthermore, upon searching this topic the authors of this review were surprised to find only 6 articles matched a sub-search that was conducted with keywords: "early repolarization" and "college athletes". This can be attributed to simply an issue of keywords used in the search, the time frame limitation (12 years), or the available databases. When removing the word "college" from the keyword search and using simply "early repolarization" and "athletes", a much larger volume (187) articles were found. This further strengthens the point that more evaluation into common EKG abnormalities should be done at the college-aged level in athletes and particularly in Division III athletics.

EKG as a prescreening tool: Future directions in college athletics

There has been little discussion about the use of EKGs as a prescreening tool in DIII athletics versus DI or DII athletics. Some authors have noted that DI schools are more likely to incorporate EKG testing and Echocardiography testing as part of their pre-screening routine [5]. Furthermore, these same authors noted that although DI schools are more likely to utilize EKG, more than 80% of the 235 schools included in this study (all athletic divisions) had cardiac magnetic resonance imaging (MRI) availability within 25 miles [5]. Cardiac MRI and electrophysiology could be argued as more specialized than ECG or echocardiography. Conway and colleagues [5] noted that simple 12-lead EKG and resting echocardiography were available to 97% of the schools that were observed from their study. From this situation, practitioners can infer that DI schools are more likely to utilize ECG due to less budgetary constraints. Further discussion on standards of pre-participation screening in athletes should continue to occur if a disparity in pre-participation screening is occurring between colleges and universities of different divisions.

Disparities among college and university division levels appears to be evident, and if schools don't want to implement resting EKG for all their athletes, a school might begin with high(er) risk individuals such as male basketball players. Athletics at the DI level in the "Power 5" utilize EKG testing in 62% of the schools in those 5 divisions [21]. Male basketball players are considered higher risk and thus the percentage of schools in the "Power 5" that utilize EKG with their male basketball players is as high as 78% [21]. A deeper discussion regarding ethics should also be had when talking about the standards of pre-participation screening in college and university athletes. Arguably there should be one standard amongst all divisions. Referring to the study by Conway and colleagues [5], with 97% of schools having accessibility and availability to 12-lead EKG testing, this should be seen as a vital opportunity for those institutions. Particularly institutions with health science, exercise science, nursing, physician assistant study, or related programs as 12-lead EKG is a common skill taught to undergraduate students in these programs. Institutions with these programs could use undergraduate students to conduct the 12-lead ECGs and a primary provider who may already be on campus to prepare them, such as a physician's assistant, nurse practitioner, or any qualified physician. Not only would this service be a vital part of the health spectrum and pre-participation screening for the student athletes, but also as a crucial skill and experience for students in the health professions.

Conclusion

The use of 12-lead EKGs in collegiate athletes as a pre-screening tool for athletics continues to be a highly debated topic. Researchers have established that most universities and schools in the United States have access to 12-lead EKG within a short distance [21]. Still many medical experts will argue that because the risk of sudden cardiac death and other dangerous arrythmias remain low, that 12-lead EKGs may not be the best use of time and funds when screening athletes [2,5,10,20,24]. Future research studies aim to determine if utilizing 12-lead EKGs in collegiate athletes can yield other benefits such as a teaching tool for students in exercise science, health science, or other related majors. Additionally, 12-lead EKG machines are common on campuses with exercise science or other related health programs and athletes on campuses can be valuable volunteers for young students to learn and practice this extremely valuable skill.

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