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ORIGINAL

ABNORMAL ELECTROCARDIOGRAPHIC FINDINGS IN PROFESSIONAL SOCCER PLAYERS

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ABSTRACT

Cardiac adaptations to training are influenced by the type of exercise performed. In some instances, these adaptations can lead to changes that might result in sudden death, detectable through electrocardiographic manifestations. This is why the ECG has been suggested as a screening tool in pre-participation evaluations. The objective of this study is to describe such findings in a group of professional soccer players training at an altitude of 2600 meters above sea level between 2017 and 2022. A total of 111 soccer players participated, including 81 men and 30 women, with an average age of 26 and 24 years respectively, none of whom exhibited cardiovascular symptoms. The average heart rate was 59 bpm in men and 62 bpm in women. Fourteen participants showed electrocardiographic changes, including early repolarization disorder, incomplete right bundle branch block, T wave inversion, and sinus bradycardia. Only one player met echocardiographic criteria for concentric hypertrophy.

KEYWORDS: Professional Soccer Players, Electrocardiogram, Echocardiogram, High Performance

1. INTRODUCTION

Physical activity and physical exercise have been linked to certain

cardiovascular, metabolic, neurological and osteomuscular adaptations that are correlated with multiple health benefits in all aspects, but which are mainly related to a decrease in cardiovascular mortality. However, for the cardiac muscle there is a threshold, after which the excessive volume of training begins to generate adaptations that are detrimental because they result in pathological alterations of the rhythm or in changes so beneficial to health (Cordero, Masiá, & Galve, 2014). The cardiovascular system is the one that can present these paradoxical changes because it must respond to the demands required by the exposure to exercise, mainly when it comes to performing high intensity intervals for prolonged periods, which leads to different adaptations, which in turn depend on the stimulus (Baggish & Wood, 2011). The type of training has also been related to possible electrophysiological and morphological alterations (Barbier, Ville, Kervio, Walther, & Carré, 2006). Strength training, for example, may be related more to ventricular hypertrophy and possible complications, while endurance training may be related mainly to alterations in heart rhythm (Maron & Pelliccia, 2006), all of which will depend on the way in which specific adaptations occur and these in turn also depend on factors such as race, age, sex and gender (D'Silva & Sharma, 2014).The most relevant situation that has been linked to professional sports training is sudden cardiac death. It is for this reason that our objective is to broaden the criteria applicable by means of electrocardiographic and echocardiographic analysis to high performance athletes who train at high altitude (intermediate; 2600 AMSL) since there are no specific data for this type of soccer player population.

2. Methods

Observational, descriptive study consisting of collecting data from the clinical history of the soccer players at the same time as the electrocardiogram and echocardiogram were taken independently by two cardiologists. In case of discrepancies in the concepts issued, the differences in the interpretation were analyzed by a third-party cardiologist. The electrocardiographic interpretation was performed using the 2015 Seattle criteria and data were processed with IBM SPSS statistics v.25 software. In the univariate analysis, proportions are reported for qualitative variables. For quantitative variables, means, standard deviation and coefficient of variation are reported; for variables that do not follow a normal distribution, medians and quartiles are reported. s 1 and 3. A pilot test was carried out with 5% of the study population to adjust ensure complete collection and to evaluate the quality of the sources of information. This study will be carried out once it has been approved by the Medical Ethics Committee of the Universidad Nacional de Colombia, in compliance with national and international legislation.

3. Results

A total of 81 men (73%) and 30 women participated. The average age

for men was 26 years (Percentile 1-3: 23-29) and 23 years for women (Percentile 1-3: 20-27). The body mass index was 22.86 in men and 21.9 in women. The time of training at the time of the examination was 8 years on average for men and 6 for women. No data were found in the medical records related to coronary heart disease except for one of the men who had an unclear family history of sudden death (not associated with exercise or sports training at a professional level).

