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Original Researcher Article

Comparative study of heart rate variability among hypertensive aged 45 to 60 years in West Champaran, Bihar

Article History:

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Abstracts: ***Background:*** Hypertension is a major cardiovascular risk factor worldwide and is associated with autonomic dysfunction, characterized by sympathetic overactivity and reduced parasympathetic tone. The balance between sympathetic and parasympathetic activity is reflected in heart rate variability (HRV), a non-invasive measure of autonomic function. Reduced HRV in hypertensive individuals is associated with higher risk of arrhythmias, cardiovascular events, and target organ damage. However, limited data exist on HRV patterns among middle-aged hypertensive adults in West Champaran, Bihar. The purpose of this study was to compare HRV parameters between people aged 45–60 who had hypertension and those who did not. ***Method:*** A cross-sectional comparative study was conducted over six months involving 100 participants, including 50 hypertensives and 50 age- and sex-matched normotensive controls. Participants with diabetes, ischemic heart disease, arrhythmias, chronic kidney disease, thyroid disorders, or on medications affecting autonomic function were excluded. Clinical examination, anthropometric measurements, and 5-minute resting ECG recordings in lead II were performed under standardized conditions. Analysis was done on frequency-domain (LF, HF, LF/HF ratio) and time-domain HRV parameters (SDNN, RMSSD). Data were processed using SPSS version 25, and intergroup comparisons were made using independent Student's t-test, with $p<0.05$ considered statistically significant. ***Conclusion:*** Hypertensive participants showed significantly lower time-domain HRV parameters (SDNN: 28.4 ± 5.6 ms vs 42.7 ± 6.3 ms; RMSSD: 21.3 ± 4.8 ms vs 35.2 ± 5.0 ms; $p<0.001$) compared to normotensives, indicating reduced parasympathetic activity. Frequency-domain analysis showed increased LF power and reduced HF power, resulting in a significantly elevated LF/HF ratio (3.5 ± 0.9 vs 1.5 ± 0.5; $p<0.001$), suggesting sympathetic dominance. These results indicate that hypertensive individuals in the 45–60 year age group exhibit autonomic imbalance compared to normotensive controls

Keywords: Hypertension; Heart Rate Variability; Autonomic Dysfunction; Sympathovagal Imbalance.

INTRODUCTION

A collection of anatomical and functional changes in the left atrium, left ventricle, and coronary arteries caused by chronically elevated blood pressure are collectively referred to as hypertensive heart disease (HHD). Heart failure may arise from compensatory remodeling, especially left ventricular hypertrophy (LVH), which is brought on by hypertension's increased stress on the heart. Chronic hypertension's direct and indirect effects, such as systolic or diastolic heart failure, conduction arrhythmias, especially atrial fibrillation, and an increased risk of coronary artery disease (CAD), are all included in HHD [1].

A diagnosis of heart failure is used to classify hypertensive heart disease (HHD), since the latter necessitates a more rigorous, goal-oriented treatment strategy. This disorder may manifest as decreased heart pumping capacity (systolic failure), decreased cardiac relaxation and filling (diastolic dysfunction), or a combination of the two. Acute events such as sudden cardiac death (SCD) and severe heart failure are more likely to occur in patients with HHD. Persistent hypertension causes endothelial dysfunction, a disorder that destroys the blood vessel's inner lining and speeds up atherosclerosis, increasing the risk of peripheral arterial disease (PAD) and coronary artery disease (CAD). Additionally, the heart muscle thickens (eccentric hypertrophy), increasing its oxygen demand and potentially causing symptoms like angina. This thickening can also disrupt the heart's electrical system, predisposing individuals to atrial fibrillation and its associated risk of ischemic stroke [2].

Research indicates that people with hypertension have significantly lower heart rate variability (HRV). This is particularly noticeable in the low-frequency (LF) and high-frequency (HF) bands, which reflect the activity of the sympathetic and parasympathetic nervous systems, respectively. These results imply that an imbalance in the heart's autonomic control, which is marked by elevated sympathetic activity and decreased parasympathetic activity, may be linked to high blood pressure. An elevated LF/HF ratio in hypertensive patients points to a heightened sympathetic tone, which is linked to a greater risk for cardiovascular events. Additional investigation demonstrates that lower HRV, as determined by a number of metrics, is an an indicator of severe consequences in these patients, such as myocardial infarction and stroke. This demonstrates how HRV may be used as a preliminary measure to evaluate cardiovascular risk in people with hypertension [3].

