Original Article

Analysis of the mean electrical axis of the ventricular depolarization from standard electrographic leads in normal adult males

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ABSTRACT

Background: The ECG is vital in diagnosing cardiovascular health by examining heart activity. This study investigates the relationship between the cardiac vector and body composition parameters (height, weight, BMI) in young Nepali males, aiming to improve ECG interpretation by identifying population-specific physiological influences on cardiac vector orientation. The objective of this study is to analyze the correlation between the cardiac vector and physical attributes—height, weight, BSA, and BMI—in healthy males aged 18-25, establishing a reference for how these factors impact cardiac vector, thus enhancing ECG interpretation accuracy for this demographic.

Methods: A cross-sectional study was conducted among 116 male subjects, aged 18-25 years, comprising students and staff of Gandaki Medical College Teaching Hospital and Research Center, Pokhara, Nepal, over the period from June to September 2023. Electrocardiograms (ECGs) were recorded using a standard ECG machine with conventional limb leads. The mean electrical axis of the heart for each individual was determined by plotting the net voltage of the QRS complex in Lead-I and Lead-III. The study aimed to analyze the correlation between the cardiac vector and physical measurements, such as height, weight, Body Surface Area (BSA), and Body Mass Index (BMI). Data analysis was performed using SPSS version 27.0.

Results: The normal mean electrical axis of the healthy male subjects was observed as 57.88 · 24.55°. There was significant positive correlation of cardiac vector with height ($p < 0.05$), whereas negative correlation was observed with weight and BMI ($p < 0.01$). However, there was no significant correlation with BSA. In our study we observed the maximum left axis cardiac vector as -10° and right axis as 90° among 116 male subjects.

Conclusion: We established a cardiac vector with values differing from those reported in other studies, using standard bipolar limb leads in normal, healthy male subjects. It is also examined that greater BMI has shifted the electrical activity of the ventricles to the left.

Keywords: Axis deviation, BMI, cardiac vector, electrocardiograph

Article Information

Received: 30 April 2024 Accepted: 29 November 2024 Published online: 29 November 2024

INTRODUCTION

Electrocardiograms (ECGs) are essential tools for diagnosing coronary artery disease [1], widely used since the 1980s due to their non-invasive and cost-effective nature [2]. The mean electrical axis, calculated using the net voltage of the QRS complex in Leads I and III, indicates the net direction of ventricular depolarization, normally between -30° and +90°[3]. Deviations from this range, caused by factors like increased cardiac muscle mass, conduction defects, or infarct tissue, can indicate underlying cardiac issues [4].

Studies show population-specific variations in the mean electrical axis. For instance, an Indian study reported an average angle of 68.93° [5], while our previous study noted a mean electrical axis of 61.7±23.51° in healthy females [6]. Such differences highlight the need for population-specific reference values to avoid misinterpretations. Factors influencing ECG parameters include individual traits (gender, age, body size, race, physical activity) and environmental influences (socio-economic status, altitude, smoking history, posture, and technical aspects) [7].

The misuse of control data of normal electrical axis of the heart from non-native populations often leads to misinterpretation of ECG results. To address these issues, it is crucial to determine appropriate reference values for each population to ensure accurate interpretation. To the best of our knowledge, no such reference values have been set for cardiac function test in male in this country. Therefore, this research will contribute to the development of health science. The traditional assumption has been examined that there is a close relationship between the electrical and anatomical axis of the heart [8]. Keeping in mind the observations of the researchers that electrical activity direction is linked to anatomical position of chest cavity; the aim of the study was to investigate the effect of different physical and anthropometric parameters on the mean electrical activity direction in males.

METHODS

A prospective cross-sectional study was conducted among 114 male subjects, aged 18-25 years, including students and staff of Gandaki Medical College Teaching Hospital and Research Center, Pokhara, Nepal. The study spanned four months, from June to September 2023. Ethical clearance was obtained from the Institutional Review Committee (IRC) of Gandaki Medical College (Ref no: 295/079/080). All recordings were taken under laboratory conditions (26 ± 2°C) in the skill lab of the Department of Physiology.

Participants were provided with a detailed explanation of the study and were asked to sign a written consent form, which included information on their name, height, weight, age, body surface area (BSA), and body mass index (BMI). Each participant was interviewed to assess demographic information, health history, and personal habits, including alcohol consumption and smoking. Relevant alcohol and smoking histories were elicited to ensure that subjects met the criteria of normal and healthy individuals. All subjects were apparently fit and not receiving any medication at the time of the study.