3.1 Electrocardiographic Findings

The average heart rate in men was 59 beats per minute, while in women it was 62. With respect to the Seattle criteria (Table 1), it was found that 85% of men could be classified as normal, while in women this percentage was 96.7% (i.e., only one of the women had borderline findings corresponding to deviation to the right of the cardiac axis).

Table 1(a): Electrocardiographic Findings

	DESCRIPTION OF THE FINDING	MEN	WOMEN
NORMAL FINDINGS	Left Ventricular Hypertrophy	15%	8%
	Right Ventricular Hypertrophy	8%	8%
	Incomplete Right Bundle Branch Block	38%	23%
	Early Repolarization	66%	62%
	ST Elevation and Negative T Wave	20%	29%
	Sinus Bradycardia	28%	29%
	Sinus Arrhythmia	9%	29%
	Atrial Union Rhythm	1%	0%
	First Degree AV Block	5%	0%
BOUNDARY FINDINGS	Mobitz I Second Degree AV Block	0%	0%
	Left Axis Deviation	1%	0%
	Left Atrial Enlargement	3%	0%
	Right Axis Deviation	5%	4%
	Right Atrial Enlargement	3%	0%
	Complete Right Bundle Branch Block	1%	0%
ABNORMAL FINDINGS	T-Wave Inversion	4%	0%
	ST Depression	0%	0%
	Pathological Q Waves	0%	0%
	Left Bundle Branch Block	0%	0%
	QRS Greater Than 140 Ms	0%	0%
	Epsilon Wave	0%	0%
	Ventricular Pre-Excitation	0%	0%
	Prolonged QT	0%	0%
	Brugada Pattern Type 1	0%	0%
	Deep Bradycardia	0%	0%
	Third Degree AV Block	0%	0%

Table 1(b): Electrocardiographic Findings

	DESCRIPTION OF THE FINDING	MEN	WOMEN
ABNORMAL FINDINGS	Mobitz II Second-Degree AV Block	0%	0%
	More Than 2 Extrasystoles	0%	0%
	Ventricular Tachyarrhythmias	0%	0%

3.2 Echocardiographic Characteristics

The imaging examination was performed to determine structural changes, ventricular function, valvular function and spectral and tissue Doppler findings (Table 2). Once these data were obtained, the degree of cardiac remodeling was obtained, finding that 85% of the participants presented normal results and the main abnormal result was concentric remodeling.

Table 2: Echocardiographic findings

	DESCRIPTION OF THE FINDING	MEN	WOMEN
STRUCTURAL CHARACTER-ISTICS	Septal wall	9	7
	Posterior wall	9	8
	Parietal Relative Thickness (Cutoff Point 0.42) (Prevalence)	17%	3%
	Free Wall	9	7
	Left Ventricular Muscle Mass Index		
	Aortic Root Diameter	28	25
	Right Ventricular Diameter	32	29
	Fractional Area Change	37	44
	Right Ventricular Mean Diameter	3,2	2,9
	Right Ventricular Basal Diameter	4,1	3,7
	Longitudinal Diameter	7,9	7
	Tricuspid Annular Plane Systolic Excursion	2,7	2,6
	Vena Cava Diameter	1	1,3
	Left Atrial Volume	36	22
	Left Atrial Area	15	14
	Right Atrial Volume	41	20
	Right Atrial Area	18	13
VENTRICULAR FUNCTION AND VOLUMES	Left Ventricular End-Diastolic Volume	101	85,5
	Left Ventricular End Systole Volume	36,5	32
	Left Ventricular End-Diastolic Index Volume	19,66	20,44
	End-Systole End-Systolic Indexed Volume	51,27	44,75
SPECTRAL AND TISSUE DOPPLER	E Wave	0,72	0,86
	A Wave	0,54	0,57
	E/A Ratio	1,39	1,4
	Deceleration Time	180,5	202
	Pulmonary Artery Systolic Pressure	27	27
	Maximum Velocity	2,3	2,35

