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Research Article

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Epidemiological Investigations of Cardiovascular Risk Factors: Implications of ECG and HRV Analysis

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ABSTRACT

Cardiovascular diseases (CVDs) remain a leading cause of mortality worldwide, necessitating the identification and analysis of key risk factors. This study examines the epidemiological effects of cardiovascular risk factors, such as heart rate variability (HRV) and electrocardiogram (ECG) analysis, diabetes, smoking, alcohol use, obesity, and hypertension focusing on cardiovascular diseases (CVD) in India, with a specific emphasis on the state of Madhya Pradesh. It investigates the relationship between heart rate (HR) and various risk factors associated with cardiovascular problems, along with an assessment of heart rate variability (HRV) as an indicator of cardiovascular health. Through a comprehensive analysis of epidemiological data, the study identifies key risk factors contributing to the prevalence of CVD in the region, including lifestyle habits, socio-economic factors, and genetic predispositions. Utilizing both cross-sectional and longitudinal data, the research evaluates the impact of these risk factors on HR and HRV. Findings highlight significant correlations between elevated HR, reduced HRV, and increased cardiovascular risk, providing insights into the potential for HRV assessment as a diagnostic tool for early detection and management of CVD. This study aims to contribute to a deeper understanding of cardiovascular health dynamics in Madhya Pradesh and offer evidence-based recommendations for public health interventions.

Keywords: Cardiovascular Diseases (CVD), Epidemiological Studies, Heart Rate, ECG, HRV, Risk Factors

Abbreviations

HRV	:	Heart Rate Variability
ECG	:	Electrocardiogram
HR	:	Heart Rate
CAD	:	Coronary Artery Disease
ROS	:	Reactive Oxygen Species
COVID-19	:	Coronavirus Disease 2019
RR	:	R-R Interval (time between two successive R-waves on an ECG)
MSEC	:	Milliseconds
MV	:	Millivolts
QTc	:	Corrected QT Interval
QT	:	QT Interval (time from the start of the Q wave to the end of the T wave)
HRV	:	Heart Rate Variability
SDNN	:	Standard Deviation of Normal-to-Normal RR Intervals
RMSSD	:	Root Mean Square of Successive Differences between normal heartbeats; N: Number of intervals
Hz	:	Hertz
GBD	:	Global Burden of Disease
AF or AFib	:	Atrial Fibrillation
VT	:	Ventricular Tachycardia
BPM	:	Beats Per Minute
BP	:	Blood Pressure

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Introduction

Cardiovascular diseases are one of the main reasons for deaths all over the world, affecting thousands of people each year [1]. It includes diseases like stroke, cardiac arrhythmia, hypertension, coronary artery disease (CAD), and heart failure [2]. Various factors such as hypertension, high cholesterol, obesity, smoking, diabetes, alcohol, and inactive lifestyle can be responsible for the disease. Arrhythmias and other cardiovascular illnesses are the primary cause of death in India, making for around 28% of all fatalities [3]. Recent research and data have shown that nearly around 0.1- 0.5% of the total population is affected by atrial fibrillation. This figure is anticipated to rise as people age and the prevalence of lifestyle-related illnesses like diabetes and hypertension increases. It is estimated that approximately 10% i.e., around 7,00,000 to 8,00,000 people suffer from sudden cardiac attacks annually [3,4]. Most cardiac arrhythmias initiate abruptly lacking any provocation [5]. Several lifestyle factors may contribute to increasing the risk of CVD. These include diabetes, hypertension, thyroid gland dysfunction, sleep apnea, medication, substance abuse, genetics, smoking, stress and anxiety, and COVID-19 infection [6-8]. Some of these factors are responsible for the increment in the ROS species, which is one of the major causes of cardiac arrhythmias.

Heart rate (HR) can suggest several different health issues, and changes in HR substantially influence overall health [9]. It measures cardiovascular health, and an increased HR is associated with a higher risk of cardiovascular illness [10,11]. It also affects blood pressure, and elevated HR frequently results in elevated blood pressure [12]. An abnormal heart rate is a sign of possible cardiac dysfunction. Still, HR cannot be the only factor to predict cardiac health as it may fluctuate according to physical activity, age, gender, and other physiological factors [13]. Heart rate variability is known to be the dynamic interchange between sympathetic and parasympathetic nervous systems [1]. An increased HRV represents overall health, stress tolerance, and strong cardiovascular fitness, whereas lower HRV is related to impaired autonomic regulation and increased cardiovascular risk [14]. It has been observed that lifestyle factors such as alcohol, smoking, and stress could be responsible for disrupting HRV patterns further elucidating the risk of cardiovascular diseases [15]. Factors such as age and gender also interfere with the HRV, aging results in decreased HRV and higher resting HR and is associated with an elevated risk of hypertension, myocardial infarction, stroke, and sudden cardiac death [16]. However, this is not applicable in all as there is evidence that a reduced HRV might signify improved health outcomes in some instances. Thus, HRV measurement could serve as a factor for risk stratification in people with prevalent diseases [17].