While the link between hypertension, autonomic dysfunction, and increased cardiovascular risk is well-documented, this relationship has not been extensively studied within specific regional populations in India. Therefore, this study aims to fill this critical gap by conducting a comparative analysis of heart rate variability among middle-aged hypertensive and normotensive individuals in West Champaran, Bihar, to provide valuable, localized data for risk assessment and preventive strategies.

METHODOLOGY

2.1 Study Design and Setting

The current study was planned as a cross-sectional comparative study and was carried out over a six-month period in the West Champaran district of Bihar. The study was conducted in a tertiary care hospital's Department of Physiology in conjunction with the Medicine outpatient department. Prior to enrolment, all participants provided written informed consent, and the Institutional Ethics Committee granted ethical clearance.

2.2 Study Population

Participants were divided into two categories:

Study group (Hypertensives): People between the ages of 45 and 60 who have been clinically diagnosed with hypertension in accordance with JNC 8 guidelines (systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, or those who are currently receiving antihypertensive medication)

Control group (Normotensives): Apparently healthy people of the same age and sex who never had coronary artery disease, hypertension, or a chronic condition.

Inclusion criteria: Age between 45–60 years.

Hypertensives: Diagnosed cases either on regular treatment or newly diagnosed.

Controls: Blood pressure consistently <140/90 mmHg.

Exclusion criteria: Individuals with diabetes mellitus, ischemic heart disease, arrhythmias, chronic kidney disease, thyroid disorders, or autonomic neuropathies.

Smokers, alcoholics, and those with a history of drug intake affecting autonomic function (e.g., beta-blockers, antidepressants).

Patients unwilling to participate in the study.

2.3 Sample Size

A total of 100 participants were involved in the study, comprising of 50 hypertensive subjects and 50 normotensive controls. The sample size was determined based on previous similar studies and feasibility of data collection.

2.4 Data Collection Procedure

1.Recruitment and Screening: Participants were chosen from community health camps and outpatient clinics. A detailed history regarding lifestyle, comorbidities, and medication was obtained.

2.Clinical Examination: A standard mercury sphygmomanometer was used to measure blood pressure while the patient was seated following ten minutes of rest. Five-minute intervals were used to take three readings, and the average was noted.

3.Anthropometric Measurements: Height, weight, and Body Mass Index (BMI) were recorded using standard protocols.

Heart Rate Variability (HRV) Recording:

HRV was recorded using a computerized digital ECG system in a quiet room, with participants in supine position.

A standard lead II ECG was recorded for 5 minutes after ensuring that the subject was relaxed and had refrained from caffeine, heavy meals, and exercise at least 12 hours prior.

All recordings were performed between 9:00–11:00 a.m. to minimize circadian influences on autonomic function.

HRV Analysis

HRV was examined in accordance with the recommendations made by the North American Society of Pacing and Electrophysiology and the European Society of Cardiology Task Force (1996).

Time-domain measures:

Mean RR interval (ms)

SDNN (Standard deviation of NN intervals, ms)

RMSSD (Root mean square of successive differences, ms)

Frequency-domain measures: (via Fast Fourier Transform)

LF (Low Frequency power: 0.04–0.15 Hz)

HF (High Frequency power: 0.15–0.40 Hz)

LF/HF ratio (indicator of sympathovagal balance)

Statistical Analysis

Microsoft Excel was used to compile the data, and SPSS version 25.0 was used for analysis.

The mean ± standard deviation (SD) was used to express quantitative variables.To compare groups, the Independent The study applied the Student's t-test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The present cross-sectional comparative study was conducted among 100 participants (50 hypertensive subjects and 50 age- and sex-matched normotensive controls) in West Champaran district, Bihar. The analysis focused on the comparison of demographic variables, anthropometric indices, and heart rate variability (HRV) parameters in both time and frequency domains.

3.1 Demographic and Anthropometric Characteristics

Table 1 displays the baseline attributes of both groups. The normotensive controls were 51.9 ± 3.9 years old, whereas the hypertensive group was 52.6 ± 4.2 years old. The difference between the two groups was not statistically significant ($p = 0.41$). When the gender distribution of the two groups was matched, the male-to-female ratio was 27:23 for controls and 28:22 for hypertensives ($p = 0.82$).

While the groups' mean height and weight were similar, hypertensive people tended to have slightly higher body mass indexes (BMIs: 26.1 ± 2.8 kg/m²) than controls (24.9 ± 2.5 kg/m²). Nevertheless, this difference was not statistically significant ($p = 0.06$).