4. Discussion

This research presents the initial standardized dataset combining electrocardiography (ECG) and echocardiography results from a diverse group of elite soccer players in Colombia, ensuring an inclusion in terms of both genders. Establishing standard ranges for cardiac parameters in athletes is crucial for distinguishing between adaptations due to training and potentially harmful conditions. However, the criteria for normality and abnormality are based on cohorts in which the characteristics of Afro-Caribbean athletes, and Latin Americans in general, are not adequately represented. FIFA encourages all players to undergo the FIFA Pre-Competition Medical Assessment (PCMA), which involves a thorough evaluation of cardiovascular health, general medical condition (including blood tests), and musculoskeletal health. Professional sports, such as football, are renowned for their rigorous physical demands, which come with a heightened risk of injuries, illnesses, and potentially adverse long-term health effects (Bakken et al., 2016). Colombian professional soccer players have an average age and a body mass index comparable to previously published studies (Gjerdalen et al., 2014). In the case of professional athletes, it is expected that processes of structural and functional changes of the heart will occur (Churchill et al., 2021). These changes are related to the increased oxygen needs for muscle tissue, which leads to the secondary development of bradycardia, which is not significant in the soccer players evaluated, a fact that is fully comparable with studies such as Pambo & Scharhag (Pambo & Scharhag, 2021) who report an average basal heart rate of 58 beats per minute. However, Serafini et al. (Serafini et al., 2012) report that in a country like Norway, where the style of play requires a higher level of endurance, the basal heart rate drops to 53.4 beats per minute, which has sometimes been correlated with the possibility of presenting episodes of severe bradycardia and consequently pathological manifestations. In simpler terms, pre-participation cardiovascular screening (PPCS) for competitive athletes is meant to check for any heart problems that could raise the risk of sudden cardiac death (SCD) while they're playing sports. Even though sudden cardiac death during sports is uncommon, it's especially tragic when it happens to young athletes who seem healthy, causing significant grief for their families and communities (Gerling et al., 2021). The morphological adaptation of the heart to exercise is influenced by the type, duration, and intensity of training (Stein, Ferrari, & Silveira, 2023). There's a noticeable link between engaging in extensive, intense exercise and certain forms of cardiac arrhythmia. It's conceivable that cardiac remodeling plays a role in the increased risk of atrial fibrillation (AF). Furthermore, it's suggested that the changes in the atria due to athletic activity aren't purely physiological and might contribute to creating a substrate that promotes arrhythmias (La Gerche et al., 2022). An undeniable link exists between heart size and fitness level, as indicated by maximal oxygen consumption (VO2 max), however, it is necessary to consider whether there is a limit to how large the heart can grow before it becomes problematic. Systematic exercise training leads to changes

in the cardiac electrocardiogram (ECG), morphology, and function. ECG findings resulting from exercise training that do not necessitate further investigation include sinus bradycardia, first-degree atrioventricular (AV) block, Mobitz type I (Wenckebach) second-degree AV block, ectopic atrial arrhythmia, incomplete right bundle branch block (RBBB), early repolarization, anterior T-wave inversions in individuals under 16 years of age, as well as in Black athletes, and sinus arrhythmia (Martinez et al., 2021). Additionally, athletes often exhibit criteria for left ventricular hypertrophy (LVH) according to established standards, but these criteria should not be applied to athletes as they can lead to significant false-positive ECG results. During dynamic training, an increase in the size of all cardiac chambers is noticed, and this increase is directly related to the athlete's level of fitness and their body size. Among athletes participating in sports with a moderate to high dynamic component, ventricular enlargement is frequent. This might be accompanied by a slightly decreased left ventricular ejection fraction (45%-50%) in elite endurance athletes, which can make it challenging to distinguish from dilated cardiomyopathy (Martinez et al., 2021).