Electrocardiography (ECG) has become a vital tool for assessing cardiovascular health and disease risk due to the assessment of heart rate (HR) and heart rate variability (HRV) [18]. ECG is a widely utilized clinical diagnostic tool in cardiovascular health because of its affordability, ease of use, and non-invasiveness. ECG equipment may detect electric potential shifts produced by the heart during each cardiac cycle [19]. It detects various cardiac conditions such as arrhythmias, ischemic changes, and conduction abnormalities. The activity and measurement of cardiac function can be obtained through heart rate (HR), while the heart rate variability (HRV) illustrates the fluctuations in HR, that act as an important marker of autonomic regulation [20]. Numerous methods, such as electrocardiograms (ECGs), are currently in use for screening and evaluating heart health. It has been discovered that an irregular or varied ECG may help in assessing the risk of CVD because a comparison between the normal and the other affected by any heart condition can be used to determine the significance or potential risks. There can be multiple risk factors that are directly or indirectly linked to and may further increase the individual risks of cardiovascular diseases [21]. Understanding the relationship between various factors and diseases on HR and HRV using ECG will be helpful in early detection and risk assessment of cardiovascular dysfunction [22,23].

This study attempts to study the variation and irregularity in ECG obtained from normal patients and those affected with any other diseases or lifestyle disorders. Also, it will be used to calculate and analyze HRV, which could further inform about heart health or future risk of developing CVD. Sagar is a city in the region of Bundelkhand, where the risk factors of cardiovascular illness are frequent due to smoking, tobacco, hypertension, unhealthy diet, physical inactivity, and alcohol abuse. It has been observed that two out of five patients might be having problems or issues regarding their heart. Hence, a survey is indeed necessary, which must contain all the risk factors, individuals' history, and the important steps that must be taken to reduce the number of cardiovascular illnesses in the Bundelkhand region. Thus, this study will focus on the epidemiological study, the possible risk factors for the disease, and the mechanisms that may increase the chances of cardiovascular diseases among different age groups [24]. The findings may contribute to the refinement of risk prediction models and the development of effective preventive and therapeutic strategies for reducing the burden of CVDs.

Materials and Methods

Study Design

A systematic, observational, and planned study of individuals was conducted, having either angina or some other heart-related problem along with individuals showing no symptoms of cardiovascular diseases as a reference. The study aims to examine a certain range of population in Sagar district. Therefore, this study was executed at Shri Chaitanya Mahaprabhu Hospital and Sanjeevni Hospital at Sagar. The individuals were carefully diagnosed by well-trained doctors of the hospital, and then an ECG of the patients was recorded. The research was approved by Shri Chaitanya Mahaprabhu Hospital and the doctor (registration No. M.P. 5928), and the study was performed with the patient's and doctor's consent.

Equipments

This study directly implies patients who were diagnosed with some cardiovascular problems, their past history, and the possible risk factors governing the disease which was examined using a 12-lead electrocardiogram (ECG). A 12-lead electrocardiogram (ECG) uses 10 electrodes, or leads to record the heart's electrical activity from 12 different angles. Dr. Cardio's 12-channel ECG machine was used for obtaining the heart profile and ECG report. It is a portable ECG machine manufactured by Kavitul Technologies Private Limited, by which the data can be analyzed using a smartphone with a simple application 'Dr. Cardio ECG' is available on the Play Store and displays Real-time ECG waveforms.

ECG Recording and Examination

The 12 leads are divided into two categories, i.e., precordial leads and limb lead. Precordial leads consist of V1, V2, V3, V4, V5, V6 leads, Limb leads are again grouped under standard bipolar leads (I, II, III), and augmented unipolar limb leads (aVL, aVR and aVF) [25]. Limb leads' work is to record the heart's electrical activity in the vertical plane whereas the precordial leads record it in horizontal plane. A graphical recording will be imprinted on electrocardiograph paper [26]. The accuracy of a 12-lead ECG is more as compared to electronic wristwatches that are designed to monitor heart rhythm and heart rate [27]. The 12-lead ECG requires equipment such as Electrodes, skin preparation (alcohol for sterilization), clippers, antiperspirant, conductive gel, electrocardiography machine, and ECG paper.