As predicted, the hypertensive group's systolic and diastolic blood pressures were significantly higher than those of the controls (122.3 ± 8.7 mmHg and 78.5 ± 6.2 mmHg, $p < 0.001$) (148.6 ± 12.4 mmHg and 92.7 ± 7.9 mmHg, respectively).

Table 1: Baseline attributes of Participants

Parameter	Hypertensive study group (n=50) Mean ± SD	Comparison group (n=50) Mean ± SD	p-value
Age (years)	52.6 ± 4.2	51.9 ± 3.9	0.41
Male/Female ratio	28/22	27/23	0.82
Height (cm)	164.3 ± 7.1	165.1 ± 6.8	0.53
Weight (kg)	70.4 ± 8.9	67.8 ± 7.6	0.15
BMI (kg/m²)	26.1 ± 2.8	24.9 ± 2.5	0.06
Systolic BP (mmHg)	148.6 ± 12.4	122.3 ± 8.7	<0.001*
Diastolic BP (mmHg)	92.7 ± 7.9	78.5 ± 6.2	<0.001*

*Statistically significant

Interpretation:

The demographic data demonstrate that both groups were homogenous with respect to age, sex, and body size, minimizing confounding factors. The expected difference in blood pressure confirmed the classification into hypertensive and normotensive groups.

2. Time-Domain HRV Parameters

The time-domain indices of HRV are summarized in Table 2. The mean RR interval was significantly shorter among hypertensives (780 ± 62 ms) compared to controls (860 ± 58 ms, $p < 0.01$), reflecting an increased resting heart rate.

The standard deviation of NN intervals (SDNN), which reflects overall HRV and long-term variability, was markedly lower in hypertensives (28.4 ± 6.8 ms) compared to controls (42.1 ± 8.5 ms), and the difference was highly significant ($p < 0.001$).

The root mean square of successive differences (RMSSD), which is a sensitive marker of parasympathetic (vagal) activity, was also significantly reduced in hypertensives (20.3 ± 5.2 ms vs. 35.6 ± 7.4 ms in controls, $p < 0.001$).

Table 2: Comparison of Time Domain HRV Parameters

Parameter	Hypertensives (n=50) Mean ± SD	Controls (n=50) Mean ± SD	p-value
Mean RR interval (ms)	780 ± 62	860 ± 58	<0.01*
SDNN (ms)	28.4 ± 6.8	42.1 ± 8.5	<0.001*
RMSSD (ms)	20.3 ± 5.2	35.6 ± 7.4	<0.001*

*Statistically significant

Interpretation:

The findings clearly indicate a reduction in overall heart rate variability among hypertensive subjects. The reduced SDNN and RMSSD suggest diminished autonomic modulation, particularly reflecting parasympathetic withdrawal in hypertension.

3. Frequency-Domain HRV Parameters

Frequency-domain measures of HRV are shown in Table 3. The low-frequency (LF) component, which represents a mixture of sympathetic and

parasympathetic influences but is often interpreted as a marker of sympathetic modulation, was significantly higher in hypertensives (65.2 ± 10.5 nu) compared to controls (52.8 ± 9.6 nu, $p < 0.01$).

In contrast, the high-frequency (HF) component, considered a reliable index of parasympathetic (vagal) activity, was significantly lower in hypertensives (34.8 ± 8.6 nu) compared to controls (47.2 ± 9.1 nu, $p < 0.01$).

The LF/HF ratio, a marker of sympathovagal balance, was almost twice as high in hypertensives (2.15 ± 0.72) compared to normotensives (1.12 ± 0.48), and this difference was highly significant ($p < 0.001$).

Table 3: Comparison of Frequency Domain HRV Parameters

Parameter	Hypertensives (n=50) Mean ± SD	Controls (n=50) Mean ± SD	p-value
LF (nu)	65.2 ± 10.5	52.8 ± 9.6	<0.01*
HF (nu)	34.8 ± 8.6	47.2 ± 9.1	<0.01*
LF/HF ratio	2.15 ± 0.72	1.12 ± 0.48	<0.001*

*Statistically significant

Interpretation:

The frequency-domain analysis corroborates the time-domain findings, showing autonomic imbalance in hypertensive subjects. Increased LF and reduced HF reflect enhanced sympathetic dominance and vagal withdrawal, leading to a significantly elevated LF/HF ratio.