Standard ECG machine (MAC 600, GE MSIT, Inc., USA) was used and the ECG was recorded using the conventional limb leads. Before recording of the ECG, the whole procedure was explained to the subject. The subject was asked to relax in supine position for 10 minutes. The relaxed physical and mental state of the subject was confirmed and then the ECG was recorded in supine position. The individual mean electrical axis of the heart was plotted using the net voltage of QRS complex of Lead-I and Lead-III [9]. ECG reading was carried out by single observer in order to eliminate interpreter bias. We have further calculated the mean electrical axis with the formulae used in the previous research (Tan α= (1.154*aVF)/ Lead 1) [5]. BSA was recorded in sq. m. from the subject's height and weight by reference to the nomogram prepared by Boothby and Sandiford, based on Dubois's formula [10]: BSA= Weight $(kg)^{0.425}$ · Height $(m)^{0.725}$ · 71.84. BMI was calculated from the standard formula i.e. BMI= weight (kg)/ height $(m)^2$.

Various dependent and independent parameters of normal male subjects were recorded and analyzed to establish a normative database of the mean electrical axis. We also examined the potential correlation between the axis of the cardiac vector and physical measurements, such as height, weight, BSA, and BMI, which could help propose reference values for analyzing vectors in ECG.

The data were analyzed using the Pearson correlation test, with a P value of less than 0.05 considered statistically significant. All analyses were performed using the Statistical Package for Social Sciences (SPSS) version 27.0.

RESULTS

Mean electrical axis (cardiac vector) showed the normal angle

The cardiac vector of the QRS complex is a clinically significant parameter in ECG diagnostics. In our study, the normal cardiac vector in healthy male subjects was found to be 57.8±24.54° (Figure 1), which shows a left deviation compared to our previous findings.

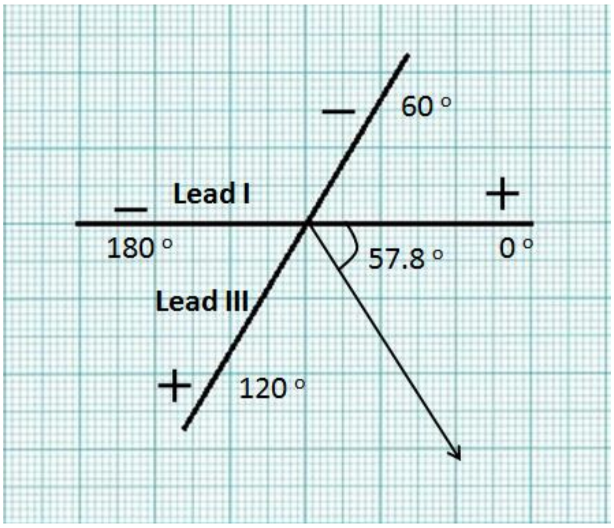


Figure 1: The mean electrical axis of the heart from lead I and III of ECG from conventional limb leads

Height showed positive and weight showed negative correlation with the cardiac vector

We investigated the correlation between the cardiac vector and various physical and anthropometric parameters. Correlation analysis of the cardiac vector with different physical parameters (Table 1) revealed a significant positive correlation with height ($P < 0.05$) and a significant negative correlation with weight and BMI ($P < 0.01$). This indicates that overweight individuals are more prone to develop left axis deviation. Additionally, BSA did not show a significant correlation with the cardiac vector.

The mean electrical axis of the heart from the graph and by using the formulae showed the same result

Our results showed the normal cardiac vector plotted from the mean electrical axis of the heart using the net voltage of the QRS complex from Lead-I and Lead-III. To further validate our findings, we randomly calculated the axis in ECG using the formula: Tan α= (1.154 x aVF)/ Lead 1.

The mean electrical axis of the heart obtained from both methods yielded consistent results, as demonstrated in the figure below. This method provides accuracy comparable to conventional methods that involve plotting the graph.

