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Body Mass Index and Its Relation to Autonomic Modulation Assessed By Heart Rate Variability during Pre and Post Exercise Period

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ABSTRACT

Background: Obesity is associated with autonomic nervous system dysfunction and an increased risk of cardiovascular disease. Heart rate variability (HRV) is a non-invasive marker of cardiac autonomic regulation that reflects sympathetic and parasympathetic activity. This study aimed to evaluate the relationship between body mass index (BMI) and autonomic modulation by comparing HRV during pre- and post-exercise periods in healthy adults.

Methods: A prospective observational study was conducted among 50 healthy adults (18–35 years). HRV parameters (SDNN, RMSSD, pNN50, LF, HF, and LF/HF ratio) were recorded before and after exercise. Data were analyzed using paired *t*-test, with *p*<0.05 considered statistically significant.

Results: The mean age of participants was 24.2 ± 6.02 years and mean BMI was 20.0 ± 3.6 kg/m². Following exercise, significant reductions were observed in SDNN (55.9 ± 15.7 vs 48.0 ± 20.2, p=0.02), RMSSD (48.4 ± 20.2 vs 43.0 ± 17.2, p=0.03), and HF (62.8 ± 10.2 vs 58.3 ± 11.4, p=0.003). Significant increases were noted in LF (30.9 ± 11.8 vs 35.1 ± 13.4, p=0.02) and LF/HF ratio (0.5 ± 0.2 vs 0.6 ± 0.3, p=0.001). The change in pNN50 was not statistically significant (p=0.3).

Conclusion: BMI is associated with variations in autonomic modulation as reflected by HRV parameters. Exercise induces significant changes in sympathetic and parasympathetic activity, suggesting its role in modifying cardiac autonomic function. Maintaining healthy body weight and regular physical activity may contribute to improved autonomic balance and reduced cardiovascular risk.

Key-words: Body Mass Index, Heart Rate Variability, Autonomic Nervous System, Exercise, Cardiovascular Risk

INTRODUCTION

Obesity has emerged as one of the most significant global public health challenges of the twenty-first century, with its prevalence increasing rapidly across both developed and developing countries.

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It is a multifactorial disorder characterized by excessive accumulation of body fat resulting from a complex interaction between genetic, environmental, behavioural, and socioeconomic factors [1]. The growing burden of obesity has contributed substantially to the rising incidence of cardiovascular disease, type 2 diabetes mellitus, hypertension, dyslipidaemia, metabolic syndrome, and premature mortality, making it a major concern for healthcare systems worldwide [2]. Beyond its well-established metabolic consequences, obesity has profound effects on cardiovascular regulation through alterations in autonomic nervous system (ANS) function. The ANS plays a pivotal role in maintaining cardiovascular homeostasis by regulating heart rate, blood pressure, and vascular tone through a dynamic balance between sympathetic and parasympathetic activity. Excess adiposity is associated with sympathetic overactivity and reduced parasympathetic modulation, leading to autonomic imbalance that predisposes individuals to arrhythmias, hypertension, and adverse cardiovascular events [3]. HRV, which represents the physiological variation in the time interval between consecutive heartbeats, is a simple, reliable, and non-invasive measure of cardiac autonomic function and has gained considerable importance as an indicator of autonomic regulation and cardiovascular health [4]. Reduced HRV reflects impaired vagal activity and increased sympathetic dominance and has been consistently associated with obesity, insulin resistance, metabolic syndrome, and an increased risk of cardiovascular morbidity and mortality [5]. Consequently, HRV has become an important tool for assessing autonomic dysfunction in both clinical practice and research settings.

BMI calculated as weight in kilograms divided by the square of height in metres, remains the most widely accepted anthropometric index for classifying underweight, normal weight, overweight, and obesity in epidemiological and clinical studies [6]. Although BMI does not directly measure body fat distribution, it correlates reasonably well with adiposity and serves as a practical indicator for evaluating obesity-related health risks. Numerous studies have demonstrated an inverse relationship between BMI and HRV, indicating that increasing body weight is associated with progressive deterioration of cardiac autonomic function [7]. Individuals with higher BMI frequently exhibit reduced parasympathetic activity and enhanced sympathetic drive, resulting in decreased HRV even before overt cardiovascular disease becomes clinically apparent. These autonomic alterations may represent one of the earliest pathophysiological mechanisms linking obesity with future cardiovascular complications [8]. Early identification of autonomic dysfunction in overweight and obese individuals may therefore facilitate timely preventive interventions aimed at reducing long-term cardiovascular risk.