Various parameters/variables can be obtained manually. A big square is made up of 5 small squares. Heart rate can be calculated through the ECG by the formula- 300/ no. of big squares between R intervals, or 1500/ no. of small squares between R intervals. RR intervals can be calculated from the lead II, the distance between two R waves is measured as a big square is 200 milliseconds, measurement of one small square is 40 milliseconds. Duration is measured in milliseconds (msec) and amplitude is measured in millivolts (mV). QTc can be measured as $QTc = \frac{QT(m\sec)}{\sqrt{RR(\sec)}}$.HRV can be obtained through time-domain measures, frequency-domain measures, non-linear methods, and geometrical methods. Time domain measures include SDNN and RMSSD which depict sympathetic and parasympathetic health.

$$SDNN = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(RR_i - \overline{RR})}$$

$$RMSSD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N-1}(RR_{i+1} - RR_i)^2}$$

Procedure

Individuals were made to lie in a supine position for the study. Clothes were asked to be removed as the leads are to be attached to the chest. The conductive gel was applied on the leads to provide better conduction between electrodes and the body. The individuals were asked to rest for about a minute to normalize the heartbeat. The ECG machine has 10 leads in which precordial leads will be attached to the chest surface labeled as C1, C2, C3, C4, C5, and C6, and limb leads are labeled as R, L, F, and N. C1 lead was attached over 4th intercoastal space, on the edge of the right sternum. C2 lead was attached over the 4th intercoastal space, on the edge of the left sternum. C4 lead was attached over the 5th intercoastal space, along the mid-clavicular line. C3 lead was attached midway between C2 and C4. C5 lead was attached at the anterior axillary line in a straight line with C4. C6 lead was attached in a straight line with C4 and C5 in the mid-axillary position. R-limb lead was attached to the right wrist. L limb lead was attached to the left wrist. F limb lead was attached to the left lower leg near the ankle. N limb lead was attached to the right lower leg near the ankle. The mobile application (Dr. Cardio ECG) was turned on and a Bluetooth connection was set up. By clicking on the 'Heart icon' it starts taking ECG. At least 20 seconds of ECG is necessary. The ECG would be taken for 5 minutes for better accuracy and analysis. The reports were generated in pdf format after saving it. The ECG obtained represents dimensions, X-axis = 25mm/s, Y-axis = 10mm/mV and frequency filter used is between 0 to 40 Hz. The reports give cardiac information such as Heart rate, RR interval, duration of PR segment, duration of QRS complex, and duration of QT segment. The above-mentioned information regarding heart will help to analyze and diagnose various cardiovascular disease and their adversity. RR interval helps to measure HRV (Heart rate variability) which is directly associated with the parasympathetic and sympathetic condition of the human body.

Statistical Analysis

All statistical analyses were performed using one way ANOVA and t-test. HRV, SDNN and RMSSD were calculated and obtained using above mentioned formulae, followed by comparison among different factors using applicable statistical test.

Results

Based on the study conducted in the Sagar district of Madhya Pradesh, the outcomes are analyzed on various perspectives including, at first, the epidemiological studies which consist of the people, associated risk factors and the mortality due to cardiovascular diseases. Secondly it is focused on effect of various parameters that directly or indirectly impact the heart rate of an individual ultimately increasing the risk of CVDs. And at last, this study implies the risk factors and various HRV variables that influence the overall health of an individual, including not only sympathetic health but also parasympathetic health.

Epidemiological Studies

This Epidemiological study comprises a population-based study, in which various types of CVDs and their impact on mortality of people is studied. At first, it is important to begin with the overall census, so the mortality rate in India due to various CVDs must be studied. For a better understanding, analysis is done for mortality per 1,00,000 people, so that the mortality rate could be concisely examined and analyzed, followed by the analysis of Madhya Pradesh.

Indian Scenario

Nearly a quarter (24.46%) of all fatalities in India are attributed to CVD, according to all-age estimates from the Global Burden of Disease study (2021). India has an all-age CVD death rate of 300 deaths per 100,000 people [28]. ischemic heart diseases cover 13.90% of all CVDs, surpassing stroke, which covers 6.58% of all CVDs. Other types of CVDs, such as Rheumatic heart disease (1.41%) and hypertensive heart disorders (1.27%), also cover a significant part.

Scenario in Madhya Pradesh

The rate of 22.32% of all deaths in Madhya Pradesh are due to CVD, according to all age estimates from the Global Burden of Disease study (2021) (Figure 1). Approximately 1420 deaths per 1,00,000 people are the all-age CVD death rate of Madhya Pradesh.28 Of 22.32% of all CVD deaths, 11.90% are ischemic heart diseases and 6.69% are stroke deaths, exceeding rheumatic heart diseases (1.40%) and hypertensive heart disease (1.18%). As per analysis, calculated from GBD Compare 2021, it is clear that there was a substantial increase in CVD deaths in 2019 and a small decline in the number of deaths due to CVD in 2021. Also, yearly observation is done based on age, and the results show

that people 50-69 years of age had the highest mortality rate due to CVD exceeding the mortality rate of people over 70 years, and Subsequent CVD deaths are the least in people of 15-49 years of age. In year 2021, 16.80% per 1,00,000 deaths occur in people 15-49 years of age, 29.54% per 1,00,000 deaths occur in people of 50-69 years of age, 27.14% per 1,00,000 deaths occur in people which are of age above 70.

