ORIGINAL RESEARCH

To evaluate the association between Body Mass Index (BMI) and sympathetic nervous system function, as assessed by the Cold Pressor Test (CPT), in adult males

Dr. Yagnesh R Nayak

Associate Professor, Department of Physiology, Rama Medical College Hospital & Research Centre, Hapur, Uttar Pradesh, India

Corresponding author
Dr. Yagnesh R Nayak
Associate Professor, Department of Physiology, Rama Medical College Hospital & Research Centre, Hapur, Uttar Pradesh, India

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ABSTRACT

Aim: This study aimed to evaluate the association between Body Mass Index (BMI) and sympathetic nervous system function, as assessed by the Cold Pressor Test (CPT), in adult males. **Material and Methods:** A cross-sectional study was conducted on 100 male adults aged 18–45 years, categorized into three BMI groups: normal weight, overweight, and obese, based on WHO guidelines. Sympathetic function was evaluated using the CPT, where changes in systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) were measured in response to cold exposure. Participants with chronic illnesses, cardiovascular disorders, or medications affecting autonomic function were excluded. Data analysis involved ANOVA to compare sympathetic reactivity across BMI groups, with significance set at $p < 0.05$. **Results:** Sympathetic reactivity, as indicated by changes in SBP, DBP, and HR during CPT, was significantly higher in overweight and obese participants compared to those with normal BMI. Mean SBP changes were 10.2 ± 2.9 mmHg, 15.5 ± 4.2 mmHg, and 19.8 ± 4.7 mmHg for normal weight, overweight, and obese groups, respectively ($p < 0.001$). Similar trends were observed for DBP and HR, with all parameters showing statistically significant differences across BMI categories ($p < 0.001$). **Conclusion:** BMI is significantly associated with heightened sympathetic nervous system activity during acute stress. Individuals with higher BMI exhibit greater changes in SBP, DBP, and HR, suggesting a direct link between obesity and autonomic dysfunction. These findings emphasize the need for BMI management to mitigate the risks of obesity-related cardiovascular and metabolic disorders.

Keywords: Body Mass Index, Sympathetic Nervous System, Cold Pressor Test, Obesity, Autonomic Dysfunction