Table 1: Correlation coefficients between cardiac vector and physical anthropometric variables

Parameters	Mean ± SD	Pearson Correlation	P value
Cardiac Vector	57.88±24.540		
Height	1.68±.074	.215*	.020
Weight	64.30±8.053	-.259**	.005
BSA	614.56±44.38	-.093	.320
BMI	22.68±2.77	-.425**	.000

**. Correlation is significant at the 0.01 level.
*. Correlation is significant at the 0.05 level.

Greater BMI has induced the electrical activity of the ventricles to the left

We observed a negative correlation between BMI and the cardiac vector ($p<0.01$). To further investigate the effect of BMI on the cardiac vector, we categorized BMI according to nutritional status based on World Health Organization criteria and analyzed the cardiac vector distribution (Figure 2). The results indicate that the cardiac vector deviates towards the right axis in individuals with low BMI, while it shifts towards the left axis in those with high BMI. This trend shows that as BMI increases, the cardiac vector decreases, reinforcing the observed negative correlation.

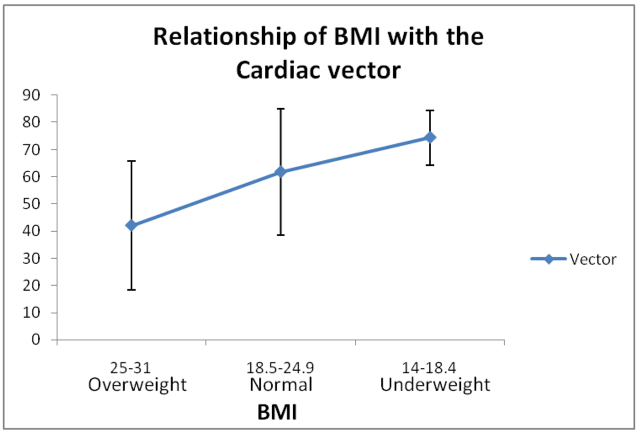
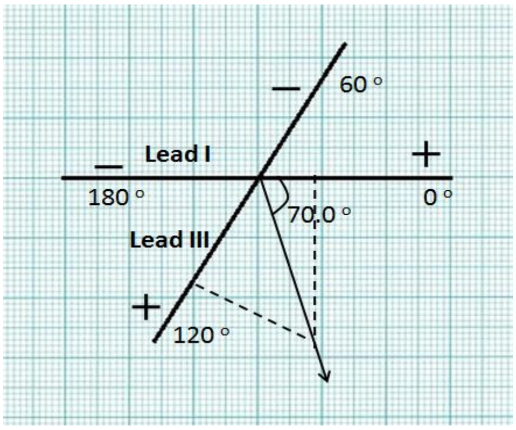


Figure 2: The inverse relationship between BMI and the cardiac vector

A.



B.

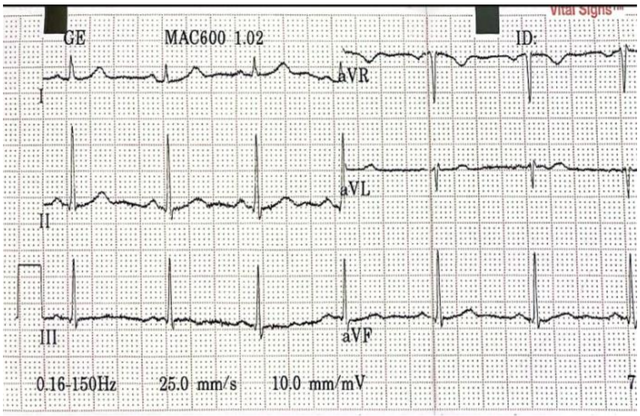


Figure 3: Representative figure showing the axis of cardiac vector with representative ECG graph.
(A) The mean electrical axis of the heart from lead I and III of ECG from conventional limb leads. (B) The representative ECG of figure A.

Table 2: QRS voltage values from the above ECG figure and the calculation of an angle using the fourmule.