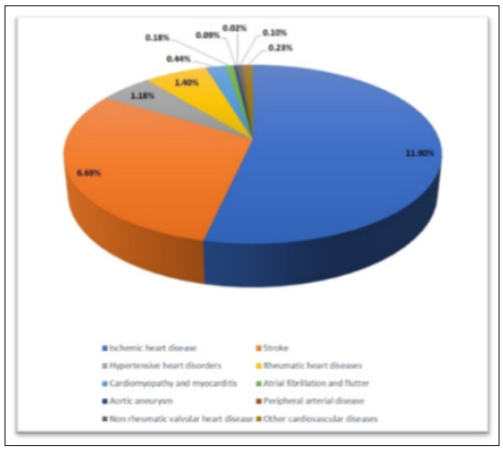

Figure 1: Death rate in Madhya Pradesh due to different cardiovascular diseases. The rate of 22.32% of all deaths in Madhya Pradesh are due to CVD, according to all age estimates from the Global Burden of Disease study (2021) as mentioned in figure 2. Approximately 1420 deaths per 1,00,000 people are the all-age CVD death rate of Madhya Pradesh (GBD Compare, n.d.). Of 22.32% of all CVD deaths, 11.90% are ischemic heart diseases and 6.69% are stroke deaths, exceeding rheumatic heart diseases (1.40%) and hypertensive heart disease (1.18%).

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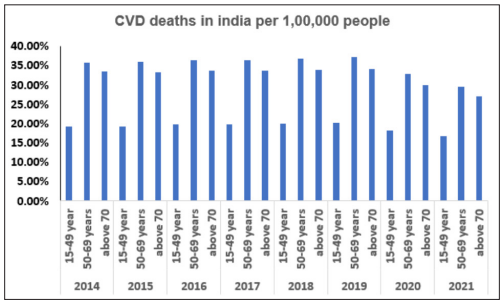

Figure 2: CVD deaths in India per 1,00,000 people. The graph represents mortality rate due to CVD in India based on the age from year 2014- 2021.

Heart Rate and CVD-Associated Risk Factors

Among various factors affecting the heart rate of an individual, the most associated risk factors are Age, Hypertension, Stress, anxiety, and some behavioral factors like smoking and tobacco, etc. Mean Heart rate and cardiovascular health are intimately related along with other risk factors, and heart rate variations can indicate several cardiovascular disorders. Among all factors, stress and anxiety result in an elevated heart rate (Figure3). An elevated resting heart rate has been linked to a higher risk of heart attacks, strokes, and cardiac fatalities. It also controls cardiac output, which is vital for getting nutrients and oxygen into tissues. Blood pressure is also directly related to heart rate as increased heart rates are frequently associated with elevated blood pressure. Arrhythmias might indicate that conditions like atrial fibrillation or ventricular tachycardia and abnormal heart rate are signs of cardiac dysfunction.

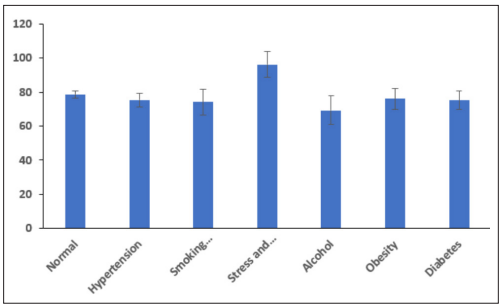

Figure 3: Mean heart rate of individuals with risk factors compared to normal. The relationship of mean heart rate between normal and various factors including hypertension, smoking, stress, alcohol consumption, obesity, and diabetes. *p<0.05 (95% CI) vs normal, ns= non-significant. Values are represented as Mean ± SEM.

Table 1 shows various risk factors associated with heart issues and the average heart rate, along with the RR interval. It indicates the average heart rate and average RR interval of persons with the associated risk factors compared to normal persons.

This data is derived from the study of all 50 individuals, from which 10 individuals were without any risk factors and are considered normal, 19 individuals had hypertension, 9 individuals had diabetes, 8 individuals were consuming tobacco or smoking for at least 5 years or more, 5 individuals were consuming alcohol for at least 5 years or more, 5 people were overweight and obese, 5 were diagnosed with stress or anxiety. Also, some people were indulged in multiple risk factors. Table 1 also shows that the highest heart rate is found in people with stress and anxiety and the lowest in individuals who indulge in tobacco or smoking.