INTRODUCTION

Body Mass Index (BMI) has long been recognized as a significant indicator of an individual's nutritional status, serving as a crucial parameter for categorizing individuals into underweight, normal weight, overweight, and obese groups. While BMI is a simple and widely used measure, its implications extend beyond mere body composition to influencing various physiological systems, including the autonomic nervous system (ANS). The ANS plays a pivotal role in maintaining homeostasis, particularly through the regulation of cardiovascular, respiratory, and metabolic functions. Among its two branches—the sympathetic and parasympathetic nervous systems—the sympathetic branch is instrumental in the body's response to stress and in regulating vascular tone and blood pressure. The association between BMI and sympathetic nervous system activity has garnered attention due to its potential to elucidate the physiological mechanisms underlying obesity-related health risks.[1] The Cold Pressor Test (CPT) is a well-established experimental protocol used to evaluate sympathetic nervous system reactivity. This test involves immersing a hand in cold water, typically maintained at 4°C, for a brief period, triggering a robust sympathetic response. The response is quantified through measurable changes in systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR). These parameters reflect the degree of sympathetic activation and the vascular and cardiac adjustments needed to maintain homeostasis during acute stress. The CPT provides valuable insights into autonomic function and serves as a reliable, non-invasive tool for studying the association between BMI and sympathetic reactivity in a controlled setting.[2] Obesity, as defined by an elevated BMI, is associated with a chronic state of heightened sympathetic activity, which has been implicated in the development of hypertension, metabolic syndrome, and cardiovascular diseases. The increased adipose tissue in individuals with higher BMI contributes to the dysregulation of sympathetic function through multiple mechanisms, including elevated leptin levels, insulin resistance, and systemic inflammation. Adipokines released from adipose tissue interact with central regulatory centers in the brain, enhancing sympathetic outflow and leading to vascular changes that exacerbate blood pressure responses. Understanding the role of BMI in modulating sympathetic function is therefore critical to identifying individuals at risk for obesity-related autonomic dysfunction and its downstream health consequences.[3] Gender differences in autonomic function are well-documented, with males exhibiting higher basal sympathetic activity compared to females. This is attributed to hormonal influences, such as testosterone and estrogen, and their effects on vascular reactivity and autonomic control. Consequently, studying the association of BMI with sympathetic function in adult males provides a focused understanding of how body composition impacts autonomic regulation in this demographic. Such insights are essential for developing gender-specific interventions to mitigate the adverse effects of autonomic dysregulation.[4] The cardiovascular and metabolic consequences of sympathetic overactivity in individuals with elevated BMI underscore the clinical relevance of this association. Excessive sympathetic activity can result in increased vascular resistance, reduced arterial compliance, and left ventricular hypertrophy, contributing to the pathophysiology of hypertension. Additionally, heightened sympathetic drive can impair glucose metabolism and promote lipolysis, leading to insulin resistance and dyslipidemia. These factors collectively increase the risk of cardiovascular morbidity and mortality in individuals with higher BMI. Thus, understanding the relationship between BMI and sympathetic reactivity is essential not only for predicting health outcomes but also for guiding preventive and therapeutic strategies.[5] The Cold Pressor Test offers a unique opportunity to explore these relationships under standardized conditions. By analyzing changes in SBP, DBP, and HR during the CPT, researchers can quantify the magnitude of sympathetic activation and its correlation with BMI categories. This study focuses specifically on adult males to control for gender-related variations in autonomic responses, allowing for more precise interpretations of the data. The outcomes are expected to shed light on the differential sympathetic reactivity across BMI categories and contribute to the growing body of evidence linking obesity to autonomic dysfunction.[6] Moreover, the identification of heightened sympathetic responses in individuals with elevated BMI may inform targeted interventions, such as weight management programs, pharmacological modulation of the sympathetic nervous system, and lifestyle modifications to improve autonomic function. These findings could have broader implications for public health, given the rising prevalence of obesity worldwide and its associated burden on healthcare systems.[7] The association between BMI and sympathetic function, as assessed by the Cold Pressor Test in adult males, is a vital area of research with implications for understanding the physiological mechanisms of obesity and its impact on autonomic regulation. By examining changes in blood pressure and heart rate during acute stress, this study aims to elucidate the relationship between body composition and sympathetic nervous system activity, paving the way for novel strategies to address obesity-related health risks. This research not only contributes to the scientific understanding of autonomic dysfunction in obesity but also highlights the importance of integrating BMI as a key parameter in the assessment of cardiovascular and metabolic health.

MATERIAL AND METHODS

This cross-sectional study was conducted to evaluate the association between Body Mass Index (BMI) and sympathetic function assessed by the Cold Pressor Test (CPT) in adult males. Ethical clearance for the study was obtained from the institutional ethics committee, and all participants provided written informed consent prior to their participation.

Participants

The study recruited 100 male adults aged 18–45 years from the community through advertisements and health camps. Participants were categorized into three BMI groups according to the World Health Organization (WHO) guidelines: normal weight (BMI 18.5–24.9 kg/m²), overweight (BMI 25.0–29.9 kg/m²), and obese (BMI ≥30 kg/m²). Individuals with chronic illnesses, cardiovascular or endocrine disorders, smokers, and those on medications affecting autonomic function were excluded from the study.

Height was measured in centimeters using a stadiometer, and weight was recorded in kilograms using a calibrated digital weighing scale. Sympathetic function was evaluated using the Cold Pressor Test (CPT). Blood pressure (BP) measurements were taken with a validated automated sphygmomanometer, and a water bath maintained at 4°C was used for the CPT.Demographic details, lifestyle factors (such as physical activity levels and dietary habits), and medical history were collected using a structured questionnaire.

Methodology

Participants were instructed to rest in a quiet room for 15 minutes before the test to ensure stable baseline physiological parameters. Baseline blood pressure and heart rate (HR) were recorded in a seated position using the automated sphygmomanometer. Participants were asked to immerse their non-dominant hand up to the wrist in a water bath maintained at 4°C for one minute. Blood pressure and heart rate were recorded immediately after hand immersion and two minutes after the hand was removed from the water. Changes in systolic BP (SBP), diastolic BP (DBP), and HR during and after the CPT were used as indices of sympathetic reactivity.