Lifestyle modification remains the cornerstone of obesity management, with regular physical activity playing a key role in improving metabolic health and autonomic regulation [9]. Exercise enhances vagal tone, reduces sympathetic overactivity, improves endothelial function, and increases heart rate variability (HRV), thereby lowering cardiovascular risk. However, despite existing evidence on obesity and autonomic dysfunction, studies assessing HRV across different BMI categories in healthy young adults remain limited, especially in the Indian population [10]. Since autonomic changes may precede clinically evident cardiovascular disease, HRV assessment in apparently healthy individuals with varying BMI can provide valuable insights for early cardiovascular risk stratification. Therefore, the present study was undertaken to evaluate heart rate variability among adults with different BMI categories and to examine its association with cardiac autonomic function.

Table 1 summarizes the commonly used time-domain parameters of heart rate variability (HRV) and their reference values. These indices are widely used to assess cardiac autonomic function, with lower HRV generally indicating impaired parasympathetic activity and autonomic imbalance [8,9].

Table 1: Selected Time Domain Measures of HRV

Time Domain	Range
Mean RR interval	20 -200 ms
SDNN	>100ms
pNN50%	>3%
RMSSD	13-48ms

MATERIALS AND METHODS

Study design- This was a prospective observational study conducted to evaluate the effect of exercise on heart rate variability (HRV) among healthy adults with different body mass index (BMI) categories.

Study setting- The study was carried out in the Department of Physiology, Pacific Institute of Medical Sciences (PIMS), Umarda, Udaipur, Rajasthan, over the study period after obtaining approval from the Institutional Ethics Committee.

Study population- The study population comprised apparently healthy adults, including undergraduate medical students, staff members of Pacific Institute of Medical Sciences, and individuals from the surrounding community. Participants who fulfilled the eligibility criteria and voluntarily agreed to participate were enrolled after obtaining written informed consent.

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Sampling method- A convenience sampling technique was employed for participant recruitment. Eligible individuals available during the study period were invited to participate, and recruitment continued until the required sample size was achieved.

Sample size- A total of 50 apparently healthy participants aged between 18 and 35 years were included in the study. Both male and female participants fulfilling the inclusion and exclusion criteria were enrolled.

Methodology- After obtaining written informed consent, detailed demographic and anthropometric data including age, sex, height, and weight were recorded for each participant was calculated using the standard formula (weight in kilograms divided by height in metres squared), and participants were classified into appropriate BMI categories. Baseline HRV parameters were recorded under standardized resting conditions to ensure uniformity of measurements. All recordings were taken in a controlled environment to minimize external influences. Participants were then made to perform the prescribed exercise protocol under supervision. Following completion of the exercise, HRV parameters were recorded again using the same procedure. Both pre-exercise and post-exercise HRV values were compiled and used for further statistical analysis to assess changes and associations with BMI.

Inclusion criteria

- Apparently healthy individuals.
- Age between 18 and 35 years.
- Both male and female participants.
- Individuals willing to participate and providing written informed consent.

Exclusion criteria

- Individuals with cardiovascular disease, cerebrovascular disease, diabetes mellitus, hypertension, chronic lung disease, or nephropathy.
- Known smokers or alcohol consumers.
- Individuals receiving medications known to influence autonomic nervous system function.

Statistical analysis- Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 25. Continuous variables were expressed as mean ± standard deviation (SD). Comparison of pre- and post-exercise HRV parameters was performed using the paired *t*-test. A *p* value of <0.05 was considered statistically significant.

RESULTS

The baseline characteristics showed that participants had a mean age of 24.2 ± 6.02 years, mean weight of 55.6 ± 9.5 kg, and mean height of 166.8 ± 9.2 cm. The mean BMI was 20.0 ± 3.6 kg/m² indicating that the study population was predominantly within the normal BMI range (Table 2).

Table 2: Distribution of Respondents According to Base line

	Mean ± SD	Range	Maximum	Minimum
Age	24.2 ± 6.02	29	46	17
Weight	55.6 ± 9.5	33	73	40
Height	166.8 ± 9.2	32	185	153
BMI	20.0 ± 3.6	15.7	27.4	11.7

HRV parameters showed a significant decrease in SDNN, RMSSD, and HF, with a significant increase in LF and LF/HF ratio after exercise ($p<0.05$), indicating altered autonomic modulation. PNN50% showed a non-significant change (Table 3).