Table 2 indicates the mean PR, QRS, QT and QTc intervals of 50 individuals, in which a total of 10 individuals were found to be risk-free and classified as normal, 19 had hypertension, 9 had diabetes; 8 had consumed tobacco products or smoked for at least five years; 5 of them were alcohol addict for the same amount of time; 5 were overweight or obese; and 5 had been diagnosed with stress or anxiety. Additionally, some individuals were engaged in more than one risk factor. The table clearly shows that people with stress or anxiety have the most disrupted or abnormal intervals, but the heart rates and intervals alone cannot determine the effect of stress and anxiety on the heart. More precise estimation of its effect can be determined by HRV analysis.

Different interval of ECG follows a pattern and are of different time frames. Several factors may affect these segments,

affecting normal functions. The segments of ECG for various factors are represented (Figure 4); stress, anxiety, and alcohol can be directly observed altering various segments compared to normal, whereas other factors also alter the pattern compared to normal Men have better HRV scores than women of all age groups (Figure5). As one ages, the HRV score starts to decrease. Our study's observed result showed that among the individuals of Sagar district, mostly women were affected by stress or anxiety problems. Still, only a few men were under stress. Also, mean RR, SDNN, and RMSSD, the indicators of HRV, are been represented for different age groups among men and women.

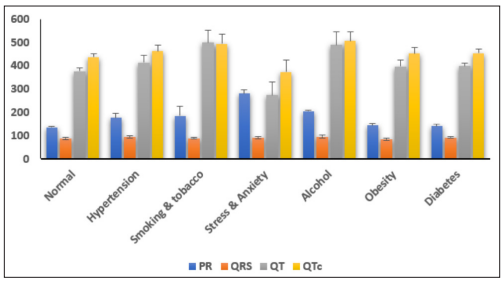

Figure 4: Different parameters of ECG in the case of Normal individuals and associated risk factors. There is an increment in the PR interval of the individuals related to risk factors. The QT and QTc intervals also increase in individuals with risk factors. Values are represented as mean ± SEM.

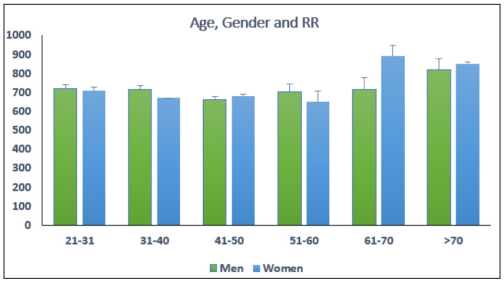

Figure 5: Relation Between Age, Gender and HRV. It gives the relationship between the mean RR of men and women of different age groups. Values are represented as mean ± SEM.

The RMSSD and SDNN values for both men and women of different age groups (Figure 6) depict that the change in RMSSD could be observed mostly in women of age group 21-31 as compared to men. Also, the SDNN and RMSSD have been decreased in women of the age group above 70 as compared to men. Table 3 shows Mean RR, SDNN, and RMSSD among Men and Women of different age groups.

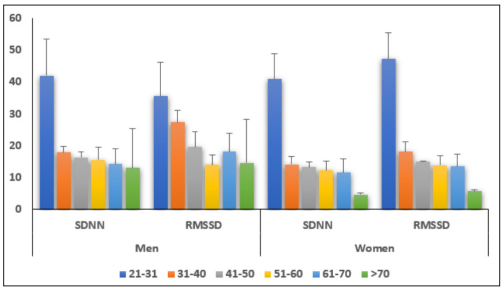

Figure 6: Indicate SDNN & RMSSD values of men and women of different age groups. The RMSSD and SDNN values for both men and women of different age groups, clearly depict that the change in RMSSD could be observed mostly in women of age group 21-31 as compared to men. Also, the SDNN and RMSSD have been decreased in women of age group above 70 as compared to men.

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Stress and anxiety are one of the risk factors that are better understood by the HRV analysis rather than general ECG segmental analysis (Figure7), clearly showing that Stress and anxiety, along with alcohol and hypertension, are the most significant values and are also ones that can be assessed by HRV determination. Table 4 represents association of HRV and several risk factors of CVD, representing P value, SDNN, RMSSD and HR (max-min) of different factors.

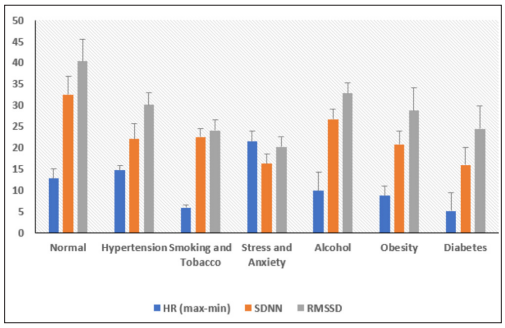

Figure 7: HRV association of individuals with risk factors compared to normal individuals Values are represented as mean ± SEM. It clearly shows that Stress and anxiety, along with alcohol and hypertension, are the most significant values and are also ones that can be assessed by HRV determination.