Moreover, certain research indicates that the electrocardiograms (ECGs) of African athletes exhibit distinct characteristics compared to athletes from other backgrounds (Ekomy et al., 2024). Specifically, studies have revealed a higher prevalence of ECG abnormalities among African athletes relative to their counterparts (Pambo, Adu-Adadey, Agbodzakey, & Scharhag, 2021). These findings carry significant implications for enhancing the accuracy of electrocardiogram interval assessments during the initial screening and subsequent monitoring of football players, potentially leading to cost-effective measures (Huttin et al., 2018). Genetic and ethnic factors significantly influence the left ventricular remodeling process during the initial years of life among elite athletes. It is widely acknowledged that ECGs obtained from elite athletes typically exhibit distinctive alterations that mirror the structural and electrical adaptations of the heart (Galanti et al., 2019). However, distinguishing these athlete-specific ECG abnormalities from those associated with underlying disease, which poses a risk of sudden cardiac death during exercise, can be challenging. Despite establishing upper limits for normal heart size in athletes, there remains a gray area where the physiological adaptations of the heart overlap with cardiac conditions associated with exercise-related sudden cardiac death (Galanti et al., 2019). When examining elite male and female soccer players alongside athletes from different sports, it was noted that their average heart chamber dimensions were relatively smaller, particularly when not adjusted for body size, compared to professional basketball and American football players. This observation isn't unexpected, considering the link between left ventricle chamber size and individual body size. Additionally, the wall thickness of the heart was slightly lesser in soccer athletes, underscoring the necessity for sport-specific reference data (Churchill et al., 2021). While the publication of the International Criteria has indeed helped reduce false-positive

rates in interpreting ECGs for athletes, there remain patterns that clinicians often misinterpret, especially those lacking experience with athlete ECGs. Numerous studies indicate that inexperienced physicians frequently mistake normal athlete ECGs as abnormal, leading to additional costs and unnecessary restrictions for athletes, along with added psychological stress. However, when clinicians use a standardized ECG interpretation tool, accuracy improves. In comparisons between local interpretations and expert reviews, common misinterpretations by local providers include LVH, non-pathological TWI, isolated axis deviation, etc. Conversely, ECGs deemed normal locally but reconsidered as abnormal by experts often include pathologic TWI, biatrial enlargement, etc. These studies underscore the necessity for ongoing medical education for clinicians involved in cardiovascular care for athletes (Petek, Drezner, & Churchill, 2024). The International Criteria presently incorporate a segment for "borderline" ECG irregularities (such as left atrial enlargement, right atrial enlargement, left axis deviation, right axis deviation, complete RBBB), requiring the presence of two or more abnormalities within this category to justify additional testing (Price et al., 2014). Winkelmann et al. (Winkelmann & Crossway, 2017) report, in terms of screening methods, the ECG showed a sensitivity of 94% and a specificity of 93%, while the history had a sensitivity of 20% and a specificity of 94%, and PE had a sensitivity of 9% and a specificity of 97%. The false-positive rate for ECG was 6%, lower than that for history (8%) or PE (10%). The positive likelihood ratios were 14.8 for ECG, 3.22 for history, and 2.93 for PE, while the negative likelihood ratios were 0.055 for ECG, 0.85 for history, and 0.93 for PE. In total, 160 potentially lethal cardiovascular conditions were identified, with a detection rate of 0.3% or 1 in 294 patients. The most common conditions diagnosticated the ECG included Wolff-Parkinson-White syndrome (42%), long QT syndrome (11%), hypertrophic cardiomyopathy (11%), dilated cardiomyopathy (7%), coronary artery disease or myocardial ischemia (6%), and arrhythmogenic right ventricular cardiomyopathy (3%) (Winkelmann et al., 2017). Employing 12-lead ECG interpreted according to contemporary standards is recommended as the gold standard for cardiovascular disease screening in athletes, prompting a reassessment of relying solely on history and physical examination for screening purposes (Harmon, Zigman, & Drezner, 2015). However, the optimal approach to cardiovascular screening among young competitive athletes remains a subject of intense debate. According to the American Heart Association (AHA) and American College of Cardiology (ACC), cardiovascular screening aims to proactively identify or arouse suspicion regarding previously undetected cardiovascular conditions, primarily genetic or congenital in nature, which are linked to instances of sudden cardiac arrest (SCA) and sudden death in young individuals. Screening methods, including standardized history, physical examination, and a resting 12-lead electrocardiogram (ECG), in athletes suggesting that ECG in athletes has a low false-positive rate and can offer superior accuracy in detecting potentially dangerous cardiovascular