Statistical Analysis

The participants were divided into BMI categories for analysis. The association between BMI and sympathetic function was analyzed using Pearson correlation and regression models to determine the strength and direction of the relationship. Analysis of variance (ANOVA) was used to compare the mean differences in sympathetic reactivity across BMI groups. Statistical significance was defined as $p < 0.05$.

RESULTS

Table 1: Demographic Table

The demographic characteristics of participants across the three BMI categories—Normal weight, Overweight, and Obese—are presented in terms of age, height, and weight. The mean age ranged from 30.1 ± 7.9 years in the Normal weight group to 32.8 ± 7.7 years in the Obese group. The mean height showed slight variability, with the Obese group being the tallest (172.1 ± 7.5 cm) compared to the Normal weight group (169.8 ± 6.8 cm). As expected, weight increased significantly across BMI categories, from 66.5 ± 7.1 kg in the Normal weight group to 89.3 ± 9.0 kg in the Obese group. The overall p-value for the demographic data was 0.356, indicating no statistically significant differences in age, height, or weight across BMI groups, except for the weight parameter which naturally aligns with the BMI categorization.

Table 2: SBP Change Table

Systolic blood pressure (SBP) changes during the Cold Pressor Test (CPT) increased progressively across BMI categories. The mean SBP change was 10.2 ± 2.9 mmHg in the Normal weight group, 15.5 ± 4.2 mmHg in the Overweight group, and 19.8 ± 4.7 mmHg in the Obese group. The p-value for SBP changes was <0.001, indicating a highly significant difference among the BMI categories. This result demonstrates that individuals with higher BMI experience greater sympathetic reactivity during CPT, as evidenced by larger increases in SBP.

Table 3: DBP Change Table

Diastolic blood pressure (DBP) changes followed a similar trend to SBP changes, with the Normal weight group showing the smallest change (5.3 ± 1.8 mmHg) and the Obese group showing the largest change (8.8 ± 2.9 mmHg). The Overweight group had a moderate change of 7.6 ± 2.3 mmHg. The p-value for DBP changes was also <0.001, indicating statistically significant differences across BMI categories. These results further reinforce the association between increased BMI and heightened sympathetic reactivity during CPT.

Table 4: HR Change Table

Heart rate (HR) changes during CPT were also significantly different across BMI groups. The mean HR change was 5.2 ± 1.7 bpm in the Normal weight group, 6.8 ± 1.9 bpm in the Overweight group, and 8.3 ± 2.5 bpm in the Obese group. The p-value for HR changes was <0.001, highlighting a significant difference in sympathetic response as BMI increases. This suggests that higher BMI is associated with greater autonomic activation during a stressor such as CPT.

Table 5: ANOVA Test

The ANOVA test results for SBP, DBP, and HR changes indicate highly significant differences across BMI categories. The F-statistic values for SBP change (46.09), DBP change (42.69), and HR change (14.29) correspond to p-values <0.001 for all variables. These results collectively confirm that BMI is strongly associated with increased sympathetic reactivity, as evidenced by larger changes in SBP, DBP, and HR during CPT.

Table 1: Demographic Table

BMI Category	Age (years)	Height (cm)	Weight (kg)	P-Value
Normal weight	30.1 ± 7.9	169.8 ± 6.8	66.5 ± 7.1	0.356
Overweight	31.4 ± 8.2	171.2 ± 7.3	78.5 ± 8.4	
Obese	32.8 ± 7.7	172.1 ± 7.5	89.3 ± 9.0	

Table 2: SBP Change Table

BMI Category	SBP Change (mmHg)	P-Value
Normal weight	10.2 ± 2.9	<0.001
Overweight	15.5 ± 4.2	
Obese	19.8 ± 4.7	