Discussion

The present study was conducted to obtain ECG-based HRV data and its association with cardiovascular diseases. The data obtained against different parameters and individuals a comparative study was done that could help us to predict and prevent the upcoming risks of developing cardiovascular diseases. Heart rate and heart rate variability (HRV) are key indicators of CVDs and functioning of autonomic nervous system. It is already known that different factors such as age, gender, hypertension, and others directly or indirectly regulate the heart rate, and also irregular heartbeat may correspond to the future complexity of heart function [29]. HRV provides more in-depth knowledge about the functioning of the heart. As from the results obtained in the above study, it can be related that heart rate and its relation with various factors may seem normal, but a keen analysis of the HRV and its variables reveals that even a normal heart rate may have an irregular or abnormal HRV corresponding to CVD risk. A higher HRV generally indicates better autonomic flexibility and cardiovascular health, while a lower HRV is associated with increased risk for various cardiovascular conditions. Thus, identifying different factors that may influence HR and HRV in

different individuals becomes important for public health and may reduce the risk of CVD and deaths associated with it [30].

The analysis of GBD 2021, shows the epidemiological study in the results compared; it involves the study of cardiovascular diseases, mortality rate, and their causing factors worldwide, in India and states. An epidemiological study is the best method for comparing mortality rates and various parameters, including worldwide comparison across countries, states, age, gender, and other risk factors [31]. He studied GBD compare 2017 depicts a slight increase in mortality due to CVDs in India. Previous study shows that a fall in high-income areas age-standardized cardiovascular death rates, whereas most low- and middle-income nations' rates have only marginally decreased or even slightly increased age-standardized cardiovascular death rates, whereas most low- and middle-income nations' rates have only marginally decreased or even slightly increased [32]. The study shows the analysis of GBD compared to 2021 and that the CVD mortality rates across Madhya Pradesh show that ischemic heart diseases are the major cause of death in Madhya Pradesh. A study by D Prabhakaran et al., also demonstrated that M.P. had the most deaths due to Rheumatic heart disease. according to their analysis of GBD Compare 2016, ischemic heart disease was the main cause of mortality in Maharashtra [33]. As there are no such previous studies carried out in Madhya Pradesh in the year 2021, the study shows the mortality caused by various heart diseases, which gives a strong groundwork for further analytical and survey studies. This study shows the age-standardized basis of the mortality rate in India in the year 2021 so that there would be a better understanding and analytical help for future studies in India. Thus, the results obtained in this study for the first time provide a comparative study of the different types of CVD and mortality rates in India and Madhya Pradesh in the year 2021.

The heart rate and CVD factors have been the most stereotypical relation. The mean heart rate as well as resting heart rate are the measures by which cardiac health can be understood [34,35]. The variations in heart rate can depict the cardiac health. Lifestyle factors may affect the optimum heart rate, whereas stress and anxiety are responsible for a significant increase in heart rate (96.25 ± 7.5 bpm) and a decrease in RR interval (598.62 ± 42.7). Trotman, et. al., during the study of association of heart rate and anxiety or stress validated that heart rate can increase abruptly under the situation of stress or anxiety, also the RR interval decreases during stress, as during stress body releases hormones like epinephrine and nor adrenaline which are responsible for increase in the blood pressure, heart rate and also respiratory rate [36]. Smoking or tobacco consuming individuals can be seen as somewhat lower mean heart rate because a biphasic reaction is seen in cases of nicotine poisoning, initially stimulating excitation like tachycardia and hypertension, and then eventually showing bradycardia and hypotension symptoms [37].

Hypertension activates sympathetic activity and eventually injures the endothelium, which further leads to heart problems. Our study includes the mean heart rate of people having hypertension that is 80.47 ±3.95 bpm (mean ± SEM) and RR interval as 739.26 ± 29.68 which clearly shows increase in heart rate compared to optimum heart rate which is significantly related to the study by Rao G et. al., A cross-sectional investigation from India called the BEAT survey was done and it was found that the average resting heart rate among 3743 young hypertensive individuals (18 to 55 years old) was 82.79 ± 10.41 bpm, HR and BP are significantly positively correlated [33-38].

The study conducted by Y Kawano showed that Peripheral vascular resistance decreased as a result of alcohol, lowering blood pressure in hypertensive patients. Additionally, it is found that after consuming alcohol, red blood cells' intracellular salt content drops by lowering the intracellular calcium concentration, this alteration may potentially cause blood vessels to dilate [39]. Hence, the results of our study showed the significant mean heart rate of people addicted to alcohol i.e., 69.25 ± 8.5 bpm and RR is 790.6 ± 46.2, which is lower than the optimum HR (72 bpm) and the RR interval is more than normal individuals.