conditions, may lack balance[24]. The Belgian Health Care Knowledge Centre recently stated that until individuals at high risk of sudden death can be reliably identified and managed appropriately, young athletes should not undergo pre-participation screening. Similarly, the National Collegiate Athletic Association has issued a statement that does not endorse universal ECG screening for student athletes before granting clearance to participate in sports (Drezner et al., 2016). In simplified terms, whether all athletes should get an electrocardiogram (ECG) as a standard screening is still a subject of debate. American guidelines do support using ECG alongside medical history and physical exams for certain groups, given there's proper oversight and resources for further testing (Petek & Baggish, 2020b). The criteria for ECG screening have improved, leading to fewer incorrect positive results while still catching heart issues in athletes. However, the high expenses, lack of experienced ECG interpreters, and uncertainties about how well ECG works in some groups are the main drawbacks (Petek & Baggish, 2020a).

Athletes undergo changes in response to exercise training, which can differ based on their ethnic background. Even though athletes are usually in top physical condition, sudden cardiac death is a rare but devastating event that happens 2.5 times more often in elite athletes than in young people of the same age who are not athletes. A few studies looked at Hispanic athletes, and they were found to be like Caucasian athletes in those studies. Although there's a hint that different ethnicities might affect how we interpret athletes' ECGs, there isn't enough evidence from existing studies to recommend changes to the current ECG interpretation criteria for athletes (Davis, Semsarian, Orchard, La Gerche, & Orchard, 2022). Further research comparing athletes from different ethnic backgrounds is needed to improve guidelines for ECG interpretation in athletes. In our group of high-level elite athletes, the occurrence of abnormal ECGs was notably rare based on the latest ECG interpretation criteria. The most common relevant ECG alteration observed was isolated T-wave inversion (Perrin et al., 2017). For instance, convex ST-segment elevation with terminal T-wave inversion in anterior precordial leads is probably a benign variant, sometimes observed in Japanese individuals, without significant clinical implications. On the other hand, diffuse and deeply inverted T-waves in precordial leads, sometimes accompanied by ST-segment depression, likely indicate the early stages or incomplete manifestation of a pathological heart condition like hypertrophic cardiomyopathy (HCM), irrespective of ethnicity (Kervio et al., 2013). While European guidelines and most sporting societies recommend ECG screening, US guidelines do so only under certain circumstances. Significant limitations of ECG screening include high costs, the need for significant expertise for accurate interpretation, higher than optimal FPR in some populations, and potential false negatives in certain conditions (e.g., coronary anomalies) (Petek & Baggish, 2020a). The ECG and ECHO results clearly indicate that being of black race or ethnicity significantly predisposes individuals to "abnormal" ECGs according to criteria based on

Caucasian populations. These key findings align with those reported in other studies focused on different ethnicities, involving both adult and adolescent amateur and professional athletes (Pambo et al., 2021).

5. Conclusion

In summary, this study presents the first comprehensive collection of normative electrocardiographic (ECG) and echocardiographic data obtained from elite male and female soccer players in the United States. Our findings reveal a high occurrence of harmless ECG changes related to training, as well as the identification of specific abnormal ECG patterns that lack precision in indicating true underlying cardiac issues. Consistent with findings from other groups of elite athletes, our data confirm an increased prevalence of structural changes in the heart due to training, surpassing the typical clinical thresholds observed in the general population. We anticipate that the insights provided in this study will serve as a valuable resource for future clinical evaluations of elite male and female soccer players.

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