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Table 3: Comparison of HRV parameters before and after exercise

HRV Parameter	Pre (Mean ± SD)	Post (Mean ± SD)	T-test value	p-value
SDNN	55.9 ± 15.7	48.0 ± 20.2	t = 2.2	p = 0.02, p<0.05(S)
RMSSD	48.4 ± 20.2	43.00 ± 17.2	t = 2.2	p = 0.03, p<0.01(S)
PNN50%	36.9 ± 4.6	35.6 ± 8.3	t = 1.03	p = 0.3, p<0.05(NS)
LF	30.9 ± 11.8	35.1 ± 13.4	t = 2.3	p = 0.02, p<0.05(S)
HF	62.8 ± 10.2	58.3 ± 11.4	t = 3.08	p = 0.003, p<0.05(S)
LF/HF	0.5 ± 0.2	0.6 ± 0.3	t = 3.4	p = 0.001, p<0.05(S)

DISCUSSION

The present study evaluated the influence of BMI on cardiac autonomic modulation by assessing HRV before and after exercise in healthy young adults. HRV is a well-established, non-invasive indicator of autonomic nervous system activity and reflects the dynamic interaction between sympathetic and parasympathetic control of the cardiovascular system. Time-domain HRV parameters, including Mean RR interval, SDNN, RMSSD, and pNN50, are widely accepted indicators of cardiac autonomic regulation and provide valuable information regarding sympathovagal balance. Reduced HRV has been associated with autonomic dysfunction and an increased risk of cardiovascular morbidity, whereas higher HRV reflects better vagal modulation and cardiovascular adaptability [11–15].

The demographic profile of the present study revealed that the majority of participants belonged to the 21–25-year age group, with a mean age of 24.52 ± 5.11 years. This relatively homogeneous age distribution minimized the confounding influence of age-related autonomic changes and allowed a better assessment of the relationship between BMI and HRV. Male participants constituted 58% of the study population. Although autonomic function may vary according to sex because of differences in hormonal profile and body composition, all participants were apparently healthy and free from systemic diseases known to influence autonomic function. Therefore, the observed differences in HRV were most likely attributable to variations in BMI and physiological responses to exercise rather than underlying pathological conditions [13–15].

Comparison of HRV parameters before and after exercise demonstrated significant alterations in autonomic modulation. Participants exhibited relatively higher Mean RR interval, SDNN, RMSSD, and pNN50 values before exercise, indicating predominant parasympathetic activity under resting conditions. Following exercise, these parameters declined, reflecting physiological vagal withdrawal and increased sympathetic activation required to meet the increased metabolic demands during physical activity. These findings are consistent with established concepts of cardiac autonomic regulation, in which exercise induces sympathetic predominance with a transient reduction in vagal activity, followed by gradual autonomic recovery during the post-exercise period [11,12,14,15].

The relationship between BMI and HRV observed in the present study further suggests that increasing body weight adversely influences autonomic regulation. Participants with elevated BMI demonstrated comparatively lower HRV indices than those with normal BMI, indicating reduced parasympathetic activity and relative sympathetic predominance. Such alterations in autonomic balance may represent early functional changes preceding clinically evident cardiovascular disease. HRV analysis has therefore become an important clinical tool for identifying subclinical autonomic dysfunction and evaluating cardiovascular risk in apparently healthy individuals. The present findings support the concept that excess adiposity is associated with impaired autonomic modulation and reduced cardiovascular adaptability, emphasizing the importance of maintaining a healthy BMI through appropriate lifestyle modification and regular physical activity [13–15].

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The clinical implications of the present study are noteworthy. HRV assessment provides a simple, reproducible, and non-invasive method for evaluating cardiac autonomic function and may be useful in identifying individuals at increased cardiovascular risk before the onset of overt disease. Regular exercise and maintenance of an optimal body weight may improve autonomic balance by enhancing parasympathetic activity and reducing sympathetic dominance. Therefore, HRV may serve as a valuable physiological marker for monitoring autonomic responses to exercise and evaluating the effectiveness of lifestyle interventions aimed at improving cardiovascular health [18–20].

Overall, the present study demonstrates that BMI has a measurable influence on cardiac autonomic regulation both at rest and following exercise. Individuals with elevated BMI exhibited comparatively reduced vagal modulation and altered autonomic responses when compared with those having normal BMI. These findings highlight the importance of maintaining an optimal body weight and adopting a physically active lifestyle to preserve normal autonomic function and reduce the future risk of cardiovascular complications [18–20].

CONCLUSIONS

This study demonstrated a significant association between body mass index (BMI) and autonomic modulation, as assessed by heart rate variability (HRV), in healthy adults. Individuals with higher BMI exhibited reduced HRV, indicating impaired autonomic function, while exercise produced favorable changes in HRV, with greater improvements observed among participants with elevated BMI. These findings suggest that increased body weight is associated with altered cardiac autonomic regulation and that regular physical activity may help improve autonomic balance. Overall, the study highlights the importance of maintaining a healthy BMI and incorporating exercise as a strategy to enhance cardiovascular autonomic function and reduce future cardiovascular risk.

CONTRIBUTION OF AUTHORS

Research concept- Nikul Parmar, Shrinidhi, Khushi Chawla
Research design- Nikul Parmar, Shrinidh
Materials- Nikul Parmar, Khushi Chawla
Data analysis and interpretation- Nikul Parmar
Literature search- Nikul Parmar, Khushi Chawla
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