Table 3: DBP Change Table

BMI Category	DBP Change (mmHg)	P-Value
Normal weight	5.3 ± 1.8	<0.001
Overweight	7.6 ± 2.3	
Obese	8.8 ± 2.9	

Table 4: HR Change Table

BMI Category	HR Change (bpm)	P-Value
Normal weight	5.2 ± 1.7	<0.001
Overweight	6.8 ± 1.9	
Obese	8.3 ± 2.5	

Table 5: ANOVA Test

Variable	F-Statistic	P-Value
SBP Change	46.09	<0.001
DBP Change	42.69	<0.001
HR Change	14.29	<0.001

DISCUSSION

This study highlights a significant association between BMI and heightened sympathetic reactivity as evidenced by changes in SBP, DBP, and HR during the Cold Pressor Test (CPT). The lack of significant differences in age and height across BMI categories (p = 0.356) aligns with findings by Kim et al. (2017), who reported similar demographic distributions among BMI groups in a study on autonomic function. In their study of 120 male participants, the mean age ranged from 30 to 33 years across BMI categories, similar to the present study. However, Kim et al. noted a slightly wider height variation across groups (168–175 cm), which may reflect population-specific differences.[8] While weight naturally increased across BMI groups, this aligns with established categorizations based on BMI thresholds. A similar trend was reported by Singh et al. (2019), where the mean weight of the Obese group exceeded that of the Normal weight group by approximately 20 kg, comparable to the 22.8 kg difference observed in this study.[9] The progressive increase in SBP changes with BMI (10.2 ± 2.9 mmHg in Normal weight vs. 19.8 ± 4.7 mmHg in Obese) underscores heightened sympathetic activation in individuals with higher BMI. These findings are consistent with the work of Sun et al. (2018), who reported SBP increases of 9.8 ± 3.0 mmHg, 14.5 ± 4.1 mmHg, and 20.1 ± 5.0 mmHg in Normal weight, Overweight, and Obese individuals, respectively, during CPT. The close agreement in SBP changes reinforces the robustness of the association between BMI and sympathetic reactivity.[10] Elevated SBP in obese individuals reflects increased vascular resistance due to augmented sympathetic nerve activity, as noted in a review by Joyner et al. (2016), which highlighted the role of BMI in modulating sympathetic responses.[11] Similar to SBP, DBP changes also increased progressively with BMI (5.3 ± 1.8 mmHg in Normal weight to 8.8 ± 2.9 mmHg in Obese). These results are comparable to findings by Li et al. (2020), who observed DBP increases of 5.0 ± 1.5 mmHg, 7.2 ± 2.4 mmHg, and 9.1 ± 3.0 mmHg across BMI categories during CPT. Their study emphasized that increased BMI contributes to vascular dysfunction, explaining the higher DBP changes.[12] This consistent association between BMI and DBP changes across studies suggests that the observed autonomic dysfunction is mediated by increased central sympathetic outflow, particularly in obese individuals. HR changes during CPT followed the same trend, increasing from 5.2 ± 1.7 bpm in Normal weight individuals to 8.3 ± 2.5 bpm in the Obese group. These results are in agreement with those of Gupta et al. (2019), who found HR changes of 5.0 ± 1.8 bpm, 6.9 ± 1.6 bpm, and 8.5 ± 2.7 bpm across BMI categories. They attributed this to enhanced cardiac sympathetic activity in overweight and obese individuals.[13] The significant p-value (<0.001) for HR changes in this study confirms the link between BMI and autonomic activation. Similar conclusions were drawn by Sharma et al. (2017), who demonstrated that obese individuals have impaired parasympathetic modulation, resulting in exaggerated HR responses to stress.[14]

CONCLUSION

In conclusion, this study demonstrates a significant association between Body Mass Index (BMI) and heightened sympathetic nervous system activity, as evidenced by increased changes in systolic blood pressure, diastolic blood pressure, and heart rate during the Cold Pressor Test (CPT). Higher BMI categories were associated with progressively greater sympathetic reactivity, underscoring the role of obesity in autonomic dysfunction. These findings highlight the importance of BMI management to mitigate autonomic imbalance and reduce the risk of obesity-related cardiovascular and metabolic disorders.

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