Leads	QRS wave net voltage measured in mm
Lead I	5
Lead II	13
Lead III	11
aVR	-10
aVL	-4
aVF	12
Calculated angle using the formulae: **Tan α= (1.154 X aVF)/ Lead 1**	70.08

DISCUSSION

Assessment of mean electrical axis of the heart is one of the important parameters to be studied in ECG, as it provides information about the conduction defects and also the hypertrophy of the ventricles of heart [11]. We observed that the axis of mean cardiac vector in our study is less than that observed in the Indian study [5]. It may be due to differences among the populations, gender or technical and procedural issues. Several studies have attempted to explore the relation between gender and the electrical activity of the heart and found significant gender differences in vectors. In our study, we observed that the normal mean electrical axis of the healthy male subjects is (57.8±24.54°) which is deviated towards the left in compare to the result obtained from our previous study in female subjects (61.7±23.51°) [6]. Athletes showed a higher prevalence of left atrial enlargement and left axis deviation compared to controls. De Bacquer et al. [12] found that the prevalence of left axis deviation was 21.7% with higher prevalence in males than in females. The prevalence of left ventricular hypertrophy was 9.6%, with a higher prevalence in males than in females. Zerkiebel et al. [13] found that men had a lower heart rate than women, younger men had lower a heart rate than older men. They attributed the inverse relation of heart rate to a higher level of physical activity. Moreover, the lower heart rate in men compared to that in women may be explained by the same phenomenon. Our findings agree with the findings of the above studies with respect to left deviation in male in compare to female. Hence, this research shows the need of population based normal ventricular electrical axis of the heart for the accuracy.

Further, we revealed the correlation between the electrical activities and physical parameters in our study. We observed that the greater BMI has shifted the electrical activity of the ventricles to the left. In this study, there was a pronounced tendency toward the horizontal cardiac vector with increasing body weight and in general, the influence of relative body weight was more prominent to influence the cardiac vector. Hence, we conclude that BMI is novel key player for a more precise definition of normal electrocardiographic standards. It is clear from these data that, in healthy males, differences in relative fatness or leanness are reflected in characteristic differences in the electrocardiograms and affecting the axis of cardiac vector. The BMI is negatively correlated to the electrical activity of the heart which may be because, the greater BMI has shifted the electrical activity of repolarization of the ventricles to the left [14]. An increase in body mass index (BMI) leads to a corresponding rise in total blood volume and cardiac output, primarily due to the higher metabolic demands imposed by excess body weight [15]. As a result, at any given level of physical activity, obese individuals experience a greater cardiac workload compared to their lean counterparts [16]. Furthermore, obesity shifts the Frank-Starling curve to the left due to increases in left ventricular filling pressure and volume, which over time can result in ventricular chamber dilation. This dilation subsequently elevates wall stress, which predisposes the myocardium to an increase in mass, potentially leading to left ventricular hypertrophy [17]. From our study we can presume that the increase in BMI (overweight) causes the increase in left ventricle mass which leads to cardiac vector towards the left or horizontal position.

The concept of cardiac vector describing the electrical activity of the heart and the three cardinal bipolar limb lead vectors (lead I, lead II & lead III) forming an equilateral triangle was first described by Einthoven. However, plotting of vectors and then measuring the angle is not practically possible in clinical setting. It is also possible to calculate the Cardiac vector accurately by using the formula derived in the present paper, hence we randomly plotted the mean electrical axis of the heart using the net voltage of QRS complex from Lead-I and Lead-III and also calculated the axis in ECG using the formulae: Tan α= (1.154 x aVF)/ Lead 1. The result obtained from this formula is comparable with existing method of accurate measurement by plotting the voltage on axes of Lead-I and Lead-III. This research illustrates the efficiency, accuracy and good results. Hence, the accurate assessment of the cardiac vector by this formula can also help the physicians, of the primary as well as secondary level hospitals without using a graph.

Conclusion

In conclusion, establishing population-specific reference values for the electrical axis of the heart is crucial for improving diagnostic accuracy for cardiac hypertrophy and other heart conditions in diverse populations. This study lays a robust foundation for future research, advocating for more extensive and inclusive studies that account for a wider range of variables influencing the electrical axis of the heart. Future findings may provide valuable reference values of the cardiac vector for health-monitoring systems.

Study Limitation:

The current study is limited to a specific population affecting the generalizability of the findings. Additionally, the sample size may be insufficient to capture the full diversity within the population, leading to biased results. Furthermore, the absence of a local population-based normal angle of the cardiac vector as a reference may limit the study's ability to provide accurate assessments and comparisons. Therefore, establishing population-specific reference values for the electrical axis of the heart can enhance diagnostic accuracy for cardiac hypertrophy and other heart conditions in diverse populations. This study provides a foundation for future research, encouraging more extensive and inclusive studies that consider a broader range of variables affecting the electrical axis of the heart. Additionally, incorporating the importance of population-specific reference values into medical education and training programs will increase awareness and understanding.

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