According to Poirier Paul, et al, obesity influences established risk factors including dyslipidemia and hypertension, and indeed increase the heart rate and decreases the RR interval [40]. Our study also resembles the increase of HR (76.16 ± 6.05) and decrease in RR intervals (677.08 ± 52.9). The study conducted by Hillis et al, concluded that there is an increased risk of all-cause death with a higher resting heart rate, which is directly in correlation with diabetes [41]. The mean heart rate of diabetic people in our study is 75.3 ± 5.4, and the RR interval is 794.63 ± 56.2, which is significantly more than that of normal individuals.

Previous studies have shown that men have higher RR intervals than women, and age-wise, it starts to increase [42,43]. This study shows the same results but also depicts that women above age 60 have a higher mean RR interval than men of the same age group. The mean ± SEM value of intervals of ECG of normal individuals representing various segments was calculated, giving the significance for our study [44]. This study shows a shortened QT value – 299 ± 81.2***ms, which is the only significant factor still determined in the previous studies. as per Ray, the study revealed that smokers had a shorter QTc interval, although there was no statistically significant difference in the findings [45]. There was a statistically significant increase in heart rate among smokers in which shorter QT and RR intervals were found.

According to Bhide A et al., stress can cause alterations in T wave and QT interval characteristics of the ECG, as well as atrial and ventricular arrhythmias [46]. Acute mental stress has also been demonstrated to raise heart rate, shorten QT interval, and lengthen QTc interval in humans [47]. Similarly, in our study, the QT value is 273.5±56.3 ms, which is shorter than normal, and the QTc value is 472.2±75.8, which is higher than normal. From the study of Sun et al., it is concluded that obese individuals showed a 4.0-msec broader QRS length and a 4.2-msec longer PR interval which in turn validates this study in which QRS length is 83.25±5.32***ms, which is clearly just 4 ms broader than the normal value of QRS in our study [48]. By the study of Stern S et al., ECG abnormalities such as extended QTc, QT dispersion, and ST-T shifts may be seen even early in the course of diabetes mellitus [49]. This study validates our study as the QTc value-453.22±18.9*** and QT value-397.78±12.21*** are both higher than normal ranges.

In the Previous study of GR Geovanini et. al., the effect of HRV on both age and gender as factors, states that men have higher RR interval than women, and age wise it starts to decrease, HRV

is not just based on age and gender but also some variables like smoking, stress, anxiety and alcohol [42]. In this study states that males have a higher HRV than females in every age group, Also the study depicts that as the age increases, the HRV is decreasing. But it is seen that the HRV score is not so good among any age group except 21-30 years of age, it can be due to poor lifestyle, stress, smoking, hypertension, and many more. The SDNN value depicts the sympathetic balance, and RMSSD value depicts parasympathetic modulations of any individual, which ultimately leads to the overall health of the autonomic nervous system.

This study attempts to calculate HRV and its parameters, relating them to various risk factors of CVDs. Schroeder E et al., concluded that HR max-min tends to increase in hypertensive individuals, whereas SDNN and RMSSD value is less in hypertensive individuals as compared to normal SDNN and RMSSD values [50]. Similar results were obtained in our study of HRV and hypertension. The SDNN (mean ± SEM) value of both normal (32.49 ± 5.36) and hypertensive individuals (36.37 ± 5.2) along with RMSSD (mean ± SEM) value of normal (37.03 ± 11.2) and hypertensive individuals (33.13 ± 17.5) but the HR max-min value increase in hypertensive individuals (14.69 ± 4.2) as compared to normal HR max-min value (12.69 ± 2.39).

Al Awar et al., suggested that suspended particles in cigarette smoke and nicotine in tobacco are some of the factors responsible for declining HRV in other words, SDNN and RMSSD also decline in these individuals [51]. Our study also suggests the same as SDNN (mean ± SEM) value is 14.5 ± 1.95, and RMSSD (mean ± SEM) value is 20.05 ± 2.55 for the affected individuals, which is less than the normal value. From the study by L Carnevali, the conclusion can be brought up that individuals suffering from stress have the lowest RMSSD value compared to normal ones [52]. Our study also shows the lowest mean ± SEM value of RMSSD (8.13 ± 5.9) in the individuals with stress. Our study also examined other risk factors, but the lowest value of RMSSD was in the individuals with stress. As it is known that RMSSD is the ultimate score of parasympathetic activity and stress/anxiety is highly related to vagal activity, hence HRV is the best measure for understanding stress as a factor affecting cardiac health.

The study of E Ralevski et al., shows that moderate to heavy alcohol consumers had some low scores of HRV, which includes time domain as well as frequency domain measures, which signifies our study where the SDNN and RMSSD values are 30.74 ± 18.2 & 25.82 ± 10.4 respectively that are lower than the normal values [53].

Yadav R et. al., concluded in one of their studies that SDNN and RMSSD values are lower they signify the SDNN value of obese people 35.55 (26.77–49.25) with normal once 46.15 (37.22–58.57) with p value 0.038 and RMSSD value of obese people 28.75 (16.72-38.35) with normal once 41.55 (30.6-56.75) with p-value 0.018 [54]. Our study also revealed a lower SDNN and RMSSD value of 12.71 ±3.07 & 22.79 ±7.4, respectively.