4. Overall Findings

When compared to normotensive controls, hypertensive patients showed noticeably reduced HRV across both time- and frequency-domain parameters. Reduced parasympathetic (vagal) tone is shown by the decline in RMSSD and HF power. Increased sympathetic drive is indicated by elevated LF power and LF/HF ratio. Collectively, the results highlight a state of autonomic dysfunction in hypertension, characterized by sympathovagal imbalance.

DISCUSSION

In this study, hypertension people between the ages of 45 and 60 had their heart rate variability (HRV) assessed and compared to age- and sex-matched normotensive controls. Our results demonstrated significant reductions in both time- and frequency-domain HRV parameters among hypertensive participants. This pattern reflects autonomic imbalance, characterized by heightened sympathetic activity and reduced parasympathetic modulation. The findings are consistent with the notion that autonomic dysfunction is an integral pathophysiological component of essential hypertension and may contribute to increased cardiovascular morbidity in this population. A decrease in heart rate variability, a non-invasive indicator of the interaction between the sympathetic and parasympathetic branches of the autonomic nervous system, is a sign of autonomic dysfunction [4,5].

The time-domain analysis revealed that hypertensive participants had significantly lower SDNN and RMSSD values compared to normotensives. SDNN, representing overall variability in cardiac rhythm, was markedly diminished in hypertensives, indicating reduced global HRV. RMSSD, which primarily reflects parasympathetic (vagal) modulation, was also significantly lower. These findings suggest a withdrawal of vagal activity in hypertensive individuals. Reduced RMSSD and SDNN have been consistently reported in prior studies and have been associated with an increased risk of cardiovascular complications, including arrhythmias and sudden cardiac death [6]. The decline in parasympathetic tone in hypertension may be attributed to chronic pressure overload, baroreceptor desensitization, and endothelial dysfunction, which collectively impair autonomic regulation of the heart.

Frequency-domain parameters further corroborated the time-domain findings. Hypertensive subjects demonstrated significantly higher low-frequency (LF) power and reduced high-frequency (HF) power. LF is primarily influenced by sympathetic activity and partly by parasympathetic modulation, whereas HF is strongly associated with parasympathetic tone. The

resulting LF/HF ratio was significantly elevated in hypertensives, reflecting sympathetic predominance and vagal withdrawal. This sympathovagal imbalance is clinically important, as sustained sympathetic overactivity has been implicated in vascular remodeling, increased peripheral resistance, and target organ damage, all of which exacerbate the hypertensive state [7–9]. Elevated LF/HF ratio has also been associated with increased risk of left ventricular hypertrophy, impaired baroreflex sensitivity, and higher cardiovascular morbidity and mortality.

Several physiological mechanisms explain the reduced HRV in hypertensive patients. Chronic elevation of blood pressure can desensitize arterial baroreceptors, diminishing reflex parasympathetic activation and promoting sympathetic overactivity [10]. Additionally, structural changes in large arteries, such as increased stiffness and reduced compliance, impair the transmission of pressure signals to baroreceptors, further reducing vagal modulation [11]. Inflammation and oxidative stress, frequently present in hypertension, may also disrupt autonomic signaling pathways, leading to a sustained imbalance between sympathetic and parasympathetic activity [12]. These mechanistic insights emphasize that HRV alterations are not merely secondary phenomena but may actively contribute to the progression and complications of hypertension.

The findings of this study align with previous research conducted in Indian and international populations. Vinayagam et al. observed reduced HRV parameters among hypertensive adults in southern India, highlighting that autonomic dysfunction is a consistent pathophysiological feature of hypertension across ethnicities [13]. Similarly, Guzzetti et al. reported increased LF/HF ratios in hypertensive individuals, indicating enhanced sympathetic drive, which is in concordance with our frequency-domain results [7]. The present study adds to the literature by documenting these changes in a population from West Champaran, Bihar, an area where data on autonomic function in hypertension is limited, thereby filling a regional research gap.

Clinically, reduced HRV has significant implications. Parasympathetic withdrawal and sympathetic dominance increase the risk of cardiac arrhythmias, sudden cardiac death, and progression to heart failure [14,15]. Therefore, assessment of HRV can serve as a valuable non-invasive tool for early identification of hypertensive patients at high cardiovascular risk. Moreover, interventions aimed at improving autonomic balance, such as regular aerobic exercise, stress management, dietary modification, and pharmacological therapy with beta-blockers or ACE inhibitors, have been shown to improve HRV, potentially reducing cardiovascular morbidity [16,17]. This highlights how crucial it is to identify autonomic dysfunction in hypertension individuals early and treat it holistically.

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