In the study of Benichou T et al., people with type 2 diabetes have normal HRV values, and they concluded that lower SDNN (–0.65; –0.83 to –0.47), lower RMSSD (–0.92; –1.37 to –0.47) values than normal ones [55]. Our study also concluded that diabetic people have low HRV, although the findings were non-significant, as the number of individuals screened was comparatively less. Thus, the findings of the study reveal that a lower HRV is an indicator of autonomic dysfunction and heightened susceptibility to heart-related disorders, particularly in those with hypertension, diabetes, obesity, stress, and unhealthy behaviors such as smoking and alcohol consumption. Additionally, age and gender also play a pivotal role and may have a distinct pattern and severity of risks to CVDs.

Conclusion

Cardiovascular diseases are among the most considerable causes of mortality at the current time and are known as crucial matters of concern all over the world. It encompasses a range of heart and blood vessel disorders, including coronary artery disease, heart failure, arrhythmias, and stroke. Early diagnosis of cardiovascular diseases is crucial for effective management and prevention of complications. Diagnostic evaluation should include a History and Physical Examination which identifies symptoms and risk factors and an electrocardiogram (ECG) which detects electrical activity of the heart.

Epidemiological research provides valuable insights into potential hazards and consequences. Factors such as RR interval, average heart rate, QTc, SDNN, RMSSD, amplitude and duration of segments like PQ, QT, and ST, and many more are provided by the evaluation of HRV analysis and ECG interpretation. Numerous details about the heart and the autonomic nervous system—which is closely related to the brain—are provided by these components. Thus, it may be concluded that these elements taken together provide information on the brain and heart.

Significant changes are shown when heart rate (HR) and heart rate variability (HRV) are analyzed across various demographic and lifestyle characteristics. These variances are essential for comprehending the risks associated with cardiovascular health. The two main variables are age and gender. As people age, their heart rate variability (HRV) often decreases, which is a sign of decreased autonomic flexibility. Gender differences indicate that men frequently have higher HRV than women, possibly as a result of hormonal factors. This calls for gender-specific strategies for managing cardiovascular risk.

The HRV is significantly lower in hypertensive individuals, indicating a compromised autonomic nervous system. This emphasizes the significance of proficient blood pressure regulation. Lifestyle choices like drinking and smoking make this autonomic dysfunction worse. This increases the risk of cardiovascular disease by raising HR and lowering HRV. The negative impacts of stress, anxiety, and tobacco use are also readily apparent. These variables lead to increased sympathetic activity and decreased parasympathetic function, which in turn results in lower HRV. Diabetes patients have especially severe autonomic dysfunction, which lowers HRV significantly and raises the risk of harmful cardiovascular events. Because obesity affects autonomic function, it also causes increased heart rate and decreased heart rate variability (HRV), highlighting the significance of weight control for cardiovascular health.

The study concludes by highlighting the intricate interactions between gender, age, and a variety of lifestyle and health factors that affect HR and HRV. These results highlight the necessity of additional interventions targeting these particular risk factors in order to improve cardiovascular outcomes and improve general health. In highrisk populations in particular, careful observation of these related variables may serve to lessen the detrimental effects on HR and HRV and, in turn, lower the burden of cardiovascular disease.

Public Health and Future Implications

The results of this study have significant ramifications for both individual and national health. Identification of the key variables impacting HRV emphasizes the need for focused therapies and offers insightful information about the mechanisms behind cardiovascular risk. Improving HRV and lowering the burden of cardiovascular disease require public health programs that support quitting smoking, cutting back on alcohol use, managing stress, regulating blood pressure, and supporting weight loss. Subsequent investigations ought to center on clarifying the additional ways these variables impact HRV and investigating the possibility of utilizing HRV as a biomarker for evaluating cardiovascular risk and the efficacy of interventions. Research that monitors changes in heart rate variability (HRV) over time in response to therapies may offer important new perspectives on the long-term advantages of these tactics for heart health.

CRediT authorship contribution statement

Jat Deepali: writing- review and editing, Visualization, Validation, Supervision. Jain Suyash: Writing – original draft, Methodology, investigation, Data Curation. Dwivedi Ankita: Writing- review, editing, Visualization, Validation, Methodology, Formal analysis. Bibyan Sneha: Writing- review and editing. Formal analysis. Jain Abhishek- Resources, project administration, supervision, Validation.

Author contributions statement

DJ conceived the hypothesis and designed and supervised the study. SJ performed the experiment and wrote the manuscript, AD prepared tables and figures, checked and edited the manuscript, SB checked and edited the manuscript. AJ assisted and supervised the complete work and all listed authors read and approved the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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